8. Thinking and Problem Solving

Piaget's theory of cognitive development; Concept formation processes; Information processing, Reasoning and problem solving, Facilitating and hindering factors in problem solving, Methods of problem solving: Creative thinking and fostering creativity; Factors influencing decision-making and judgment; Recent trends.

Thinking and Problem Solving

Piaget's theory of cognitive development

Piaget's theory of cognitive development is a comprehensive theory about the nature and development of human intelligence first developed by Jean Piaget. It is primarily known as a developmental stage theory, but in fact, it deals with the nature of knowledge itself and how humans come gradually to acquire it, construct it, and use it. Moreover, Piaget claims the idea that cognitive development is at the centre of human organism and language is contingent on cognitive development. Below, there is first a short description of Piaget's views about the nature of intelligence and then a description of the stages through which it develops until maturity.

The Nature of Intelligence: Operative and Figurative Intelligence

Piaget believed that reality is a dynamic system of continuous change, and as such is defined in reference to the two conditions that define dynamic systems that change. Specifically, he argued that reality involves transformations and states. Transformations refer to all manners of changes that a thing or person can undergo. States refer to the conditions or the appearances in which things or persons can be found between transformations. For example, there might be changes in shape or form (for instance, liquids are reshaped as they are transferred from one vessel to another, humans change in their characteristics as they grow older), in size (e.g., a series of coins on a table might be placed close to each other or far apart) in placement or location in space and time (e.g., various objects or persons might be found at one place at one time and at a different place at another time). Thus, Piaget argued, that if human intelligence is to be adaptive, it must have functions to represent both the transformational and the static aspects of reality. He proposed that operative intelligence is responsible for the representation and manipulation of the dynamic or transformational aspects of reality and that figurative intelligence is responsible for the representation of the static aspects of reality).

Operative intelligence is the active aspect of intelligence. It involves all actions, overt or covert, undertaken in order to follow, recover, or anticipate the transformations of the objects or persons of interest. Figurative intelligence is the more or less static aspect of intelligence, involving all means of representation used to retain in mind the states (i.e., successive forms, shapes, or locations) that intervene between transformations. That is, it involves perception, imitation, mental imagery, drawing, and language. Therefore, the figurative aspects of intelligence derive their meaning from the operative aspects of intelligence, because states cannot exist independently of the transformations that interconnect them. Piaget believed that the figurative or the representational aspects of intelligence are subservient to its operative and dynamic aspects, and therefore, that understanding essentially derives from the operative aspect of intelligence.

At any time, operative intelligence frames how the world is understood and it changes if understanding is not successful. Piaget believed that this process of understanding and change involves two basic functions: Assimilation and accommodation.

Assimilation and Accommodation

Through studying the field of education Piaget focused on accommodation and assimilation. Assimilation, one of two processes coined by Jean Piaget, describes how humans perceive and adapt to new information. It is the process of taking one’s environment and new information and fitting it into pre-existing cognitive schemas. Assimilation occurs when humans are faced with new or unfamiliar information and refer to previously learned information in order to make sense of it. Accommodation, unlike assimilation is the process of taking one's environment and new information, and altering one's pre-existing schemas in order to fit in the new information.

With the disciplining of psychology came the methods approaching psychologist's observations towards internalizing the technical means in knowing what terms processes like assimilation can be thought in. The term ‘assimilation’ was derived in this manner and defined explicitly as one's own perspective on an issue that anchors all other perspectives. Judging the stimuli close to that anchor (the 'latitude of acceptance') will always assimilate easier, while stimuli further from one's perspective anchor (the 'latitude of rejection') manages to take a longer time in assimilating. This particular form of social and psychological judgment is referenced within disciplined psychology as the "assimilation-contrast model." Jean Piaget first discovered this as a result of observing his infant son "grab and thrust" a rattle into his mouth and then assimilated the "grab and thrust" motion, also placing Piaget's expensive watch into his mouth.

Through a series of stages, Piaget explains the ways in which characteristics are constructed that lead to specific types of thinking; this chart is called Cognitive Development. To Piaget, assimilation is integrating external elements into structures of lives or environments or those we could have through experience. It is through assimilation that accommodation is derived. Accommodation is imperative because it is how people will continue to interpret new concepts, schemas, frameworks, etc. Assimilation is different than accommodation because of how it relates to the inner organism due to the environment. Piaget believes that the human brain has been programmed through evolution to bring equilibrium, and to move upwards in a process to equilibriate what is not. The equilibrium is what Piaget believes ultimately influences structures because of the internal and external processes through assimilation and accommodation.

Piaget's understanding is that these two functions cannot exist without the other. To assimilate an object into an existing mental schema, one first needs to take into account or accommodate to the particularities of this object to a certain extent; for instance, to recognize (assimilate) an apple as an apple one needs first to focus (accommodate) on the contour of this object. To do this one needs to roughly recognize the size of the object. Development increases the balance or equilibration between these two functions. When in balance with each other, assimilation and accommodation generate mental schemas of the operative intelligence. When one function dominates over the other, they generate representations which belong to figurative intelligence.

Following from this conception Piaget theorized that intelligence is active and constructive. It is active in the literal sense of the term as it depends on the actions (overt or covert, assimilatory or accommodatory), which the thinker executes in order to build and rebuild his models of the world. It is also constructive because actions, particularly mental actions, are coordinated into more inclusive and cohesive systems, thus they are raised to more stable and effective levels of functioning. Piaget believed that this process of construction leads to systems of mental operations better able to resist the illusions of perceptual appearances and thus less prone to error. In other words, the gradual construction of the system of mental operations involved in the operative aspect of intelligence enables the developing person to grasp more hidden and complex aspects of the world. Below we will summarize the development of operative intelligence.

Piaget's four stages

According to Jean Piaget's theory of cognitive development, intelligence is the basic mechanism of ensuring equilibrium in the relations between the person and the environment. This is achieved through the actions of the developing person on the world. At any moment in development, the environment is assimilated in the schemes of action that are already available and these schemes are transformed or accommodated to the peculiarities of the objects of the environment plus of the surroundings and entire universe, if they are not completely appropriate. Thus, the development of intelligence is a continuous process of assimilations and accommodations that lead to increasing expansion of the field of application of schemes, increasing coordination between them, increasing interiorization, and increasing abstraction. The mechanism underlying this process of increasing abstraction, interiorization, and coordination is reflecting abstraction. That is, reflecting abstraction gradually leads to the rejection of the external action components of sensorimotor operations on objects and to the preservation of the mental, planning or anticipatory, components of operation. These are the mental operations that are gradually coordinated with each other, generating structures of mental operations. These structures of mental operations are applied on representations of objects rather than on the objects themselves. Language, mental images, and numerical notation are examples of representations standing for objects and thus they become the object of mental operations. Moreover, mental operations, with development, become reversible. For instance, the counting of a series of objects can go both forward and backward with the understanding that the number of objects counted is not affected by the direction of counting because the same number can be retrieved both ways. Piaget described four main periods in the development towards completely reversible equlibrated thought structures. These are the periods described below. As shown below, for Piaget intelligence is not the same at different ages. It changes qualitatively, attaining increasingly broader, more abstract, and more equilibrated structures thereby allowing access to different levels of organization of the world.

Sensorimotor stage

The sensorimotor stage is the first of the four stages in cognitive development which "extends from birth to the acquisition of language". "In this stage, infants construct an understanding of the world by coordinating sensory experiences (such as seeing and hearing) with physical, motoric actions. Infants gain knowledge of the world from the physical actions they perform on it. An infant progresses from reflexive, instinctual action at birth to the beginning of symbolic thought toward the end of the stage. Piaget divided the sensorimotor stage into six sub-stages":0–2 years, Infants just have senses-vision, hearing, and motor skills, such as grasping, sucking, and stepping.---from Psychology Study Guide by Bernstein, Penner, Clarke-Stewart, Roy:

Sub Stages:

1. **Simple Reflexes** --- Birth-6 weeks --- "Coordination of sensation and action through reflexive behaviors". Three primary reflexes are described by Piaget: sucking of objects in the mouth, following moving or interesting objects with the eyes, and closing of the hand when an object makes contact with the palm (palmar grasp). Over the first six weeks of life, these reflexes begin to become voluntary actions; for example, the palmar reflex becomes intentional grasping.
2. **First habits and primary circular reactions phase** --- 6 weeks-4 months --- "Coordination of sensation and two types of schemes: habits (reflex) and primary circular reactions (reproduction of an event that initially occurred by chance). Main focus is still on the infant's body." As an example of this type of reaction, an infant might repeat the motion of passing their hand before their face. Also at this phase, passive reactions, caused by classical or operant conditioning, can begin.

3. **Secondary circular reactions phase** --- 4–8 months --- Development of habits. "Infants become more object-oriented, moving beyond self-preoccupation; repeat actions that bring interesting or pleasurable results." This stage is associated primarily with the development of coordination between vision and prehension. Three new abilities occur at this stage: intentional grasping for a desired object, secondary circular reactions, and differentiations between ends and means. At this stage, infants will intentionally grasp the air in the direction of a desired object, often to the amusement of friends and family. Secondary circular reactions, or the repetition of an action involving an external object begin; for example, moving a switch to turn on a light repeatedly. The differentiation between means and ends also occurs. This is perhaps one of the most important stages of a child's growth as it signifies the dawn of logic.
4. **Coordination of secondary circular reactions stages** --- 8–12 months --- "Coordination of vision and touch--hand-eye coordination; coordination of schemes and intentionality." This stage is associated primarily with the development of logic and the coordination between means and ends. This is an extremely important stage of development, holding what Piaget calls the "first proper intelligence." Also, this stage marks the beginning of goal orientation, the deliberate planning of steps to meet an objective.
5. **Tertiary circular reactions, novelty, and curiosity** --- 12–18 months --- "Infants become intrigued by the many properties of objects and by the many things they can make happen to objects; they experiment with new behavior." This stage is associated primarily with the discovery of new means to meet goals. Piaget describes the child at this juncture as the "young scientist," conducting pseudo-experiments to discover new methods of meeting challenges.
6. **Internalization of Schemes** --- 18–24 months --- "Infants develop the ability to use primitive symbols and form enduring mental representations." This stage is associated primarily with the beginnings of insight, or true creativity. This marks the passage into the preoperational stage.

By the end of the sensorimotor period, objects are both separate from the self and permanent.Object permanence is the understanding that objects continue to exist even when they cannot be seen, heard, or touched. Acquiring the sense of object permanence is one of the infant's most important accomplishments, according to Piaget.

Preoperational stage

The preoperative stage is the second of four stages of cognitive development. By observing sequences of play, Piaget was able to demonstrate that towards the end of the second year, a qualitatively new kind of psychological functioning occurs.

(Pre)Operatory Thought is any procedure for mentally acting on objects. The hallmark of the preoperational stage is sparse and logically inadequate mental operations. During this stage, the child learns to use and to represent objects by images, words, and drawings. The child is able to form stable concepts as well as mental reasoning and magical beliefs. The child however is still not able to perform operations; tasks that the child can do mentally rather than physically. Thinking is still egocentric: The child has difficulty taking the viewpoint of others. Two substages can be formed from preoperative thought.

The Symbolic Function Substage

Occurs between about the ages of 2 and 7. During 2-4 years old , kids cannot yet manipulate and transform information in logical ways, but they now can think in images and symbols. The child is able to formulate designs of objects that are not present. Other examples of mental abilities are language and pretend play. Although there is an advancement in progress, there are still limitations such as egocentrism and animism. Egocentrism occurs when a child is unable to distinguish between their own perspective and that of another person's. Children tend to pick their own view of what they see rather than the actual view shown to others. An example is an experiment performed by Piaget and Barbel Inhelder. Three views of a mountain are shown and the child is asked what a traveling doll would see at the various angles; the child picks their own view compared to the actual view of the doll. Animism is the belief that inanimate objects are capable of actions and have lifelike qualities. An example is a child believing that the sidewalk was mad and made them fall down.

The Intuitive Thought Substage

Occurs between about the ages of 4 and 7. Children tend to become very curious and ask many questions; begin the use of primitive reasoning. There is an emergence in the interest of reasoning and wanting to know why things are the way they are. Piaget called it the intuitive substage because children realize they have a vast amount of knowledge but they are unaware of how they know it. Centration and conservation are both involved in preoperative thought. Centration is the act of focusing all attention on one characteristic compared to the others. Centration is noticed in conservation; the awareness that altering a substance's appearance does not change its basic properties. Children at this stage are unaware of conservation. In Piaget's most famous task, a child is presented with two identical beakers containing the same amount of liquid. The child usually notes that the beakers have the same amount of liquid. When one of the beakers is poured into a taller and thinner container, children who are typically younger than 7 or 8 years old say that the two beakers now contain a different amount of liquid. The child simply focuses on the height and width of the container compared to the general concept. Piaget believes that if a child fails the conservation-of-liquid task, it is a sign that they are at the preoperational stage of cognitive development. The child also fails to show conservation of number, matter, length, volume, and area as well. Another example is when a child is shown 7 dogs and 3 cats and asked if there are more dogs than cats. The child would respond positively. However when asked if there are more dogs than animals, the child would once again respond positively. Such fundamental errors in logic show the transition between intuitiveness in solving problems and true logical reasoning acquired in later years when the child grows up.

Piaget considered that children primarily learn through imitation and play throughout these first two stages, as they build up symbolic images through internalized activity.

Studies have been conducted among other countries to find out if Piaget's theory is universal. Psychologist Patricia Greenfield conducted a task similar to Piaget's beaker experiment in the West African nation of Senegal. Her results stated that only 50 percent of the 10-13 year old understood the concept of conservation. Other cultures such as central Australia and New Guinea had similar results. If adults had not gained this concept, they would be unable to understand the point of view of another person. There may have been discrepancies in the communication between the experimenter and the children which may have altered the results. It has also been found that if conservation is not widely practiced in a particular country, the concept can be taught to the child and training can improve the child's understanding. Therefore, it is noted that there are different age differences in reaching the understanding of conservation base on the degree to which the culture teaches these tasks.

Concrete operational stage

The concrete operational stage is the third of four stages of cognitive development in Piaget's theory. This stage, which follows the preoperational stage, occurs between the ages of 7 and 11 years and is characterized by the appropriate use of logic. Important processes during this stage are:

Seriation—the ability to sort objects in an order according to size, shape, or any other characteristic. For example, if given different-shaded objects they may make a color gradient.

Transitivity- The ability to recognize logical relationships among elements in a serial order, and perform 'transitive inferences' (for example, If A is taller than B, and B is taller than C, then A must be taller than C).

Classification—the ability to name and identify sets of objects according to appearance, size or other characteristic, including the idea that one set of objects can include another.

Decentering—where the child takes into account multiple aspects of a problem to solve it. For example, the child will no longer perceive an exceptionally wide but short cup to contain less than a normally-wide, taller cup.

Reversibility—the child understands that numbers or objects can be changed, then returned to their original state. For this reason, a child will be able to rapidly determine that if 4+4 equals t, t−4 will equal 4, the original quantity.

Conservation—understanding that quantity, length or number of items is unrelated to the arrangement or appearance of the object or items.

Elimination of Egocentrism—the ability to view things from another's perspective (even if they think incorrectly). For instance, show a child a comic in which Jane puts a doll under a box, leaves the room, and then Melissa moves the doll to a drawer, and Jane comes back. A child in the concrete operations stage will say that Jane will still think it's under the box even though the child knows it is in the drawer. (See also False-belief task).

Children in this stage can, however, only solve problems that apply to actual (concrete) objects or events, and not abstract concepts or hypothetical tasks.

Formal operational stage

The formal operational period is the fourth and final of the periods of cognitive development in Piaget's theory. This stage, which follows the Concrete Operational stage, commences at around 11 years of age (puberty) and continues into adulthood. In this stage, individuals move beyond concrete experiences and begin to think abstractly, reason logically and draw conclusions from the information available, as well as apply all these processes to hypothetical situations. The abstract quality of the adolescent's thought at the formal operational level is evident in the adolescent's verbal problem solving ability. The logical quality of the adolescent's thought is when children are more likely to solve problems in a trial-and-error fashion. Adolescents begin to think more as a scientist thinks, devising plans to solve problems and systematically testing solutions. They use hypothetical-deductive reasoning, which means that they develop hypotheses or best guesses, and systematically deduce, or conclude, which is the best path to follow in solving the problem. During this stage the adolescent is able to understand such things as love, "shades of gray", logical proofs and values. During this stage the young person begins to entertain possibilities for the future and is fascinated with what they can be. Adolescents are changing cognitively also by the way that they think about social matters. Adolescent Egocentrism governs the way that adolescents think about social matters and is the heightened self-consciousness in them as they are which is reflected in their sense of personal uniqueness and invincibility. Adolescent egocentrism can be dissected into two types of social thinking, imaginary audience that involves attention getting behavior, and personal fable which involves an adolescent's sense of personal uniqueness and invincibility.

The Stages and Causation

Piaget sees children's conception of causation as a march from "primitive" conceptions of cause to those of a more scientific, rigorous, and mechanical nature. These primitive concepts are characterized as magical, with a decidedly nonnatural or nonmechanical tone. Piaget attributes this to his most basic assumption: that babies are phenomenists. That is, their knowledge "consists of assimilating things to schemas" from their own action such that they appear, from the child's point of view, "to have qualities which in fact stem from the organism." Consequently, these "subjective conceptions," so prevalent during Piaget's first stage of development, are dashed upon discovering deeper empirical truths. Piaget gives the example of a child believing the moon and stars follow him on a night walk; upon learning that such is the case for his friends, he must separate his self from the object, resulting in a theory that the moon is immobile, or moves independently of other agents. The second stage, from around three to eight years of age, is characterized by a mix of this type of magical, animistic, or "nonnatural" conceptions of causation and mechanical or "naturalisitic" causation. This conjunction of natural and nonnatural causal explanations supposedly stems from experience itself, though Piaget does not make much of an attempt to describe the nature of the differences in conception; in his interviews with children, he asked specifically about natural phenomena: what makes clouds move? What makes the stars move? Why do rivers flow? The nature of all the answers given, Piaget says, are such that these objects must perform their actions to "fulfill their obligations towards men." He calls this "moral explanation."

Challenges to Piagetian stage theory

Piagetians' accounts of development have been challenged on several grounds. First, as Piaget himself noted, development does not always progress in the smooth manner his theory seems to predict. 'Decalage', or unpredicted gaps in the developmental progression, suggest that the stage model is at best a useful approximation. More broadly, Piaget's theory is 'domain general', predicting that cognitive maturation occurs concurrently across different domains of knowledge (such as mathematics, logic, understanding of physics, of language, etc.). During the 1980s and 1990s, cognitive developmentalists were influenced by "neo-nativist" and evolutionary psychology ideas. These ideas de-emphasized domain general theories and emphasized domain specificity or modularity of mind. Modularity implies that different cognitive faculties may be largely independent of one another and thus develop according to quite different time-tables. In this vein, some cognitive developmentalists argued that rather than being domain general learners, children come equipped with domain specific theories, sometimes referred to as 'core knowledge', which allows them to break into learning within that domain. For example, even young infants appear to be sensitive to some predictable regularities in the movement and interactions of objects (e.g. that one object cannot pass through another), or in human behavior (e.g. that a hand repeatedly reaching for an object has that object, not just a particular path of motion), as its be the building block out of which more elaborate knowledge is constructed. More recent work has strongly challenged some of the basic presumptions of the 'core knowledge' school, and revised ideas of domain generality—but from a newer dynamic systems approach, not from a revised Piagetian perspective. Dynamic systems approaches harken to modern neuroscientific research that was not available to Piaget when he was constructing his theory. One important finding is that domain-specific knowledge is constructed as children develop and integrate knowledge. This suggests more of a "smooth integration" of learning and development than either Piaget, or his neo-nativist critics, had envisioned. Additionally, some psychologists, such as Vygotsky and Jerome Bruner, thought differently from Piaget, suggesting that language was more

Post Piagetian and Neo-Piagetian stages

In the recent years, several scholars attempted to ameliorate the problems of Piaget's theory by developing new theories and models that can accommodate evidence that violates Piagetian predictions and postulates. These models are summarized below.

The neo-Piagetian theories of cognitive development, advanced by Case, Demetriou, Halford, Fischer, and Pascual-Leone, attempted to integrate Piaget's theory with cognitive and differential theories of cognitive organization and development. Their aim was to better account for the cognitive factors of development and for intra-individual and inter-individual differences in cognitive development. They suggested that development along Piaget's stages is due to increasing working memory capacity and processing efficiency. Moreover, Demetriou´s theory ascribes an important role to hypercognitive processes of self-recording, self-monitoring, and self-regulation and it recognizes the operation of several relatively autonomous domains of thought (Demetriou, 1998; Demetriou, Mouyi, Spanoudis, 2010).

Postformal stages have been proposed. Kurt Fischer suggested two, Michael Commons presents evidence for four postformal stages: the systematic, metasystematic, paradigmatic and cross paradigmatic. (Commons & Richards, 2003; Oliver, 2004).

A "sentential" stage has been proposed, said to occur before the early preoperational stage. Proposed by Fischer, Biggs and Biggs, Commons, and Richards.

Searching for a micro-physiological basis for human mental capacity, Traill (1978, Section C5.4 ; - 1999, Section 8.4) proposed that there may be "pre-sensorimotor" stages ("M−1L", "M−2L", … …) — developed in the womb and/or transmitted genetically.

Postulated physical mechanisms underlying "schemes" and stages

Piaget himself (1967) considered the possibility of RNA molecules as likely embodiments of his still-abstract "schemes" (which he promoted as units of action) — though he did not come to any firm conclusion. At that time, due to work such as that of Holger Hydén, RNA concentrations had indeed been shown to correlate with learning, so the idea was quite plausible.

However, by the time of Piaget's death in 1980, this notion had lost favour. One main problem was over the protein which (it was assumed) such RNA would necessarily produce, and that did not fit in with observation. It then turned out, surprisingly, that only about 3% of RNA does code for protein (Mattick, 2001, 2003, 2004). Hence most of the remaining 97% (the "ncRNA") could now theoretically be available to serve as Piagetian schemes (or other regulatory roles now under investigation). The issue has not yet been resolved experimentally, but its theoretical aspects have been reviewed; (Traill 2005 / 2008).

Neo-Piagetian theories of cognitive development

Jean Piaget's theory of cognitive development has been criticized on many grounds. One criticism is concerned with the very nature of development itself. It is suggested that Piaget's theory does not explain why development from stage to stage occurs. The theory is also criticized for ignoring individual differences in cognitive development. That is, the theory does not account for the fact that some individuals move from stage to stage faster than other individuals. Finally, another criticism is concerned with the nature of stages themselves. Research shows that the functioning of a person at a given age may be so variable from domain to domain, such as the understanding of social, mathematical, and spatial concepts, that it is not possible to place the person in a single stage. To remove these weaknesses, a group of researchers, who are known as neo-Piagetian theorists, advanced models that integrate concepts from Piaget's theory with concepts from cognitive and differential psychology.

The Theory of Juan Pascual-Leone

Initially, neo-Piagetian theorists explained cognitive growth along Piagetian stages by invoking information processing capacity as the cause of both development from the one stage to the next and individual differences in developmental rate. Juan Pascual-Leone was the first to advance this approach. Specifically, he argued that human thought is organized in two levels. The first and more basic level is defined by mental power or capacity. That is, this level involves processes that define the volume and kind of information that the individual can process. Working memory is the functional manifestation of mental power. The capacity of working memory is usually specified in reference to the number of information chunks or units that one can keep in mind simultaneously at a given moment. The second level involves mental content as such. That is, it involves concepts and schemes about the physical, the biological, and the social world, and the symbols we use to refer to them, such as words, numbers, mental images. It also involves the mental operations that we can carry on them, such as arithmetic operations on numbers, mental rotation on mental images, etc. Pascual-Leone proposed that the increase of the number of mental units that one can represent simultaneously makes the persons able to handle more complex concepts. For instance, one needs to be able to hold two mental units in mind to be able to decide if one number is bigger than another number. To be able to add them, the person needs to be able to hold three units, that is, the two numbers plus the arithmetic operation to be applied, such as addition or subtraction. To be able to understand proportionality, one must be able to keep in mind five units, that is the two pairs of numbers to be compared and their relation.

According to Pascual-Leone, mental power is equal to 1 scheme or unit of information at the age of 2–3 years and it increases by one unit every second year until it reaches its maximum of 7 units at the age 15 years. He claimed that the classical Piaget's stages of pre-operational, intuitive, early concrete, late concrete, transitional from concrete to formal, early formal, and late formal thought require a mental power of 1, 2, 3, 4, 5, 6, and 7 mental units, respectively. Having a lesser degree of mental power than required by a task makes the solution of this task impossible, because the necessary relations cannot be represented and computed. Thus, each increase in mental power with age opens the way for the construction of concepts and skills up to the new level of capacity. Falling short or exceeding the mental power that is typical of a given age results in slower or faster rates of development, respectively.

The Theory of Robbie Case

Based on Pascual-Leone, several other researchers advanced alternative models of capacity development. Robbie Case rejected the idea that changes in processing capacity can be described as a progression along Pascual-Leone's single line of development. Instead, he maintained that processing capacity development recycles over a succession of four main stages and that each of them is characterized by a different kind of mental structures. These stages correspond to Piaget's main stages of sensorimotor, preoperational, concrete operational and formal operational thought. Each of these four stages involves its own executive control structures that are defined by the medium of representation and the type of relations that are possible at the stage.

Executive control structures

Executive control structures enable the person to: (1) a represent the problem situation; (2) specify the objectives of problem solving; (3) conceive of the strategy needed to attain the objectives. Case maintained that there are four types of executive control structures: sensorimotor structures from 1 to 18 months of age (i.e., perceptions and actions such as seeing and grasping); interrelational structures from 18 months to 5 years of age (i.e., mental representations that stand for actual objects in the environment, such as words or mental images); dimensional structures from 5 to 11 years (i.e., mental representations that are connected together by a consistent relation such that every particular case can be related to every other case, such as the mental number line where every number can be related to every other number); finally, vectorial structures from 11 to 19 years (i.e., relations between the dimensions of the previous stage, such as ratios and proportions which connect two or more dimensions with each other).

Case also argued that development within each of these four main stages evolves along the same sequence of the following four levels of complexity: (1) operational consolidation (when a particular mental unit specific to each of the four main stages above can be contemplated and handled, such as an action in the sensorimotor stage, a word in the relational stage, a number in the dimensional stage, etc.); (2) unifocal coordination, (when two such units may be interrelated); (3) bifocal coordination, (when three such units may be interrelated); (4) elaborated coordination, (when four such units may be interrelated). Thus, structures of increasing complexity can be handled at each of the four levels. According to Case, this expansion of the capacity of short-term storage space is caused by increasing operational efficiency. That is, the command of the operations that define each kind of executive control structures improves, thereby freeing space for the representation of goals and objectives. For example, counting becomes faster with age enabling children to keep more numbers in mind.

Successive stages are not unrelated, however. That is, the final level of a given stage is at the same time the first level of the following stage. For instance, when the concept of number is well established at the final level of elaborated coordination of the relational stage it enables children to view numbers as related to each other and this is equivalent to the first level of operational consolidation of the following dimensional stage. Thus, when the structures of a given stage reach a given level of complexity (which corresponds to the level of elaborated coordination) a new mental structure is created and the cycle starts up from the beginning.

Central conceptual structures

Case recognized that variations may occur in the organization and development of different domains, due to differences in how meaning is organized in each of the domains. Specifically, Case recognized that there are central conceptual structures. These are "networks of semantic notes and relations that have an extremely broad (but not system-wide) domain of application and that are central to children's functioning in that domain." Case and his colleagues identified central conceptual structures for quantities, space, social behavior, narrative, music, and motor behavior. Each of these structures is supposed to involve a set of core processes and principles which serve to organize a broad array of situations; for example, the concept of more and less for quantities, adjacency and inclusion relationships for space, and actions and intentions for social behavior. Thus, these are very broad structures in which many executive control structures may be constructed, relative to an individual's experiences and needs. For example, in the central conceptual structure that organizes quantities, executive control structures to solve arithmetic problems, to operate balance beams, to represent home locations according to their street address etc., may be constructed. In short, central conceptual structures function as frames and they provide the basic guiding principles and raw conceptual material for the construction of more locally focused concepts and action plans, when the need for them arises.

Learning the core elements of a central conceptual structure opens the way for fast acquisition of a wide array of executive control structures, although this does not generalize to other conceptual structures. It remains limited within the one affected, indicating that there may be variations both within and across individuals in the executive control structures that can be constructed within each central conceptual structure. These variations depend on the environmental support provided to each structure and on the individual's particular preferences and involvement.

The Theory of Graeme S Halford

Graeme S Halford raised a number of objections regarding Case's definition of working memory capacity and its role in cognitive growth. The main objection is that different persons may represent the same problem differently and thus they may analyze the goals and objectives of the problem differently. Therefore, mental capacity cannot be specified in reference to executive functions. Halford proposed an alternative way to analyze the processing demands of problems that is supposed to explain the most crucial component of understanding and problem solving. This is the grasp of the network of relations that minimally and fully define a particular concept or problem.

According to Halford, this grasp is built through structure mapping. Structure mapping is analogical reasoning that people use to give meaning to problems by translating the givens of a problem into a representation or mental model that they already have and which allows them to understand the problem. The structure mappings that can be constructed depend upon the relational complexity of the structures they involve. The relational complexity of structures depends on the number of entities or the number of dimensions that are involved in the structure. The processing load of a task corresponds to the number of dimensions, which must be simultaneously represented, if their relations are to be understood. For example, to understand any comparison between two entities (e.g., "larger than", "better than", etc.) one must be able to represent two entities and one relation between them. To understand a transitive relation one must be able to represent at least three entities (e.g., objects A, B, and C) and two relations (e.g., A is taller than B; C is shorter than B); otherwise it would not be possible to mentally arrange the entities in the right order that would reveal the relations between all entities involved.

Halford identified four levels of dimensionality. The first is the level of unary relations or element mappings. Mappings at this level are constructed on the basis of a single attribute. For instance, the mental image of an apple is a valid representation of this fruit because it is similar to it. The second is the level of binary relations or relational mappings. At this level two-dimensional concepts of the type "larger than" can be constructed. Thus, two elements connected by a given relation can be considered at this level. The next is the level of system mappings, which requires that three elements or two relations must be considered simultaneously. At this level ternary relations or binary operations can be represented. The example of transitivity, which can be understood at this level, has already been explained above. The ability to solve simple arithmetic problems, where one term is missing, such as "3 + ? = 8" or "4 ? 2 = 8" also depends on system mappings, because all three known factors given must be considered simultaneously if the missing element or operation is to be specified. At the final level multiple-system mappings can be constructed. At this level quaternary relations or relations between binary operations can be constructed. For example, problems with two unknowns (e.g., 2 ? 2 ? 4 = 4) or problems of proportionality, can be solved. That is, at this level four dimensions can be considered at once. The four levels of structure mappings are thought to be attainable at the age of 1, 3, 5, and 10 years, respectively, and they correspond, in the theory of cognitive development of Piaget, to the sensorimotor, the preoperational, the concrete operational, and the formal operational, or Case's sensorimotor, interrelational, dimensional, and vectorial stage, respectively.

The Theory of Kurt W Fischer

Kurt W Fischer advanced a theory that integrates Piagets notion of stages in cognitive development with notions from learning theory and skill construction as explained by the cognitive psychology of the sixties. Fischer's conception of the stages of cognitive development is very similar to that of Case. That is, he describes four major stages or tiers which coincide by and large with Case's major stages. Thinking at each of the tiers operates with a different type of representation. That is, first is the tier of reflexes, which structures the basic reflexes constructed during the first month of life. Then it is the sensorimotor tier, which operates on perceptions and actions. The third is the representational tier, which operates on representations that are descriptive of reality. The fourth is the abstract tier, which operates on abstractions integrating the representations of the second tier.

Moreover, like Case, he believes that development within each major stage recycles over the same sequence of four structurally identical levels. That is, at the first level of single sets individuals can construct skills involving only one element of the tier concerned, that is, sensorimotor sets, representational sets, or abstract sets. At the level of mappings they can construct skills involving two elements mapped onto or coordinated with each other, that is, sensorimotor mappings, representational mappings, or abstract mappings. At the level of systems they can construct skills integrating two mappings of the previous level, that is, sensorimotor systems, representational systems, or abstract systems. At the level of systems of systems they can construct skills integrating two systems of the previous level, that is, sensorimotor systems of systems, representational systems of systems, or abstract systems of systems.

However, Fischer's theory differs from the other neo-Piagetian theories in a number of respects. One of them is in the way it explains cognitive change. Specifically, although Fischer does not deny the operation of information processing constrains on development, he emphasizes on the environmental and social rather than individual factors as causes of development. To explain developmental change he borrowed two classic notions from Lev Vygotsky, that is, internalization and the zone of proximal development. Internalization refers to the processes that enable children to reconstruct and absorb the products of their observations and interactions in a way that makes them their own. That is, it is a process which transforms external, alien skills and concepts into internal, integral ones. The zone of proximal development expresses Vygotsky's idea that at any age the child's potential for understanding and problem solving is not identical to his actual understanding and problem solving ability. Potential ability is always greater than actual ability: the zone of proximal development refers to the range of possibilities that exist between the actual and the potential. Structured social interaction, or scaffolding, and internalization are the processes that gradually allow potential (for understanding and problem solving) to become actual (concepts and skills).

Fischer argued that variations in the development and functioning of different mental skills and functions from the one domain to the other may be the rule rather than the exception. In his opinion these variations are to be attributed to differences in the experience that individuals have with different domains and also to differences in the support that they receive when interacting with the various domains. In addition, he posited that an individual's true level, which functions as a kind of ceiling for all domains, is the level of his potential, which can only be determined under conditions of maximum familiarity and scaffolding.

The Theory of Andreas Demetriou

The models above do not systematically elaborate on the differences between domains, the role of self-awareness in development, and the role of other aspects of processing efficiency, such as speed of processing and cognitive control. In the theory proposed by Andreas Demetriou, with his colleagues, all of these factors are systematically studied. According to this theory, the human mind is organized in three functional levels. The first is the level of processing potentials which involves information processing mechanisms underlying the ability to attend to, select, represent, and operate on information. The other two of levels involve knowing processes, one oriented to the environment and another oriented to the self.

Processing potentials

Mental functioning at any moment occurs under the constraints of the processing potentials that are available at a given age. Processing potentials are specified in terms of three dimensions: speed of processing, control of processing, and representational capacity. Speed of processing refers to the maximum speed at which a given mental act may be efficiently executed. It is measured in reference to the reaction time to very simple tasks, such as the time needed to recognize an object. Control of processing involves executive functions that enable the person to keep the mind focused on a goal, protect attention of being captured by irrelevant stimuli, timely shift focus to other relevant information if required, and inhibit irrelevant or premature responses, so that a strategic plan of action can be made and sustained. Reaction time to situations where one must choose between two or more alternatives is one measure of control of processing. Stroop effect tasks are good measures of control of processing. Representational capacity refers to the various aspects of mental power or working memory mentioned above.

Domain-specific systems of thought

The level oriented to the environment includes representational and understanding processes and functions that specialize in the representation and processing of information coming from different domains of the environment. Six such environment-oriented systems are described: (1) the categorical system deals with similarity-difference relations. Forming hierarchies of interrelated concepts about class relationships is an example of the domain of this system. For instance, the general class of plants includes the classes of fruits and vegetables, which, in turn, include the classes of apples and lettuce, etc.; (2) the quantitative system deals with quantitative variations and relations in the environment. Mathematical concepts and operations are examples of the domain of this system; (3) the causal system deals with cause-effect relations. Operations such as trial-and-error or isolation of variable strategies that enable a person to decipher the causal relations between things or persons and ensuing causal concepts and attributions belong to this system; (4) the spatial system deals with orientation in space and the imaginal representation of the environment. Our mental maps of our city or the mental images of familiar persons and objects and operations on them, such as mental rotation, belong to this system; (5) the propositional system deals with the truth/falsity and the validity/invalidity of statements or representations about the environment. Different types of logical relationships, such as implication (if ... then) and conjunction (and ... and) belong to this system; (6) the social system deals with the understanding of social relationships and interactions. Mechanisms for monitoring non-verbal communication or skills for manipulating social interactions belong to this system. This system also includes understanding the general moral principles specifying what is acceptable and what is unacceptable in human relations. Table 1 summarizes the core processes, mental operations, and concepts that are typical of each domain.

The domain specificity of these systems implies that the mental processes differ from the one system to the other. Compare, for instance, arithmetic operations in the quantitative system with mental rotation in the spatial system. The first require the thinker to relate quantities; the other require the transformation of the orientation of an object in space. Moreover, the different systems require different kinds of symbols to represent and operate on their objects. Compare, for instance, mathematical symbolism in the quantitative system with mental images in the spatial system. Obviously, these differences make it difficult to equate the concepts and operations across the various systems in the mental load they impose on representational capacity, as the models above assume. Case (1992) also recognized that different types of problem domains, such as the domain of social, mathematical, and spatial thought, may have a different kind of central conceptual structure. That is, concepts and executive control structures differ across domains in the semantic networks that they involve. As a result, development over different concepts within domains may proceed in parallel but it may be uneven across domains. In fact, Case and Demetriou worked together to unify their analysis of domains. That is, they suggested that Demetriou's domains may be specified in terms of Case's central conceptual structures.

Hypercognition

The third level includes functions and processes oriented to monitoring, representing, and regulating the environment-oriented systems. The input to this level is information arising from the functioning of processing potentials and the environment-oriented systems, for example, sensations, feelings, and conceptions caused by mental activity. The term hypercognition was used to refer to this level and denote the effects that it exerts on the other two levels of the mind. Hypercognition involves two central functions, namely working hypercognition and long-term hypercognition.

Working hypercognition is a strong directive-executive function that is responsible for setting and pursuing mental and behavioral goals until they are attained. This function involves processes enabling the person to: (1) set mental and behavioral goals; (2) plan their attainment; (3) evaluate each step's processing demands vis-à-vis the available potentials, knowledge, skills and strategies; (4) monitor planned activities vis-à-vis the goals; and (5) evaluate the outcome attained. These processes operate recursively in such a way that goals and subgoals may be renewed according to the online evaluation of the system's distance from its ultimate objective. These regulatory functions operate under the current structural constraints of the mind that define the current processing potentials. Recent research suggests that these processes participate in general intelligence together with processing potentials and the general inferential processes used by the specialized thought domains described above.

Consciousness is an integral part of the hypercognitive system. The very process of setting mental goals, planning their attainment, monitoring action vis-à-vis both the goals and the plans, and regulating real or mental action requires a system that can remember and review and therefore know itself. Therefore, conscious awareness and all ensuing functions, such as a self-concept (i.e., awareness of one's own mental characteristics, functions, and mental states) and a theory of mind (i.e., awareness of others' mental functions and states) are part of the very construction of the system.

In fact, long-term hypercognition gradually builds maps or models of mental functions which are continuously updated. These maps are generally accurate representations of the actual organization of cognitive processes in the domains mentioned above. When needed, they can be used to guide problem solving and understanding in the future. Optimum performance at any time depends on the interaction between actual problem solving processes specific to a domain and our representations of them. The interaction between the two levels of mind ensures flexibility of behavior, because the self-oriented level provides the possibility for representing alternative environment-oriented representations and actions and thus it provides the possibility for planning.

Development

All of the processes mentioned above develop systematically with age. Speed of processing increases systematically from early childhood to middle age and it then starts to decrease again. For instance, to recognize a very simple object takes about 750 milliseconds at the age of 6 years and only about 450 milliseconds in early adulthood. Control of processing also becomes more efficient and capable of allowing the person to focus on more complex information, hold attention for longer periods of time, and alternate between increasingly larger stacks of stimuli and responses while filtering out irrelevant information. For instance, to recognize a particular stimulus among conflicting information may take about 2000 milliseconds at the age of 6 years and only about 750 milliseconds in early adulthood.

All components of working memory (e.g., executive functions, numerical, phonological and visuospatial storage) increase with age. However, the exact capacity of working memory varies greatly depending upon the nature of information. For example, in the spatial domain, they may vary from 3 units at the age of six to 5 units at the age of 12 years. In the domain of mathematical thought, they may vary from about 2 to about 4 units in the same age period. If executive operations are required, the capacity is extensively limited, varying from about 1 unit at 6 to about 3 units at 12 years of age. Demetriou proposed the functional shift model to account for these data. This model presumes that when the mental units of a given level reach a maximum degree of complexity, the mind tends to reorganize these units at a higher level of representation or integration so as to make them more manageable. Having created a new mental unit, the mind prefers to work with this rather than the previous units due to its functional advantages. An example in the verbal domain would be the shift from words to sentences and in the quantitative domain from natural numbers to algebraic representations of numerical relations. The functional shift models explains how new units are created leading to stage change in the fashion described by Case and Halford.

The specialized domains develop through the life span both in terms of general trends and in terms of the typical characteristics of each domain. In the age span from birth to middle adolescence, the changes are faster in all of the domains. With development, thought in each of the domains becomes able to deal with increasingly more representations. Moreover, representations become increasingly interconnected with each other and they acquire their meaning from their interrelations rather than simply their relations with concrete objects. As a result, concepts in each of the domains become increasingly defined in reference to rules and general principles bridging more local concepts and creating new, broader, and more abstract concepts. Moreover, understanding and problem solving in each of the domains evolve from global and less integrated to differentiated, but better integrated, mental operations. As a result, planning and operation from alternatives becomes increasingly part of the person's functioning, as well as the increasing ability to efficiently monitor the problem solving process. This offers flexibility in cognitive functioning and problem solving across the whole spectrum of specialized domains. Table 2 summarizes the development of the domains from early childhood to adolescence.

Self-awareness and self-regulation in the hypercognitive system also develop systematically with age. Specifically, with development, self-awareness of cognitive processes becomes more accurate and shifts from the external and superficial characteristics of problems (e.g., this is about numbers and this is about pictures) to the cognitive processes involved (e.g., the one requires addition and the other requires mental rotation). Moreover, self-representations: (i) involve more dimensions which are better integrated into increasingly more complex structures; (ii) move along a concrete (e.g., I am fast and strong) to abstract (e.g., I am able) continuum so that they become increasingly more abstract and flexible; and (iii) become more accurate in regard to the actual characteristics and abilities to which they refer (i.e., persons know where they are cognitively strong and where they are weak). The knowledge available at each phase defines the kind of self-regulation that can be affected. Thus, self-regulation becomes increasingly focused, refined, efficient, and strategic. Practically this implies that our information processing capabilities come under increasing a priori control of our long-term hypercognitive maps and our self-definitions. Moreover, as we move into middle age, intellectual development gradually shifts from the dominance of systems that are oriented to the processing of the environment (such as spatial and propositional reasoning) to systems that require social support and self-understanding and management (social understanding). Thus, the transition to mature adulthood makes persons intellectually stronger and more self-aware of their strengths.

There are strong developmental relations between the various processes, such that changes at any level of organization of the mind open the way for changes in other levels. Specifically, changes in speed of processing open the way for changes in the various forms of control of processing. These, in turn, open the way for the enhancement of working memory capacity, which subsequently opens the way for development in inferential processes, and the development of the various specialized domains through the reorganization of domain-specific skills, strategies, and knowledge and the acquisition of new ones.

There are top-down effects as well. That is, general inference patterns, such as implication (if ... then inferences), or disjunction (either ... or inferences), are constructed by mapping domain-specific inference patterns onto each other through the hypercognitive process of metarepresentation. Metarepresentation is the primary top-down mechanism of cognitive change which looks for, codifies, and typifies similarities between mental experiences (past or present) to enhance understanding and problem-solving efficiency. In logical terms, metarepresentation is analogical reasoning applied to mental experiences or operations, rather than to representations of environmental stimuli. For example, if ... then sentences are heard over many different occasions in everyday language: if you are a good child then I will give you a toy; if it rains and you stay out then you become wet; if the glass falls on the floor then it brakes in pieces; etc. When a child realizes that the sequencing of the if ... then connectives in language is associated with situations in which the event or thing specified by if always comes first and it leads to the event or thing specified by then, this child is actually formulating the inference schema of implication. With development, the schema becomes a reasoning frame for predictions and interpretations of actual events or conversations about them.

Brain and cognitive development

Modern research on the organization and functioning of the brain lends support to this architecture. This research shows that some general aspects of the brain, such as myelination, plasticity, and connectivity of neurons, are related to some dimensions of general intelligence, such as speed of processing and learning efficiency. Moreover, there are brain regions, located mainly in the frontal and parietal cortex that subserve functions that are central to all cognitive processing, such as executive control, and working memory. Also, there are many neural networks that specialize in the representation of different types of information such as verbal (temporal lobe of the brain), spatial (occipital lobe of the brain) or quantitative information (parietal lobe of the brain).

Moreover, several aspects of neural development are related to cognitive development. For example, increases in the myelination of neuronal axons, which protect the transmission of electrical signalling along the axons from leakage, are related to changes in general processing efficiency. This, in turn, enhances the capacity of working memory, thereby facilitating transition across the stages of cognitive development. Also it is assumed that changes within stages of cognitive development are associated with improvements in neuronal connectivity within brain regions whereas transitions across stages are associated with improvements in connectivity between brain regions.

Dynamic systems theory

In recent years, there has been an increasing interest in theories and methods that show promise for capturing and modeling the regularities underlying multiple interacting and changing processes. Dynamic systems theory is one of them. When multiple processes interact in complex ways, they very often appear to behave unsystematically and unpredictably. In fact, however, they are interconnected in systematic ways, such that the condition of one process at a given point of time t (for example, speed of processing) is responsible for the condition of another process (for example working memory), at a next point of time t + 1, and together they determine the condition of a third process (for example thought), at a time t + 2, which then influences the conditions of the other two processes at a time t + 3, etc. Dynamic systems theory can reveal and model the dynamic relationships among different processes and specify the forms of development that result from different types of interaction among processes. The aim is to explain the order and systematicity that exist beneath a surface of apparent disorder or "chaos". It needs to be noted that there is no limitation as to what processes may be involved in this kind of modeling. That is, the processes may belong to any of the levels of mind, such as the level of the processing capacity and the level of problem solving skills.

Paul van Geert was the first to show the promise that dynamic systems theory holds for the understanding of cognitive development. Van Geert assumed that the basic growth model is the so-called "logistic growth model", which suggests that the development of mental processes follows an S-like pattern of change. That is, at the beginning, change is very slow and hardly noticeable; after a given point in time, however, it occurs very rapidly so that the process or ability spurts to a much higher level in a relatively short period of time; finally, as this process approaches its end state, change decelerates until it stabilizes.

According to van Geert, logistic growth is a function of three parameters: the present level, the rate of change, and a limit on the level that can be reached that depends on the available resources for the functioning of the process under consideration. The first parameter, i.e., the present level, indicates the potential that a process has for further development. Obviously, the further away a process is from its end state the more its potential of change would be. The second (the rate of change), is an augmenting or multiplying factor applied to the present level. This may come from pressures for change from the environment or internal drives or motives for improvement. It operates like the interest rate applied to a no-withdrawal savings account. That is, this is a factor that indicates the rate at which an ability changes in order to approach its end state. The third parameter refers to the resources available for development. For example, the working memory available is the resource for the development of cognitive processes which may belong to any domain. Many theorists, including Case, Demetriou, and Fischer, used dynamic systems modeling to investigate and explore the dynamic relations between cognitive processes during development.

Relations between theories

The neo-Piagetian theories above are related. Pascual-Leone, Case, and Halford attempt to explain development along the sequence of Piagetian stages and substages. Pascual-Leone aligned this sequence with a single line of development of mental power that goes from one to seven mental units. Case suggested that each of four main stages involves different kinds of mental structures and he specified the mental load of the successive levels or substages of complexity within each of the main stages. Moreover, he recognized that there may be different central conceptual structures within each level of executive control structures that differ between each other in reference to the concepts and semantic relations involved. Halford attempted to specify the cognitive load of the mental structure that is typical of each of the main stages. Demetriou integrated into the theory the constructs of speed and control of processing and he formulated the functional shift model which unifies Pascual-Leone's notion of underlying common dimension of capacity development with the notion of qualitative changes in mental structure as development progresses along this dimension. Moreover, Demetriou did justice to the role of self-awareness in cognitive development and the relevant autonomy in the development of different domains of thought. Fischer stressed the importance of skill construction processes in building stage-like constructs and he emphasized the role of the environment and social support in skill construction. The Model of Hierarchical Complexity formulated by Michael Commons offers a useful language of description of the successive levels of cognitive development while allowing for the explicit reference to the particularities of concepts and operations specific to each of the domains. Dynamic systems modeling can capture and express how different processes interact dynamically when developmental hierarachies are built.

Moreover, Demetriou's theory integrated models from cognitive, psychometric, and developmental psychology into an overarching model that describes the architecture of the human mind, its development, and individual differences in regard to both architecture and development. In as far as architecture is concerned, it is maintained that both general and specialized capabilities and processes do exist, which are organized hierarchically so that more complex and specialized processes include more simple or general processes. This type of architecture converges with more than a century of psychometric research. in suggesting that general intelligence or g is a very powerful component of human intelligence. This can be reduced to mechanisms underlying processing efficiency, processing capacity, executive control, and working memory, which have been the primary target of research and theory in cognitive psychology and differential psychology. Many scholars argue that fluid intelligence, that is the general mechanisms underlying learning, problem solving, and the handling of novelty, depends on these processes. Also, changes in these very mechanisms seem able to explain, to a considerable extent, the changes in the quality of understanding and problem solving at successive age levels, which is the object of developmental psychology and individual differences in regard to it.

Thus, an overarching definition of intelligence can be as follows: The more mentally efficient (that is, the faster and more focused on goal), capable (that is, the more information one can hold in mind at a given moment), foresighted (that is, the more clearly one can specify his goals and plan how to achieve them), and flexible (that is, the more one can introduce variations in the concepts and mental operations one already possesses) a person is, the more intelligent (both in regard to other individuals and in regard to a general developmental hierarchy) this person is. In psychometric terms, this is tantamount to saying that differences in the processes associated with g cause differences in general inferential and reasoning mechanisms. In developmental terms, this is tantamount to saying that changes in the processes underlying g result in the qualitative transformation of the general structures of thought underlying understanding and reasoning at successive ages so that more complex and less familiar problems can be solved and more abstract concepts can be constructed. Thus, differences between persons in IQ or in the rate of development result, additively, from differences in all of the processes mentioned here. Thus, this theory, on the one hand, surpasses Arthur Jensen's theory of general intelligence in that it recognizes the importance of specialized domains in the human mind, which are underestimated in Jensen's theory. On the other hand, by recognizing the role of general processes and showing how specialized competences are constrained by them, it also surpasses Howard Gardner's theory of multiple intelligences, which underestimates the operation of common processes.

Implications for education

Education and the psychology of cognitive development converge on a number of crucial assumptions. First, the psychology of cognitive development defines human cognitive competence at successive phases of development. That is, it specifies what aspects of the world can be understood at different ages, what kinds of concepts can be constructed, and what types of problems can be solved. Education aims to help students acquire knowledge and develop skills which are compatible with their understanding and problem-solving capabilities at different ages. Thus, knowing the students' level on a developmental sequence provides information on the kind and level of knowledge they can assimilate, which, in turn, can be used as a frame for organizing the subject matter to be taught at different school grades. This is the reason why Piaget's theory of cognitive development was so influential for education, especially mathematics and science education.

In the 60s and the 70s, school curricula were designed to implement Piaget's ideas in the classroom. For example, in mathematics, teaching must build on the stage sequence of mathematical understanding. Thus, in preschool and early primary (elementary) school, teaching must focus on building the concept of numbers, because concepts are still unstable and uncoordinated. In the late primary school years operations on numbers must be mastered because concrete operational thought provides the mental background for this. In adolescence the relations between numbers and algebra can be taught, because formal operational thought allows for conception and manipulation of abstract and multidimensional concepts. In science teaching, early primary education should familiarize the children with properties of the natural world, late primary education should lead the children to practice exploration and master basic concepts such as space, area, time, weight, volume, etc., and, in adolescence, hypothesis testing, controlled experimentation, and abstract concepts, such as energy, inertia, etc., can be taught.

In the same direction, the neo-Piagetian theories of cognitive development suggest that in addition to the concerns above, sequencing of concepts and skills in teaching must take account of the processing and working memory capacities that characterize successive age levels. In other words, the overall structure of the curriculum across time, in any field, must reflect the developmental processing and representational possibilities of the students as specified by all of the theories summarized above. This is necessary because when understanding of the concepts to be taught at a given age requires more than the available capacity, the necessary relations cannot be worked out by the student. In fact, Demetriou has shown that speed of processing and working memory are excellent predictors of school performance.

Second, the psychology of cognitive development involves understanding how cognitive change takes place and recognizing the factors and processes which enable cognitive competence to develop. Education also capitalizes on cognitive change. The transmission of information and the construction of knowledge presuppose effective teaching methods. Effective teaching methods have to enable the student to move from a lower to a higher level of understanding or abandon less efficient skills for more efficient ones. Therefore, knowledge of change mechanisms can be used as a basis for designing instructional interventions that will be both subject- and age-appropriate. Comparison of past to present knowledge, reflection on actual or mental actions vis-à-vis alternative solutions to problems, tagging new concepts or solutions to symbols that help one recall and mentally manipulate them are just a few examples of how mechanisms of cognitive development may be used to facilitate learning. For example, to support metarepresentation and facilitate the emergence of general reasoning patterns from domain specific processing, teaching must continually raise awareness in students of what may be abstracted from any particular domain-specific learning. Specifically, the student must be led to become aware of the underlying relations that surpass content differences and of the very mental processes used while handling them (for instance, elaborate on how particular inference schemas, such as implication, operate in different domains).

Finally, the psychology of cognitive development is concerned with individual differences in the organization of cognitive processes and abilities, in their rate of change, and in their mechanisms of change. The principles underlying intra- and inter-individual differences could be educationally useful, because it highlights why the same student is not an equally good learner in different domains, and why different students in the same classroom react differently to the same instructional materials. For instance, differences between same age students in the same classroom in processing efficiency and working memory may differentiate these students in their understanding and mastering of the concepts or skills taught at a given moment. That is, students falling behind the demands would most probably have problems in capturing the concepts and skills taught. Thus, knowing the students' potentials in this regard would enable the teacher to develop individual examples of the target concepts and skills that would cater for the needs of the different students so that no one is left behind. Also, differences in the developmental condition, experience, familiarity, or interest in respect to the various domains would most certainly cause differences in how students would respond to teaching related to them. This is equally true for both differences between students and differences within the same student. In Case's terms, the central conceptual structures available in different domains would not necessarily match the complexity of executive control structures that are possible based on the students' processing and representational capacity. As a result, teaching would have to accommodate these differences if it is to lead each of the students to the optimum of their possibilities across all domains. Finally, identifying individual differences with regard to the various aspects of cognitive development could be the basis for the development of programs of individualized instruction which may focus on the gifted student or which may be of a remedial nature.

The discussion here about the educational implications of the neo-Piagetian theories of cognitive development taken as whole suggests that these theories provide a frame for designing educational interventions that is more focused and specific than traditional theories of cognitive development, such as the theory of Piaget, or theories of intelligence, such as the theories discussed above. Of course, much research is still needed for the proper application of these theories into the various aspects of education.

Psychology of reasoning

The psychology of reasoning is the study of how people reason, often broadly defined as the process of drawing conclusions to inform how people solve problems and make decisions. It is at the intersection of psychology, philosophy, linguistics, cognitive science, artificial intelligence, logic, and probability theory.

Overview

Psychological experiments on how humans and other animals reason have been carried out for over 100 years. An enduring question is whether or not people have the capacity to be rational. What does it mean to be rational? Current research in this area addresses various questions about reasoning, rationality, intelligence, relationships between emotion and reasoning, and development.

Everyday reasoning

How do people reason about sentences in natural language? Most experimentation on deduction has been carried out on hypothetical thought, in particular, examining how people reason about conditionals, e.g., If A then B. Participants in experiments make the modus ponens inference, given the indicative conditional If A then B, and given the premise A, they conclude B. But given the indicative conditional and the minor premise for the modus tollens inference, not-B, about half of the participants in experiments conclude not-A and the remainder conclude that nothing follows.

The ease with which people make conditional inferences is affected by content, as demonstrated in the well-known selection task developed by Peter Wason. Participants are better able to test a conditional that contains sensible content, e.g., if the envelope is sealed then it must have a 50 cent stamp on it compared to one that contains symbolic content, e.g., if the letter is a vowel then the number is even. Background knowledge can also lead to the suppression of even the simple modus ponens inference. Participants given the conditional if Lisa has an essay to write then she studies late in the library and the premise Lisa has an essay to write make the modus ponens inference 'she studies late in the library', but the inference is suppressed when they are also given a second conditional if it the library stays open then she studies late in the library. Interpretations of the suppression effect are controversial.

Other investigations of propositional inference examine how people think about disjunctive alternatives, e.g., A or else B, and how they reason about negation, e.g., It is not the case that A and B. Many experiments have been carried out to examine how people make relational inferences, including comparisons, e.g., A is better than B. Such investigations also concern spatial inferences, e.g. A is in front of B and temporal inferences, e.g. A occurs before B. Other common tasks include categorical syllogisms, used to examine how people reason about quantifiers such as All or Some, e.g., Some of the A are not B.

Theories of reasoning

There are several alternative theories of the cognitive processes that human reasoning is based on. One view is that people rely on a mental logic consisting of formal (abstract or syntactic) inference rules similar to those developed by logicians in the propositional calculus. Another view is that people rely on domain-specific or content-sensitive rules of inference. A third view is that people rely on mental models, that is, mental representations that correspond to imagined possibilities. A fourth view is that people compute probabilities.

One controversial theoretical issue is the identification of an appropriate competence model, or a standard against which to compare human reasoning. Initially classical logic was chosen as a competence model. Subsequently some researchers opted for non-monotonic logic and Bayesian probability. Research on mental models and reasoning has led to the suggestion that people are rational in principle but err in practice. Connectionist approaches towards reasoning have also been proposed.

Development of reasoning

How does reasoning develop? Jean Piaget's theory of cognitive development describes a sequence of stages in the development of reasoning from infancy to adulthood. According to the neo-Piagetian theories of cognitive development, changes in reasoning with development come from increasing working memory capacity, increasing speed of processing, and enhanced executive functions and control. Increasing self-awareness is also an important factor.

Mental model

A mental model is an explanation of someone's thought process about how something works in the real world. It is a representation of the surrounding world, the relationships between its various parts and a person's intuitive perception about their own acts and their consequences. Our mental models help shape our behaviour and define our approach to solving problems (akin to a personal algorithm) and carrying out tasks.

Overview

A mental model is a kind of internal symbol or representation of external reality, hypothesized to play a major role in cognition, reasoning and decision-making. Kenneth Craik suggested in 1943 that the mind constructs "small-scale models" of reality that it uses to anticipate events.

One example is provided in the following description from Richard Feynman:

I had a scheme, which I still use today when somebody is explaining something that I'm trying to understand: I keep making up examples. For instance, the mathematicians would come in with a terrific theorem, and they're all excited. As they're telling me the conditions of the theorem, I construct something which fits all the conditions. You know, you have a set (one ball) – disjoint (two balls). Then the balls turn colors, grow hairs, or whatever, in my head as they put more conditions on. Finally they state the theorem, which is some dumb thing about the ball which isn't true for my hairy green ball thing, so I say, 'False!'

Jay Wright Forrester defined general mental models as:

"The image of the world around us, which we carry in our head, is just a model. Nobody in his head imagines all the world, government or country. He has only selected concepts, and relationships between them, and uses those to represent the real system."

In psychology, the term "mental models" is sometimes used to refer to mental representations or mental simulation generally. At other times it is used to refer to mental models and reasoning and to the mental model theory of reasoning developed by Philip Johnson-Laird and Ruth M.J. Byrne.

History

The term is believed to have originated with Kenneth Craik in his 1943 book The Nature of Explanation. Georges-Henri Luquet in Le dessin enfantin (Children's Drawings), published in 1927 by Alcan, Paris, argued that children construct internal models, a view that influenced, among others, Jean Piaget.

Philip Johnson-Laird published Mental Models: Towards a Cognitive Science of Language, Inference and Consciousness in 1983. In the same year, Dedre Gentner and Albert Stevens edited a collection of chapters in a book also titled Mental Models. The first line of their book explains the idea further: "One function of this chapter is to belabor the obvious; people's views of the world, of themselves, of their own capabilities, and of the tasks that they are asked to perform, or topics they are asked to learn, depend heavily on the conceptualizations that they bring to the task." (See Mental Models (Gentner-Stevens book).)

Since then there has been much discussion and use of the idea in human-computer interaction and usability by researchers including Donald Norman and Steve Krug in his book Don't Make Me Think. Walter Kintsch and Teun A. van Dijk, using the term situation model (in their book Strategies of Discourse Comprehension, 1983), showed the relevance of mental models for the production and comprehension of discourse.

Mental models and reasoning

One view of human reasoning is that it depends on mental models. On this view mental models can be constructed from perception, imagination, or the comprehension of discourse (Johnson-Laird, 1983). Such mental models are akin to architects' models or to physicists' diagrams in that their structure is analogous to the structure of the situation that they represent, unlike, say, the structure of logical forms used in formal rule theories of reasoning. In this respect they are a little like pictures in the "picture" theory of language described by Ludwig Wittgenstein in 1922. Philip Johnson-Laird and Ruth M.J. Byrne developed a theory of mental models which makes the assumption that reasoning depends, not on logical form, but on mental models (Johnson-Laird and Byrne, 1991).

Principles of mental models

Mental models are based on a small set of fundamental assumptions, which distinguish them from other proposed representations in the psychology of reasoning (Byrne and Johnson-Laird, 2009). Each mental model represents a possibility. A mental model represents one possibility, capturing what is common to all the different ways in which the possibility may occur (Johnson-Laird and Byrne, 2002). Mental models are iconic, i.e., each part of a model corresponds to each part of what it represents (Johnson-Laird, 2006). Mental models are based on a principle of truth: they represent only those situations that are possible, and each model of a possibility represents only what is true in that possibility according to the proposition. Mental models can represent what is false, temporarily assumed to be true, e.g., in the case of counterfactual conditionals and counterfactual thinking (Byrne, 2005).

Reasoning with mental models

People infer that a conclusion is valid if it holds in all the possibilities. Procedures for reasoning with mental models rely on counterexamples to refute invalid inferences; they establish validity by ensuring that a conclusion holds over all the models of the premises. Reasoners focus on a subset of the possible models of multiple-model problems—often just a single model. The ease with which reasoners can make deductions is affected by many factors, including age and working memory (Barrouillet, et al., 2000). They reject a conclusion if they find a counterexample, i.e., a possibility in which the premises hold, but the conclusion does not (Schroyens, et al. 2003; Verschueren, et al., 2005).

Criticisms

Scientific debate continues about whether human reasoning is based on mental models, formal rules of inference (e.g., O'Brien, 2009), domain-specific rules of inference (e.g., Cheng & Holyoak, 2008; Cosmides, 2005), or probabilities (e.g., Oaksford and Chater, 2007). Many empirical comparisons of the different theories have been carried out (e.g., Oberauer, 2006).

Mental models in system dynamics

Characteristics

A mental model is generally:

- founded on hardly qualifiable, impugnable, obscure, or incomplete facts
- flexible – is considerably variable in positive as well as in negative sense
- effects as information filter – causes selective perception, perception of only selected parts of information
- compared with the complexities surrounding the world is very limited and even when the scientific model is extensive and in accordance with a certain reality in the derivation of logical consequences of it we are very limited. We must take into account such restrictions on working memory—i.e. well-known rule on the maximum number of elements that we are suddenly able to remember, gestaltismus or failure of the principles of logic, etc.
- sources of information, which one can not find anywhere else, are available at any time and can be used. If other routes are possible, which is linked with the fact that it is not always clearly understood by the other, the process of interpretation can be interpreted in different ways.

Mental models are fundamental to understanding organizational learning. Mental models are "deeply held images of thinking and acting." Mental models are so basic to our understanding of the world that we are hardly conscious of them.

Expression of mental models

Three basic forms are used:

- Polygons – whose vertices sharing the edge represent related items.
- Causal loop diagrams – displaying tendency and a direction of information connections and the resulting causality
- Flow diagram – a more appropriate way to express a dynamic system

Mental model in relation to the system dynamics and systemic thinking

The simplification of reality, you create so that we were able to find a sense of reality, seeking to overcome systemic thinking and system dynamics.

These two disciplines help us to construct a better coordinated with the reality of mental models and simulate it accurately. They increase the probability that the consequences of how we will decide and act in accordance with how we plan to.

- System dynamics – extending our mental models through the creation of explicit models, which are clear, easily communicating and can be compared with each other.
- Systemic thinking – seeking the means to improve the mental models and thereby improve the quality of dynamic decisions that are based on mental models

Single and double-loop learning

After analyzing the basic characteristics, it is necessary to bring the process of change mental models, or the process of learning. Learning is a back-loop process and feedback can be illustrated as:

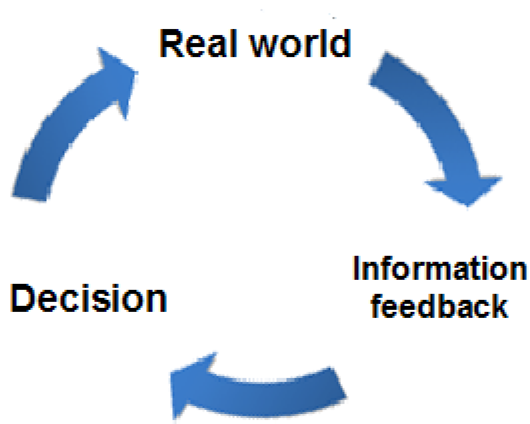
Single-loop learning

Our mental models affect the way we work with the information and determine the final decision. The decision itself changes, but the mental models remain the same. It is the predominant method of learning, because it is very convenient. One established mental model is fixed, so the next decision is very fast.

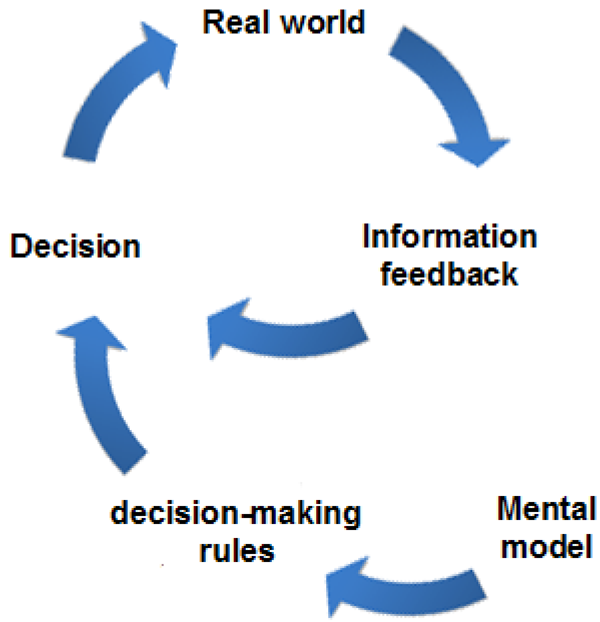
Double-loop learning

Is used when it is necessary to change the mental model on which our decision depends. Unlike single loops, this model includes a shift in understanding—from simple and static to broader and more dynamic—such as taking into account the changes in the surroundings and the need for expression changes in mental models.

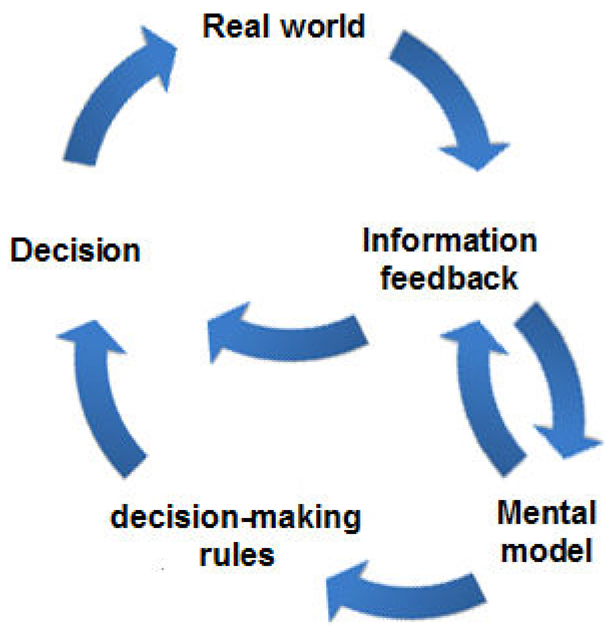
Process of learning:



Feedback process



Single-loop learning



Double-loop learning

Language to express the system of thought

For a description of the structure is used in general to understand the universal graphic symbols, which can describe the structure of generating behavior of any system in time. If individual elements correctly defined, it is possible for a computer in a software model to simulate and interpret the results (e.g. in the form of graphs).

Problem solving

Problem solving is a mental process and is part of the larger problem process that includes problem finding and problem shaping. Considered the most complex of all intellectual functions, problem solving has been defined as higher-order cognitive process that requires the modulation and control of more routine or fundamental skills. Problem solving occurs when an organism or an artificial intelligence system needs to move from a given state to a desired goal state.

Overview

The nature of human problem solving methods has been studied by psychologists over the past hundred years. There are several methods of studying problem solving, including; introspection, behaviorism, simulation, computer modeling and experiment.

Beginning with the early experimental work of the Gestaltists in Germany (e.g. Duncker, 1935), and continuing through the 1960s and early 1970s, research on problem solving typically conducted relatively simple, laboratory tasks (e.g. Duncker's "X-ray" problem; Ewert & Lambert's 1932 "disk" problem, later known as Tower of Hanoi) that appeared novel to participants (e.g. Mayer, 1992). Various reasons account for the choice of simple novel tasks: they had clearly defined optimal solutions, they were solvable within a relatively short time frame, researchers could trace participants' problem-solving steps, and so on. The researchers made the underlying assumption, of course, that simple tasks such as the Tower of Hanoi captured the main properties of "real world" problems, and that the cognitive processes underlying participants' attempts to solve simple problems were representative of the processes engaged in when solving "real world" problems. Thus researchers used simple problems for reasons of convenience, and thought generalizations to more complex problems would become possible. Perhaps the best-known and most impressive example of this line of research remains the work by Allen Newell and Herbert Simon .

Simple laboratory-based tasks can be useful in explicating the steps of logic and reasoning that underlie problem solving; however, they omit the complexity and emotional valence of "real-world" problems. In clinical psychology, researchers have focused on the role of emotions in problem solving (D'Zurilla & Goldfried, 1971; D'Zurilla & Nezu, 1982), demonstrating that poor emotional control can disrupt focus on the target task and impede problem resolution (Rath, Langenbahn, Simon, Sherr, & Diller, 2004). In this conceptualization, human problem solving consists of two related processes: problem orientation, the motivational/attitudinal/affective approach to problematic situations and problem-solving skills, the actual cognitive-behavioral steps, which, if successfully implemented, lead to effective problem resolution. Working with individuals with frontal lobe injuries, neuropsychologists have discovered that deficits in emotional control and reasoning can be remediated, improving the capacity of injured persons to resolve everyday problems successfully (Rath, Simon, Langenbahn, Sherr, & Diller, 2003).

Europe

In Europe, two main approaches have surfaced, one initiated by Donald Broadbent (1977; see Berry & Broadbent, 1995) in the United Kingdom and the other one by Dietrich Dörner (1975, 1985; see Dörner & Wearing, 1995) in Germany. The two approaches have in common an emphasis on relatively complex, semantically rich, computerized laboratory tasks, constructed to resemble real-life problems. The approaches differ somewhat in their theoretical goals and methodology, however. The tradition initiated by Broadbent emphasizes the distinction between cognitive problem-solving processes that operate under awareness versus outside of awareness, and typically employs mathematically well-defined computerized systems. The tradition initiated by Dörner, on the other hand, has an interest in the interplay of the cognitive, motivational, and social components of problem solving, and utilizes very complex computerized scenarios that contain up to 2,000 highly interconnected variables (e.g., Dörner, Kreuzig, Reither & Stäudel's 1983 LOHHAUSEN project; Ringelband, Misiak & Kluwe, 1990). Buchner (1995) describes the two traditions in detail.

To sum up, researchers' realization that problem-solving processes differ across knowledge domains and across levels of expertise (e.g. Sternberg, 1995) and that, consequently, findings obtained in the laboratory cannot necessarily generalize to problem-solving situations outside the laboratory, has during the past two decades led to an emphasis on real-world problem solving. This emphasis has been expressed quite differently in North America and Europe, however. Whereas North American research has typically concentrated on studying problem solving in separate, natural knowledge domains, much of the European research has focused on novel, complex problems, and has been performed with computerized scenarios (see Funke, 1991, for an overview).

USA and Canada

In North America, initiated by the work of Herbert Simon on learning by doing in semantically rich domains (e.g. Anzai & Simon, 1979; Bhaskar & Simon, 1977), researchers began to investigate problem solving separately in different natural knowledge domains – such as physics, writing, or chess playing – thus relinquishing their attempts to extract a global theory of problem solving (e.g. Sternberg & Frensch, 1991). Instead, these researchers have frequently focused on the development of problem solving within a certain domain, that is on the development of expertise (e.g. Anderson, Boyle & Reiser, 1985; Chase & Simon, 1973; Chi, Feltovich & Glaser, 1981).

Areas that have attracted rather intensive attention in North America include such diverse fields as:

Problem Solving (Kepner & Tregoe, 1958)

Reading (Stanovich & Cunningham, 1991)
Writing (Bryson, Bereiter, Scardamalia & Joram, 1991)
Calculation (Sokol & McCloskey, 1991)
Political decision making (Voss, Wolfe, Lawrence & Engle, 1991)
Problem Solving for Business (Cornell, 2010)
Managerial problem solving (Wagner, 1991)
Lawyers' reasoning (Amsel, Langer & Loutzenhiser, 1991)
Mechanical problem solving (Hegarty, 1991)
Problem solving in electronics (Lesgold & Lajoie, 1991)
Computer skills (Kay, 1991)
Game playing (Frensch & Sternberg, 1991)
Personal problem solving (Heppner & Krauskopf, 1987)
Mathematical problem solving (Polya, 1945; Schoenfeld, 1985)
Social problem solving (D'Zurilla & Goldfreid, 1971; D'Zurilla & Nezu, 1982)
Problem solving for innovations and inventions: TRIZ (Altshuller, 1973, 1984, 1994)

Characteristics of difficult problems

As elucidated by Dietrich Dörner and later expanded upon by Joachim Funke, difficult problems have some typical characteristics that can be summarized as follows:

Intransparency (lack of clarity of the situation)
commencement opacity
continuation opacity

Polytely (multiple goals)
inexpressiveness
opposition
transience

Complexity (large numbers of items, interrelations and decisions)
enumerability
connectivity (hierarchy relation, communication relation, allocation relation)
heterogeneity

Dynamics (time considerations)
temporal constraints
temporal sensitivity
phase effects
dynamic unpredictability

The resolution of difficult problems requires a direct attack on each of these characteristics that are encountered.

In reform mathematics, greater emphasis is placed on problem solving relative to basic skills, where basic operations can be done with calculators. However some "problems" may actually have standard solutions taught in higher grades. For example, kindergarteners could be asked how many fingers are there on all the gloves of 3 children, which can be solved with multiplication.

Problem-solving techniques

- Abstraction: solving the problem in a model of the system before applying it to the real system
- Analogy: using a solution that solved an analogous problem
- Brainstorming: (especially among groups of people) suggesting a large number of solutions or ideas and combining and developing them until an optimum is found
- Divide and conquer: breaking down a large, complex problem into smaller, solvable problems
- Hypothesis testing: assuming a possible explanation to the problem and trying to prove (or, in some contexts, disprove) the assumption
- Lateral thinking: approaching solutions indirectly and creatively
- Means-ends analysis: choosing an action at each step to move closer to the goal
- Method of focal objects: synthesizing seemingly non-matching characteristics of different objects into something new
- Morphological analysis: assessing the output and interactions of an entire system
- Reduction: transforming the problem into another problem for which solutions exist
- Research: employing existing ideas or adapting existing solutions to similar problems
- Root cause analysis: eliminating the cause of the problem
- Trial-and-error: testing possible solutions until the right one is found
- Proof: try to prove that the problem cannot be solved. The point where the proof fails will be the starting point for solving it

"A solution, to be a solution, must share some of the problems characteristics." Richard L Kempe

Problem-solving methodologies

- Eight Disciplines Problem Solving
- GROW model
- How to solve it
- Kepner-Tregoe
- PDCA
- RPR Problem Diagnosis
- TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch, "theory of solving inventor's problems")

Example applications

Problem solving is of crucial importance in engineering when products or processes fail, so corrective action can be taken to prevent further failures. Perhaps of more value, problem solving can be applied to a product or process prior to an actual fail event i.e. a potential problem can be predicted, analyzed and mitigation applied so the problem never actually occurs. Techniques like Failure Mode Effects Analysis can be used to proactively reduce the likelihood of problems occurring. Forensic engineering is an important technique of failure analysis which involves tracing product defects and flaws. Corrective action can then be taken to prevent further failures.

Abstraction

Abstraction is a process by which higher concepts are derived from the usage and classification of literal ("real" or "concrete") concepts, first principles, or other methods. An "abstraction" (noun) is a concept that acts as super-categorical noun for all subordinate concepts, and connects any related concepts as a group, field, or category.

Abstractions may be formed by reducing the information content of a concept or an observable phenomenon, typically to retain only information which is relevant for a particular purpose. For example, abstracting a leather soccer ball to the more general idea of a ball retains only the information on general ball attributes and behavior, eliminating the characteristics of that particular ball.

Origins

The first symbols of abstract thinking in humans can be traced to fossils dating between 50,000 and 100,000 years ago in Africa. However, language itself, whether spoken or written, involves abstract thinking.

Thought process

In philosophical terminology, abstraction is the thought process wherein ideas are distanced from objects.

Abstraction uses a strategy of simplification, wherein formerly concrete details are left ambiguous, vague, or undefined; thus effective communication about things in the abstract requires an intuitive or common experience between the communicator and the communication recipient. This is true for all verbal/abstract communication.

Cat on Mat (picture 1)

For example, many different things can be red. Likewise, many things sit on surfaces (as in picture 1, to the right). The property of redness and the relation sitting-on are therefore abstractions of those objects. Specifically, the conceptual diagram graph 1 identifies only three boxes, two ellipses, and four arrows (and their five labels), whereas the picture 1 shows much more pictorial detail, with the scores of implied relationships as implicit in the picture rather than with the nine explicit details in the graph.

Graph 1 details some explicit relationships between the objects of the diagram. For example the arrow between the agent and CAT:Elsie depicts an example of an is-a relationship, as does the arrow between the location and the MAT. The arrows between the gerund SITTING and the nouns agent and location express the diagram's basic relationship; "agent is SITTING on location"; Elsie is an instance of CAT.

Conceptual graph for A Cat sitting on the Mat (graph 1)

Although the description sitting-on (graph 1) is more abstract than the graphic image of a cat sitting on a mat (picture 1), the delineation of abstract things from concrete things is somewhat ambiguous; this ambiguity or vagueness is characteristic of abstraction. Thus something as simple as a newspaper might be specified to six levels, as in Douglas Hofstadter's illustration of that ambiguity, with a progression from abstract to concrete in Gödel, Escher, Bach (1979):

(1) a publication

(2) a newspaper

(3) The San Francisco Chronicle

(4) the May 18 edition of the Chronicle

(5) my copy of the May 18 edition of the Chronicle

(6) my copy of the May 18 edition of the Chronicle as it was when I first picked it up (as contrasted with my copy as it was a few days later: in my fireplace, burning)

An abstraction can thus encapsulate each of these levels of detail with no loss of generality. But perhaps a detective or philosopher/scientist/engineer might seek to learn about some thing, at progressively deeper levels of detail, to solve a crime or a puzzle.

Referents

Abstractions sometimes have ambiguous referents; for example, "happiness" (when used as an abstraction) can refer to as many things as there are people and events or states of being which make them happy. Likewise, "architecture" refers not only to the design of safe, functional buildings, but also to elements of creation and innovation which aim at elegant solutions to construction problems, to the use of space, and to the attempt to evoke an emotional response in the builders, owners, viewers and users of the building.

Instantiation

Things that do not exist at any particular place and time are often considered abstract. By contrast, instances, or members, of such an abstract thing might exist in many different places and times. Those abstract things are then said to be multiply instantiated, in the sense of picture 1, picture 2, etc., shown above.

It is not sufficient, however, to define abstract ideas as those that can be instantiated and to define abstraction as the movement in the opposite direction to instantiation. Doing so would make the concepts "cat" and "telephone" abstract ideas since despite their varying appearances, a particular cat or a particular telephone is an instance of the concept "cat" or the concept "telephone". Although the concepts "cat" and "telephone" are abstractions, they are not abstract in the sense of the objects in graph 1 above.

We might look at other graphs, in a progression from cat to mammal to animal, and see that animal is more abstract than mammal; but on the other hand mammal is a harder idea to express, certainly in relation to marsupial or monotreme.

Physicality

A physical object (a possible referent of a concept or word) is considered concrete (not abstract) if it is a particular individual that occupies a particular place and time.

Abstract things are sometimes defined as those things that do not exist in reality or exist only as sensory experiences, like the color red. That definition, however, suffers from the difficulty of deciding which things are real (i.e. which things exist in reality). For example, it is difficult to agree to whether concepts like God, the number three, and goodness are real, abstract, or both.

An approach to resolving such difficulty is to use predicates as a general term for whether things are variously real, abstract, concrete, or of a particular property (e.g. good). Questions about the properties of things are then propositions about predicates, which propositions remain to be evaluated by the investigator. In the graph 1 above, the graphical relationships like the arrows joining boxes and ellipses might denote predicates. Different levels of abstraction might be denoted by a progression of arrows joining boxes or ellipses in multiple rows, where the arrows point from one row to another, in a series of other graphs, say graph 2, etc.

Abstraction used in philosophy

Abstraction in philosophy is the process (or, to some, the alleged process) in concept-formation of recognizing some set of common features in individuals, and on that basis forming a concept of that feature. The notion of abstraction is important to understanding some philosophical controversies surrounding empiricism and the problem of universals. It has also recently become popular in formal logic under predicate abstraction. Another philosophical tool for discussion of abstraction is thought space.

In the Urantia Book glossary Dr. William S. Sadler commented that "Philosophers commit their gravest error when they are misled into the fallacy of abstraction, the practice of focusing the attention upon one aspect of reality and then of pronouncing such an isolated aspect to be the whole truth." (42.6) 2:7.5

Ontological status

The way that physical objects, like rocks and trees, have being differs from the way that properties of abstract concepts or relations have being, for example the way the concrete, particular, individuals pictured in picture 1 exist differs from the way the concepts illustrated in graph 1 exist. That difference accounts for the ontological usefulness of the word "abstract". The word applies to properties and relations to mark the fact that, if they exist, they do not exist in space or time, but that instances of them can exist, potentially in many different places and times.

Perhaps confusingly, some philosophies refer to tropes (instances of properties) as abstract particulars. E.g., the particular redness of a particular apple is an abstract particular. Akin to qualia and sumbebekos.

In linguistics

Reification, also called hypostatization, might be considered a formal fallacy whenever an abstract concept, such as "society" or "technology" is treated as if it were a concrete object. In linguistics this is called metonymy, in which abstract concepts are referred to using the same sorts of nouns that signify concrete objects. Metonymy is an aspect of the English language and of other languages. It can blur the distinction between abstract and concrete things:

1805: Horatio Nelson (Battle of Trafalgar) - "England expects that every man will do his duty"

Compression

An abstraction can be seen as a process of mapping multiple different pieces of constituent data to a single piece of abstract data based on similarities in the constituent data, for example many different physical cats map to the abstraction "CAT". This conceptual scheme emphasizes the inherent equality of both constituent and abstract data, thus avoiding problems arising from the distinction between "abstract" and "concrete". In this sense the process of abstraction entails the identification of similarities between objects and the process of associating these objects with an abstraction (which is itself an object).

For example, picture 1 above illustrates the concrete relationship "Cat sits on Mat".

Chains of abstractions can therefore be constructed moving from neural impulses arising from sensory perception to basic abstractions such as color or shape to experiential abstractions such as a specific cat to semantic abstractions such as the "idea" of a CAT to classes of objects such as "mammals" and even categories such as "object" as opposed to "action".

For example, graph 1 above expresses the abstraction "agent sits on location".

This conceptual scheme entails no specific hierarchical taxonomy (such as the one mentioned involving cats and mammals), only a progressive exclusion of detail.

The neurology of abstraction

A recent meta-analysis suggests that the verbal system has greater engagement for abstract concepts when the perceptual system is more engaged for processing of concrete concepts. This is because abstract concepts elicit greater brain activity in the inferior frontal gyrus and middle temporal gyrus compared to concrete concepts when concrete concepts elicit greater activity in the posterior cingulate, precuneus, fusiform gyrus, and parahippocampal gyrus.

Other research into the human brain suggests that the left and right hemispheres differ in their handling of abstraction. For example, one meta-analysis reviewing human brain lesions has shown a left hemisphere bias during tool usage.

Abstraction in art

Typically, abstraction is used in the arts as a synonym for abstract art in general. Strictly speaking, it refers to art unconcerned with the literal depiction of things from the visible world—it can, however, refer to an object or image which has been distilled from the real world, or indeed, another work of art. Artwork that reshapes the natural world for expressive purposes is called abstract; that which derives from, but does not imitate a recognizable subject is called nonobjective abstraction. In the 20th century the trend toward abstraction coincided with advances in science, technology, and changes in urban life, eventually reflecting an interest in psychoanalytic theory. Later still, abstraction was manifest in more purely formal terms, such as color, freed from objective context, and a reduction of form to basic geometric designs.

In music, the term abstraction can be used to describe improvisatory approaches to interpretation, and may sometimes indicate abandonment of tonality. Atonal music has no key signature, and is characterized the exploration of internal numeric relationships.

Abstraction in psychology

Carl Jung's definition of abstraction broadened its scope beyond the thinking process to include exactly four mutually exclusive, opposing complementary psychological functions: sensation, intuition, feeling, and thinking. Together they form a structural totality of the differentiating abstraction process. Abstraction operates in one of these opposing functions when it excludes the simultaneous influence of the other functions and other irrelevancies, such as emotion. Abstraction requires selective use of this structural split of abilities in the psyche. The opposite of abstraction is concretism. Abstraction is one of Jung's 57 definitions in Chapter XI of Psychological Types.

There is an abstract thinking, just as there is abstract feeling, sensation and intuition. Abstract thinking singles out the rational, logical qualities ... Abstract feeling does the same with ... its feeling-values. ... I put abstract feelings on the same level as abstract thoughts. ... Abstract sensation would be aesthetic as opposed to sensuous sensation and abstract intuition would be symbolic as opposed to fantastic intuition. (Jung, [1921] (1971):par. 678).

Abstraction in computer science

Computer scientists use abstraction and communicate their solutions with the computer in some particular computer language. Abstraction allows program designers to separate categories and concepts from instances of implementation, so that they do not depend on software or hardware.

Abstraction in mathematics

Abstraction in mathematics is the process of extracting the underlying essence of a mathematical concept, removing any dependence on real world objects with which it might originally have been connected, and generalizing it so that it has wider applications or matching among other abstract descriptions of equivalent phenomena.

The advantages of abstraction in mathematics are:

it reveals deep connections between different areas of mathematics
known results in one area can suggest conjectures in a related area
techniques and methods from one area can be applied to prove results in a related area.

The main disadvantage of abstraction is that highly abstract concepts are more difficult to learn, and require a degree of mathematical maturity and experience before they can be assimilated.

Analogy

Analogy is a cognitive process of transferring information or meaning from a particular subject (the analogue or source) to another particular subject (the target), and a linguistic expression corresponding to such a process. In a narrower sense, analogy is an inference or an argument from one particular to another particular, as opposed to deduction, induction, and abduction, where at least one of the premises or the conclusion is general. The word analogy can also refer to the relation between the source and the target themselves, which is often, though not necessarily, a similarity, as in the biological notion of analogy.

Niels Bohr's model of the atom made an analogy between the atom and the solar system.

Analogy plays a significant role in problem solving, decision making, perception, memory, creativity, emotion, explanation and communication. It lies behind basic tasks such as the identification of places, objects and people, for example, in face perception and facial recognition systems. It has been argued that analogy is "the core of cognition". Specific analogical language comprises exemplification, comparisons, metaphors, similes, allegories, and parables, but not metonymy. Phrases like and so on, and the like, as if, and the very word like also rely on an analogical understanding by the receiver of a message including them. Analogy is important not only in ordinary language and common sense (where proverbs and idioms give many examples of its application) but also in science, philosophy and the humanities. The concepts of association, comparison, correspondence, mathematical and morphological homology, homomorphism, iconicity, isomorphism, metaphor, resemblance, and similarity are closely related to analogy. In cognitive linguistics, the notion of conceptual metaphor may be equivalent to that of analogy.

Analogy has been studied and discussed since classical antiquity by philosophers, scientists and lawyers. The last few decades have shown a renewed interest in analogy, most notably in cognitive science.

Usage of the terms source and target

With respect to the terms source and target there are two distinct traditions of usage:

The logical and cultures and economics tradition speaks of an arrow, homomorphism, mapping, or morphism from what is typically the more complex domain or source to what is typically the less complex codomain or target, using all of these words in the sense of mathematical category theory.

The tradition that appears to be more common in cognitive psychology, literary theory, and specializations within philosophy outside of logic, speaks of a mapping from what is typically the more familiar area of experience, the source, to what is typically the more problematic area of experience, the target.

Models and theories

Identity of relation

This section may contain original research. Please improve it by verifying the claims made and adding references. Statements consisting only of original research may be removed. More details may be available on the talk page. (July 2009)

In ancient Greek the word αναλογια (analogia) originally meant proportionality, in the mathematical sense, and it was indeed sometimes translated to Latin as proportio. From there analogy was understood as identity of relation between any two ordered pairs, whether of mathematical nature or not. Kant's Critique of Judgment held to this notion. Kant argued that there can be exactly the same relation between two completely different objects. The same notion of analogy was used in the US-based SAT tests, that included "analogy questions" in the form "A is to B as C is to what?" For example, "Hand is to palm as foot is to ____?" These questions were usually given in the Aristotelian format:

HAND : PALM : : FOOT : ____

While most competent English speakers will immediately give the right answer to the analogy question (sole), it is more difficult to identify and describe the exact relation that holds both between hand and palm, and between foot and sole[original research?]. This relation is not apparent in some lexical definitions of palm and sole, where the former is defined as the inner surface of the hand, and the latter as the underside of the foot. Analogy and abstraction are different cognitive processes, and analogy is often an easier one.

Recently a computer algorithm has achieved human-level performance on multiple-choice analogy questions from the SAT test. The algorithm measures the similarity of relations between pairs of words (e.g., the similarity between the pairs HAND:PALM and FOOT:SOLE) by statistical analysis of a large collection of text. It answers SAT questions by selecting the choice with the highest relational similarity.

Shared abstraction

In several cultures, the sun is the source of an analogy to God.

Greek philosophers such as Plato and Aristotle actually used a wider notion of analogy. They saw analogy as a shared abstraction. Analogous objects did not share necessarily a relation, but also an idea, a pattern, a regularity, an attribute, an effect or a function. These authors also accepted that comparisons, metaphors and "images" (allegories) could be used as arguments, and sometimes they called them analogies. Analogies should also make those abstractions easier to understand and give confidence to the ones using them.

The Middle Ages saw an increased use and theorization of analogy. Roman lawyers had already used analogical reasoning and the Greek word analogia. Medieval lawyers distinguished analogia legis and analogia iuris (see below). In Islamic logic, analogical reasoning was used for the process of Qiyas in Islamic sharia law and fiqh jurisprudence. In Christian theology, analogical arguments were accepted in order to explain the attributes of God. Aquinas made a distinction between equivocal, univocal and analogical terms, the latter being those like healthy that have different but related meanings. Not only a person can be "healthy", but also the food that is good for health (see the contemporary distinction between polysemy and homonymy). Thomas Cajetan wrote an influential treatise on analogy. In all of these cases, the wide Platonic and Aristotelian notion of analogy was preserved. James Francis Ross in Portraying Analogy (1982), the first substantive examination of the topic since Cajetan's De Nominum Analogia, demonstrated that analogy is a systematic and universal feature of natural languages, with identifiable and law-like characteristics which explain how the meanings of words in a sentence are interdependent.

Special case of induction

On the contrary, Ibn Taymiyya, Francis Bacon and later John Stuart Mill argued that analogy is simply a special case of induction. In their view analogy is an inductive inference from common known attributes to another probable common attribute, which is known only about the source of the analogy, in the following form:

Premises
  a is C, D, E, F, G
  b is C, D, E, F
Conclusion
  b is probably G.
Alternative conclusion
  every C, D, E, F is probably G.

This view does not accept analogy as an autonomous mode of thought or inference, reducing it to induction. However, autonomous analogical arguments are still useful in science, philosophy and the humanities (see below), which makes this reduction philosophically uninteresting. Moreover, induction tries to achieve general conclusions, while analogy looks for particular ones.

Hidden deduction

The opposite move could also be tried, reducing analogy to deduction. It is argued that every analogical argument is partially superfluous and can be rendered as a deduction stating as a premise a (previously hidden) universal proposition which applied both to the source and the target. In this view, instead of an argument with the form:

Premises
  a is analogous to b.
  b is F.
Conclusion
  a is plausibly F.

We should have:

Hidden universal premise
  all Gs are plausibly Fs.
Hidden singular premise
  a is G.
Conclusion
  a is plausibly F.

This would mean that premises referring the source and the analogical relation are themselves superfluous. However, it is not always possible to find a plausibly true universal premise to replace the analogical premises. And analogy is not only an argument, but also a distinct cognitive process.

Shared structure

According to Shelley (2003), the study of the coelacanth drew heavily on analogies from other fish.

Contemporary cognitive scientists use a wide notion of analogy, extensionally close to that of Plato and Aristotle, but framed by Gentner's (1983) structure mapping theory. The same idea of mapping between source and target is used by conceptual metaphor and conceptual blending theorists. Structure mapping theory concerns both psychology and computer science. According to this view, analogy depends on the mapping or alignment of the elements of source and target. The mapping takes place not only between objects, but also between relations of objects and between relations of relations. The whole mapping yields the assignment of a predicate or a relation to the target. Structure mapping theory has been applied and has found considerable confirmation in psychology. It has had reasonable success in computer science and artificial intelligence (see below). Some studies extended the approach to specific subjects, such as metaphor and similarity.

Keith Holyoak and Paul Thagard (1997) developed their multiconstraint theory within structure mapping theory. They defend that the "coherence" of an analogy depends on structural consistency, semantic similarity and purpose. Structural consistency is maximal when the analogy is an isomorphism, although lower levels are admitted. Similarity demands that the mapping connects similar elements and relations of source and target, at any level of abstraction. It is maximal when there are identical relations and when connected elements have many identical attributes. An analogy achieves its purpose insofar as it helps solve the problem at hand. The multiconstraint theory faces some difficulties when there are multiple sources, but these can be overcome. Hummel and Holyoak (2005) recast the multiconstraint theory within a neural network architecture. A problem for the multiconstraint theory arises from its concept of similarity, which, in this respect, is not obviously different from analogy itself. Computer applications demand that there are some identical attributes or relations at some level of abstraction. The model was extended (Doumas, Hummel, & Sandhofer, 2008) to learn relations from unstructured examples (providing the only current account of how symbolic representations can be learned from examples).

Mark T. Keane and Brayshaw (1988) developed their Incremental Analogy Machine (IAM) to include working memory constraints as well as structural, semantic and pragmatic constraints, so that a subset of the base analog is selected and mapping from base to target occurs in a serial manner. Empirical evidence shows that human analogical mapping performance is influenced by information presentation order.

High-level perception

Douglas Hofstadter and his team challenged the shared structure theory and mostly its applications in computer science. They argue that there is no line between perception, including high-level perception, and analogical thought. In fact, analogy occurs not only after, but also before and at the same time as high-level perception. In high-level perception, humans make representations by selecting relevant information from low-level stimuli. Perception is necessary for analogy, but analogy is also necessary for high-level perception. Chalmers et al. conclude that analogy is high-level perception. Forbus et al. (1998) claim that this is only a metaphor. It has been argued (Morrison and Dietrich 1995) that Hofstadter's and Gentner's groups do not defend opposite views, but are instead dealing with different aspects of analogy.

Analogy and Complexity

Antoine Cornuéjols has presented analogy as a principle of economy and computational complexity.

Reasoning by analogy is a process of, from a given pair (x,f(x)), extrapolating the function f. In the standard modeling, analogical reasoning involves two "objects": the source and the target. The target is supposed to be incomplete and in need for a complete description using the source. The target has an existing part St and a missing part Rt. We assume that we can isolate a situation of the source Ss, which corresponds to a situation of target St, and the result of the source Rs, which correspond to the result of the target Rt. With Bs, the relation between Ss and Rs, we want Bt, the relation between St and Rt.

If the source and target are completely known:

Using Kolmogorov complexity K(x), defined as the size of the smallest description of x and Solomonoff's approach to induction, Rissanen (89), Wallace & Boulton (68) proposed the principle of Minimum description length. This principle leads to minimize the complexity K(target| Source) of producing the target from the source.

This is unattractive in Artificial Intelligence, as it requires a computation over abstract Turing machines. Suppose that Ms and Mt are local theories of the source and the target, available to the observer. The best analogy between a source case a and target case is the analogy that minimizes:

$$K(Ms) + K(Ss|Ms) + K(Bs|Ms) + K(Mt|Ms) + K(St|Mt) + K(Bt|Mt) \quad (1).$$

If the target is completely unknown:

All models and descriptions Ms, Mt, Bs, Ss, and St leading to the minimization of:

$$K(Ms) + K(Ss|Ms) + K(Bs|Ms) + K(Mt|Ms) + K(St|Mt) \quad (2)$$

are also those who allow to obtain the relationship Bt, and thus the most satisfactory Rt for formula (1).

The analogical hypothesis, which solves an analogy between a source case and a target case, has two parts:

Analogy, like induction, is a principle of economy. The best analogy between two cases is the one which minimizes the amount of information necessary for the derivation of the source from the target (1). Its most fundamental measure is the computational complexity theory.

When solving or completing a target case with a source case, the parameters which minimize (2) are postulated to minimize (1), and thus, produce the best response.

However, a cognitive agent may simply reduce the amount of information necessary for the interpretation of the source and the target, without taking into account the cost of data replication. So, it may prefer to the minimization of (2) the minimization of the following simplified formula:

$K(Ms) + K(Bs|Ms) + K(Mt|Ms)$ (3).

Applications and types

In language

Rhetoric

An analogy can be a spoken or textual comparison between two words (or sets of words) to highlight some form of semantic similarity between them. Such analogies can be used to strengthen political and philosophical arguments, even when the semantic similarity is weak or non-existent (if crafted carefully for the audience). Analogies are sometimes used to persuade those that cannot detect the flawed or non-existent arguments.

Linguistics

An analogy can be the linguistic process that reduces word forms perceived as irregular by remaking them in the shape of more common forms that are governed by rules. For example, the English verb help once had the preterite holp and the past participle holpen. These obsolete forms have been discarded and replaced by helped by the power of analogy (or by widened application of the productive Verb-ed rule.) This is called leveling. However, irregular forms can sometimes be created by analogy; one example is the American English past tense form of dive: dove, formed on analogy with words such as drive: drove.

Neologisms can also be formed by analogy with existing words. A good example is software, formed by analogy with hardware; other analogous neologisms such as firmware and vaporware have followed. Another example is the humorous term underwhelm, formed by analogy with overwhelm.

Analogy is often presented as an alternative mechanism to generative rules for explaining productive formation of structures such as words. Others argue that in fact they are the same mechanism, that rules are analogies that have become entrenched as standard parts of the linguistic system, whereas clearer cases of analogy have simply not (yet) done so (e.g. Langacker 1987.445–447). This view has obvious resonances with the current views of analogy in cognitive science which are discussed above.

In science

Analogues are often used in theoretical and applied sciences in the form of models or simulations which can be considered as strong analogies. Other much weaker analogies assist in understanding and describing functional behaviours of similar systems. For instance, an analogy commonly used in electronics textbooks compares electrical circuits to hydraulics. Another example is the analog ear based on electrical, electronic or mechanical devices.

Mathematics

Some types of analogies can have a precise mathematical formulation through the concept of isomorphism. In detail, this means that given two mathematical structures of the same type, an analogy between them can be thought of as a bijection between them which preserves some or all of the relevant structure. For example, \Bbb{R}^2 and \Bbb{C} are isomorphic as vector spaces, but the complex numbers, \Bbb{C} , have more structure than \Bbb{R}^2 does – \Bbb{C} is a field as well as a vector space.

Category theory takes the idea of mathematical analogy much further with the concept of functors. Given two categories C and D a functor F from C to D can be thought of as an analogy between C and D, because F has to map objects of C to objects of D and arrows of C to arrows of D in such a way that the compositional structure of the two categories is preserved. This is similar to the structure mapping theory of analogy of Dedre Gentner, in that it formalizes the idea of analogy as a function which satisfies certain conditions.

Artificial intelligence

Anatomy

In anatomy, two anatomical structures are considered to be analogous when they serve similar functions but are not evolutionarily related, such as the legs of vertebrates and the legs of insects. Analogous structures are the result of convergent evolution and should be contrasted with homologous structures.

Engineering

Often a physical prototype is built to model and represent some other physical object. For example, wind tunnels are used to test scale models of wings and aircraft, which act as an analog to full-size wings and aircraft.

For example, the MONIAC (an analog computer) used the flow of water in its pipes as an analog to the flow of money in an economy.

In normative matters

Morality

Analogical reasoning plays a very important part in morality. This may be in part because morality is supposed to be impartial and fair. If it is wrong to do something in a situation A, and situation B is analogous to A in all relevant features, then it is also wrong to perform that action in situation B. Moral particularism accepts analogical moral reasoning, rejecting both deduction and induction, since only the former can do without moral principles.

Law

In law, analogy is used to resolve issues on which there is no previous authority. A distinction has to be made between analogous reasoning from written law and analogy to precedent case law.

Analogies from codes and statutes

In civil law systems, where the preeminent source of law is legal codes and statutes, a lacuna (a gap) arises when a specific issue is not explicitly dealt with in written law. Judges will try to identify a provision whose purpose applies to the case at hand. That process can reach a high degree of sophistication, as judges sometimes not only look at a specific provision to fill lacunae (gaps), but at several provisions (from which an underlying purpose can be inferred) or at general principles of the law to identify the legislator's value judgement from which the analogy is drawn. Besides the not very frequent filling of lacunae, analogy is very commonly used between different provisions in order to achieve substantial coherence. Analogy from previous judicial decisions is also common, although these decisions are not binding authorities.

Analogies from precedent case law

By contrast, in common law systems, where precedent cases are the primary source of law, analogies to codes and statutes are rare (since those are not seen as a coherent system, but as incursions into the common law). Analogies are thus usually drawn from precedent cases: The judge finds that the facts of another case are similar to the one at hand to an extent that the analogous application of the rule established in the previous case is justified.

In teaching strategies

Teaching the process of thinking by analogy is one of the main themes of The Private Eye Project.

Brainstorming

Brainstorming is a group creativity technique by which a group tries to find a solution for a specific problem by gathering a list of ideas spontaneously contributed by its members. The term was popularized by Alex Faickney Osborn in 1953 through the book Applied Imagination. In the book, Osborn not only proposed the brainstorming method but also established effective rules for hosting brainstorming sessions.

Brainstorming has become a popular group technique and has aroused attention in academia. Multiple studies have been conducted to test Osborn's postulation that brainstorming is more effective than individuals working alone in generating ideas . Some researchers have concluded that the statement is false (brainstorming is not effective), while others uncovered flaws in the research and determined that the results are inconclusive. Furthermore, researchers have made modifications or proposed variations of brainstorming in an attempt to improve the productivity of brainstorming. However, there is no empirical evidence to indicate that any variation is more effective than the original technique.

Origin

The origin of brainstorming came from Osborn in 1939 as a method for creative problem solving. He was frustrated by employees' inability to develop creative ideas individually for ad campaigns. In response, he began hosting group-thinking sessions and discovered a significant improvement in the quality and quantity of ideas produced by employees. After organizing his discovery, Osborn then published Applied Imagination in 1953 in which he systematized his creative problem-solving methods. This book popularized the term brainstorming and received significant response in the industry.

Osborn's method

Osborn claimed that two principles contribute to "ideative efficacy," these being "1. Defer judgment," and "2. Reach for quantity." Following these principles were his four general rules of brainstorming, established with intention to reduce social inhibitions among group members, stimulate idea generation, and increase overall creativity of the group.

Focus on quantity: This rule is a means of enhancing divergent production, aiming to facilitate problem solving through the maxim quantity breeds quality. The assumption is that the greater the number of ideas generated, the greater the chance of producing a radical and effective solution.

Withhold criticism: In brainstorming, criticism of ideas generated should be put 'on hold'. Instead, participants should focus on extending or adding to ideas, reserving criticism for a later 'critical stage' of the process. By suspending judgment, participants will feel free to generate unusual ideas.

Welcome unusual ideas: To get a good and long list of ideas, unusual ideas are welcomed. They can be generated by looking from new perspectives and suspending assumptions. These new ways of thinking may provide better solutions.

Combine and improve ideas: Good ideas may be combined to form a single better good idea, as suggested by the slogan "1+1=3". It is believed to stimulate the building of ideas by a process of association.

Applications

Osborn notes that brainstorming should address a specific question; he held that sessions addressing multiple questions were inefficient. Further, the problem must require the generation of ideas rather than judgment; he uses examples such as generating possible names for a product as proper brainstorming material, whereas analytical judgments such as whether or not to marry do not have any need for brainstorming.

Brainstorming groups

Osborn envisioned groups of around 12 participants,including both experts and novices. Participants are encouraged to provide wild and unexpected answers. Ideas receive no criticism or discussion. The group simply provides ideas that might lead to a solution and apply no analytical judgment as to the feasibility. The judgments are reserved for a later date.

Research

Criticism

Research has failed to support Osborn's claim that group brainstorming could produce double the creative output of a group of individuals' collected ideas. Indeed, research from Michael Diehl and Wolfgang Stroebe demonstrated the opposite effect. They found that, given equal time, "real" groups, those that brainstormed together, produced fewer ideas than "nominal" groups, those wherein individuals provided ideas independently of one another and only existed as a group insofar as their work was considered as a whole by researchers. Their conclusions were based on a review of 22 other studies, 18 of which corroborated their findings.

Sources of brainstorming inadequacy

Diehl and Stroebe identified three processes that derailed brainstorming efforts. These processes were free riding, evaluation apprehension, and blocking.

- **Free Riding**: Individuals may feel that their ideas are less valuable when combined with the ideas of the group at large. Indeed, Diehl and Stroebe demonstrated that even when individuals worked alone, they produced fewer ideas if told that their output would be judged in a group with others than if told that their output would be judged on an individual basis. However, experimentation revealed free riding as only a marginal contributor to productivity loss, and type of session (i.e., real vs. nominal group) contributed much more.

- **Evaluation Apprehension**: Evaluation Apprehension was determined to occur only in instances of personal evaluation. If the assumption of collective assessment was in place, real-time judgment of ideas, ostensibly an induction of evaluation apprehension, failed to induce significant variance.

- **Blocking**: Blocking describes the reality that only one person may gainfully voice his or her ideas in a group at any given time. Diehl and Stroebe examined the question of whether this effect could reduce idea-generation, as ideas suppressed long enough to listen to another group-member's ideas might be forgotten. Their research confirmed this hypothesis.

This holds especial significance given that Osborn's central hypothesis was that listening to the ideas of others should spur the generation of new ideas. Rather, research indicates that the act of listening to others might stifle creativity.
Benefits

Under proper conditions, brainstorming can outperform nominal groups. The adoption of Group Support Systems, wherein individuals submit suggestions on a computer that become instantly (and anonymously) visible to the entire team, removes the effect of blocking as ideas can be communicated immediately upon generation. Using these technologies, brainstorming groups significantly outperformed nominal groups.

Incentives and brainstorming

Olivier Toubia's research gave strong indications that incentives can augment creative processes. Participants were divided into three conditions. In Condition I, a flat fee was paid to all participants. In the Condition II, participants were awarded points for every unique idea of their own, and subjects were paid for the points that they earned. In Condition III, subjects were paid based on the impact that their idea had on the group; this was measured by counting the number of group ideas derived from the specific subject's ideas. Condition III outperformed Condition II, and Condition II outperformed Condition I at a statistically significant level for most measures. The results demonstrated that participants were willing to work far longer to achieve unique results in the expectation of compensation.

Variations

Nominal group technique

The nominal group technique is a type of brainstorming that encourages all participants to have an equal say in the process. It is also used to generate a ranked list of ideas.

Participants are asked to write their ideas anonymously. Then the moderator collects the ideas and each is voted on by the group. The vote can be as simple as a show of hands in favor of a given idea. This process is called distillation.

After distillation, the top ranked ideas may be sent back to the group or to subgroups for further brainstorming. For example, one group may work on the color required in a product. Another group may work on the size, and so forth. Each group will come back to the whole group for ranking the listed ideas. Sometimes ideas that were previously dropped may be brought forward again once the group has re-evaluated the ideas.

It is important that the facilitator be trained in this process before attempting to facilitate this technique. The group should be primed and encouraged to embrace the process. Like all team efforts, it may take a few practice sessions to train the team in the method before tackling the important ideas.

Group passing technique

Each person in a circular group writes down one idea, and then passes the piece of paper to the next person in a clockwise direction, who adds some thoughts. This continues until everybody gets his or her original piece of paper back. By this time, it is likely that the group will have extensively elaborated on each idea.

The group may also create an "Idea Book" and post a distribution list or routing slip to the front of the book. On the first page is a description of the problem. The first person to receive the book lists his or her ideas and then routes the book to the next person on the distribution list. The second person can log new ideas or add to the ideas of the previous person. This continues until the distribution list is exhausted. A follow-up "read out" meeting is then held to discuss the ideas logged in the book. This technique takes longer, but it allows individuals time to think deeply about the problem.

Team idea mapping method

This method of brainstorming works by the method of association. It may improve collaboration and increase the quantity of ideas, and is designed so that all attendees participate and no ideas are rejected.

The process begins with a well-defined topic. Each participant brainstorms individually, then all the ideas are merged onto one large idea map. During this consolidation phase, participants may discover a common understanding of the issues as they share the meanings behind their ideas. During this sharing, new ideas may arise by the association, and they are added to the map as well. Once all the ideas are captured, the group can prioritize and/or take action.

Electronic brainstorming

Electronic brainstorming outperforms both regular brainstorming and nominal group brainstorming. It is a computerized version of the manual brainstorming technique typically supported by an electronic meeting system (EMS) but simpler forms can also be done via email and may be browser based, or use peer-to-peer software.

With an electronic meeting system, participants share a list of ideas over the Internet. Ideas are entered independently. Contributions become immediately visible to all and are typically anonymized to encourage openness and reduce personal prejudice. Modern EMS also support asynchronous brainstorming sessions over extended periods of time as well as typical follow-up activities in the creative-problem-solving process such as categorization of ideas, elimination of duplicates, assessment and discussion of prioritized or controversial ideas.

Proponents such as Gallupe, et al. argue that electronic brainstorming eliminates many of the problems of standard brainstorming, including production blocking and evaluation apprehension. A perceived advantage of this format is that all ideas can be archived electronically in their original form, and then retrieved later for further thought and discussion. Electronic brainstorming also enables much larger groups to brainstorm on a topic than would normally be productive in a traditional brainstorming session.

Some web based brainstorming techniques allow contributors to post their comments anonymously through the use of avatars. This technique also allows users to log on over an extended time period, typically one or two weeks, to allow participants some "soak time" before posting their ideas and feedback. This technique has been used particularly in the field of new product development, but can be applied in any number of areas requiring collection and evaluation of ideas.

Directed brainstorming

Directed brainstorming is a variation of electronic brainstorming (described above). It can be done manually or with computers. Directed brainstorming works when the solution space (that is, the criteria for evaluating a good idea) is known prior to the session. If known, that criteria can be used to intentionally constrain the ideation process.

In directed brainstorming, each participant is given one sheet of paper (or electronic form) and told the brainstorming question. They are asked to produce one response and stop, then all of the papers (or forms) are randomly swapped among the participants. The participants are asked to look at the idea they received and to create a new idea that improves on that idea based on the initial criteria. The forms are then swapped again and respondents are asked to improve upon the ideas, and the process is repeated for three or more rounds.

In the laboratory, directed brainstorming has been found to almost triple the productivity of groups over electronic brainstorming.

Individual brainstorming

"Individual Brainstorming" is the use of brainstorming on a solitary basis. It typically includes such techniques as free writing, free speaking, word association, and drawing a mind map, which is a visual note taking technique in which people diagram their thoughts. Individual brainstorming is a useful method in creative writing and has been shown to be superior to traditional group brainstorming.

Research has shown individual brainstorming to be more effective in idea-generation than group brainstorming.

Question brainstorming

This process involves brainstorming the questions, rather than trying to come up with immediate answers and short term solutions. Theoretically, this technique should not inhibit participation as there is no need to provide solutions. The answers to the questions form the framework for constructing future action plans. Once the list of questions is set, it may be necessary to prioritize them to reach to the best solution in an orderly way.

"Questorming" is another phrase for this mode of inquiry.

Conclusion

Brainstorming is a popular method of group interaction in both educational and business settings. Even though there has been arguments about its productivity, brainstorming is still a widely used method for coming up with creative solutions. It’s still an area under research and improvements or variations are still developing in progress. Many of these methods claimed to be more efficient than the original brainstorming however, there are too many factors that can alter the outcome of brainstorming. Therefore, how well these methods work, and whether or not they should be classified as being more effective than brainstorming, are questions that require further research.

Analysis

Analysis is the process of breaking a complex topic or substance into smaller parts to gain a better understanding of it. The technique has been applied in the study of mathematics and logic since before Aristotle (384–322 B.C.), though analysis as a formal concept is a relatively recent development.

According to Hans Niels Jahangir, "Analysis as an independent subject was created in the 17th century during the scientific revolution. Kepler, Galileo, Descartes, Fermat, Huygens, Newton and Leibniz, to mention but a few important names, contributed to its genesis.". As a formal concept, the method has variously been ascribed to Alhazen, René Descartes (Discourse on the Method) and Galileo Galilei. It has also been ascribed to Isaac Newton, in the form of a practical method of physical discovery (which he did not name or formally describe).

Use in specific fields

Chemistry

The field of chemistry uses analysis in at least three ways: to identify the components of a particular chemical compound (qualitative analysis), to identify the proportions of components in a mixture (quantitative analysis), and to break down chemical processes and examine chemical reactions between elements of matter. For an example of its use, analysis of the concentration of elements is important in managing a nuclear reactor, so nuclear scientists will analyze neutron activation to develop discrete measurements within vast samples. A matrix can have a considerable effect on the way a chemical analysis is conducted and the quality of its results. Analysis can be done manually or with a device. Chemical analysis is an important element of national security among the major world powers with Materials Measurement and Signature Intelligence (MASINT) capabilities.

Isotopes

Chemists can use isotopes to assist analysts with issues in anthropology, archeology, food chemistry, forensics, geology, and a host of other questions of physical science. Analysts can discern the origins of natural and man-made isotopes in the study of environmental radioactivity.

Business

- Financial statement analysis – the analysis of the accounts and the economic prospects of a firm
- Fundamental analysis – a stock valuation method that uses financial analysis
- Technical analysis – the study of price action in securities markets in order to forecast future prices
- Business analysis – involves identifying the needs and determining the solutions to business problems
- Price analysis – involves the breakdown of a price to a unit figure
- Market analysis – consists of suppliers and customers, and price is determined by the interaction of supply and demand

Computer science

- Requirements analysis – encompasses those tasks that go into determining the needs or conditions to meet for a new or altered product, taking account of the possibly conflicting requirements of the various stakeholders, such as beneficiaries or users.

- Competitive analysis (online algorithm) – shows how online algorithms perform and demonstrates the power of randomization in algorithms
- Lexical analysis – the process of processing an input sequence of characters and producing as output a sequence of symbols
- Object-oriented analysis and design – à la Booch
- Program analysis (computer science) – the process of automatically analyzing the behavior of computer programs
- Semantic analysis (computer science) – a pass by a compiler that adds semantical information to the parse tree and performs certain checks
- Static code analysis – the analysis of computer software that is performed without actually executing programs built from that software
- Structured Systems Analysis and Design Methodology – à la Yourdon
- Syntax analysis – a process in compilers that recognizes the structure of programming languages, also known as parsing
- Worst-case execution time – determines the longest time that a piece of software can take to run

Economics

Agroecosystem analysis

Input-output model if applied to a region, is called Regional Impact Multiplier System

Principal components analysis – a technique that can be used to simplify a dataset

Engineering

Analysts in the field of engineering look at requirements, structures, mechanisms, systems and dimensions. Electrical engineers analyze systems in electronics. Life cycles and system failures are broken down and studied by engineers. It is also looking at different factors encorporated within the design.

Intelligence

The field of intelligence employs analysts to break down and understand a wide array of questions. Intelligence agencies may use heuristics, inductive and deductive reasoning, social network analysis, dynamic network analysis, link analysis, and brainstorming to sort through problems they face. Military intelligence may explore issues through the use of game theory, Red Teaming, and wargaming. Signals intelligence applies cryptanalysis and frequency analysis to break codes and ciphers. Business intelligence applies theories of competitive intelligence analysis and competitor analysis to resolve questions in the marketplace. Law enforcement intelligence applies a number of theories in crime analysis.

Linguistics

Linguistics began with the analysis of Sanskrit and Tamil; today it looks at individual languages and language in general. It breaks language down and analyzes its component parts: theory, sounds and their meaning, utterance usage, word origins, the history of words, the meaning of words and word combinations, sentence construction, basic construction beyond the sentence level, stylistics, and conversation. It examines the above using statistics and modeling, and semantics. It analyzes language in context of anthropology, biology, evolution, geography, history, neurology, psychology, and sociology. It also takes the applied approach, looking at individual language development and clinical issues.

Literature

Literary theory is the analysis of literature. Some say that literary criticism is a subset of literary theory. The focus can be as diverse as the analysis of Homer or Freud. This is mainly to do with the breaking up of a topic to make it easier to understand.

Mathematics

Mathematical analysis can be applied in the study of classical concepts of mathematics, such as real numbers, complex variables, trigonometric functions, and algorithms, or of non-classical concepts like constructivism, harmonics, infinity, and vectors.

Music

Musical analysis – a process attempting to answer the question "How does this music work?"

Schenkerian analysis

Philosophy

Philosophical analysis – a general term for the techniques used by philosophers
Analysis is the name of a prominent journal in philosophy.

Psychotherapy

Psychoanalysis – seeks to elucidate connections among unconscious components of patients' mental processes
Transactional analysis

Signal processing

Finite element analysis – a computer simulation technique used in engineering analysis
Independent component analysis
Link quality analysis – the analysis of signal quality
Path quality analysis

Statistics

- Analysis of variance (ANOVA) – a collection of statistical models and their associated procedures which compare means by splitting the overall observed variance into different parts
- Meta-analysis – combines the results of several studies that address a set of related research hypotheses
- Time-series analysis – methods that attempt to understand a sequence of data points spaced apart at uniform time intervals

Lateral thinking

Lateral thinking is solving problems through an indirect and creative approach, using reasoning that is not immediately obvious and involving ideas that may not be obtainable by using only traditional step-by-step logic. The term lateral thinking was coined by Edward de Bono in the book New Think: The Use of Lateral Thinking published in 1967.

Methods

Critical thinking is primarily concerned with judging the true value of statements and seeking errors. Lateral thinking is more concerned with the movement value of statements and ideas. A person would use lateral thinking when they want to move from one known idea to creating new ideas. Edward de Bono defines four types of thinking tools:

1. **Idea generating tools** that are designed to break current thinking patterns—routine patterns, the status quo
2. **Focus tools** that are designed to broaden where to search for new ideas
3. **Harvest tools** that are designed to ensure more value is received from idea generating output
4. **Treatment tools** that are designed to consider real-world constraints, resources, and support

Random Entry Idea Generating Tool: Choose an object at random, or a noun from a dictionary, and associate that with the area you are thinking about.

For example imagine you are thinking about how to improve a web site. Choosing an object at random from an office you might see a fax machine. A fax machine transmits images over the phone to paper. Fax machines are becoming rare. People send faxes directly to phone numbers. Perhaps this could be a new way to embed the web site's content in emails and other sites.

Provocation Idea Generating Tool: choose to use any of the provocation techniques—wishful thinking, exaggeration, reversal, escape, or arising. Create a list of provocations and then use the most outlandish ones to move your thinking forward to new ideas.

Challenge Idea Generating Tool: A tool which is designed to ask the question "Why?" in a non-threatening way: why something exists, why it is done the way it is. The result is a very clear understanding of "Why?" which naturally leads to fresh new ideas. The goal is to be able to challenge anything at all, not just items which are problems.

For example you could challenge the handles on coffee cups. The reason for the handle seems to be that the cup is often too hot to hold directly. Perhaps coffee cups could be made with insulated finger grips, or there could be separate coffee cup holders similar to beer holders.

Concept Fan Idea Generating Tool: Ideas carry out concepts. This tool systematically expands the range and number of concepts in order to end up with a very broad range of ideas to consider.

Disproving: Based on the idea that the majority is always wrong (Henrik Ibsen, John Kenneth Galbraith[who?]), take anything that is obvious and generally accepted as "goes without saying", question it, take an opposite view, and try to convincingly disprove it.

The other focus, harvesting and treatment tools deal with the output of the generated ideas and the ways to use them.

Lateral thinking and problem solving

Problem Solving: When something creates a problem, the performance or the status quo of the situation drops. Problem solving deals with finding out what caused the problem and then figuring out ways to fix the problem. The objective is to get the situation to where it should be.

For example, a production line has an established run rate of 1000 items per hour. Suddenly, the run rate drops to 800 items per hour. Ideas as to why this happened and solutions to repair the production line must be thought of, such as giving the worker a pay raise.

Creative Problem Solving: Using creativity, one must solve a problem in an indirect and unconventional manner.

For example, if a production line produced 1000 books per hour, creative problem solving could find ways to produce more books per hour, use the production line, or reduce the cost to run the production line.

Creative Problem Identification: Many of the greatest non-technological innovations are identified while realizing an improved process or design in everyday objects and tasks either by accidental chance or by studying and documenting real world experience....

Means-ends analysis

Means-Ends Analysis (MEA) is a technique used in Artificial Intelligence for controlling search in problem solving computer programs.

It is also a technique used at least since the 1950s as a creativity tool, most frequently mentioned in engineering books on design methods. Means-Ends Analysis is also a way to clarify one's thoughts when embarking on a mathematical proof.

An important aspect of intelligent behavior as studied in AI is goal-based problem solving, a framework in which the solution of a problem can be described by finding a sequence of actions that lead to a desirable goal. A goal-seeking system is supposed to be connected to its outside environment by sensory channels through which it receives information about the environment and motor channels through which it acts on the environment. (The term "afferent" is used to describe "inward" sensory flows, and "efferent" is used to describe "outward" motor commands.) In addition, the system has some means of storing in a memory information about the state of the environment (afferent information) and information about actions (efferent information). Ability to attain goals depends on building up associations, simple or complex, between particular changes in states and particular actions that will bring these changes about. Search is the process of discovery and assembly of sequences of actions that will lead from a given state to a desired state. While this strategy may be appropriate for machine learning and problem solving, it is not always suggested for humans (e.g. cognitive load theory and its implications).

How MEA works

The MEA technique is a strategy to control search in problem-solving. Given a current state and a goal state, an action is chosen which will reduce the difference between the two. The action is performed on the current state to produce a new state, and the process is recursively applied to this new state and the goal state.

Note that, in order for MEA to be effective, the goal-seeking system must have a means of associating to any kind of detectable difference those actions that are relevant to reducing that difference. It must also have means for detecting the progress it is making (the changes in the differences between the actual and the desired state), as some attempted sequences of actions may fail and, hence, some alternate sequences may be tried.

When knowledge is available concerning the importance of differences, the most important difference is selected first to further improve the average performance of MEA over other brute-force search strategies. However, even without the ordering of differences according to importance, MEA improves over other search heuristics (again in the average case) by focusing the problem solving on the actual differences between the current state and that of the goal.

Some AI systems using MEA

The MEA technique as a problem-solving strategy was first introduced in 1963 by Allen Newell and Herbert Simon in their computer problem-solving program General Problem Solver (GPS). In that implementation, the correspondence between differences and actions, also called operators, is provided a priori as knowledge in the system. (In GPS this knowledge was in the form of table of connections.)

When the action and side-effects of applying an operator are penetrable, the search may select the relevant operators by inspection of the operators and do without a table of connections. This latter case, of which the canonical example is STRIPS, an automated planning computer program, allows task-independent correlation of differences to the operators which reduce them.

Prodigy, a problem solver developed in a larger learning-assisted automated planning project started at Carnegie Mellon University by Jaime Carbonell, Steven Minton and Craig Knoblock, is another system that used MEA.

Professor Morten Lind, at Technical University of Denmark has developed a tool called multilevel flow modeling MFM. It performs means-end based diagnostic reasoning for industrial control and automation systems.

Method of focal objects

The technique of focal object for problem solving involves synthesizing the seemingly non-matching characteristics of different objects into something new.

Another way to think of focal objects is as a memory cue: if you're trying to find all the different ways to use a brick, give yourself some random "objects" (situations, concepts, etc.) and see if you can find a use. Given "blender", for example, I would try to think of all the ways a brick could be used with a blender (as a lid?). Another concept for the brick game: find patterns in your solutions, and then break those patterns. If you keep finding ways to build things with bricks, think of ways to use bricks that don't involve construction. Pattern-breaking, combined with focal object cues, can lead to very divergent solutions. (Grind the brick up and use it as pigment?)

Morphological analysis (problem-solving)

A major contributor to this article appears to have a close connection with its subject. It may require cleanup to comply with Wikipedia's content policies, particularly neutral point of view. Please discuss further on the talk page. (August 2010)

Morphological analysis or General Morphological Analysis is a method developed by Fritz Zwicky (1967, 1969) for exploring all the possible solutions to a multi-dimensional, non-quantified problem complex.

As a problem-structuring and problem-solving technique, morphological analysis was designed for multi-dimensional, non-quantifiable problems where causal modeling and simulation do not function well or at all. Zwicky developed this approach to address seemingly non-reducible complexity. Using the technique of cross consistency assessment (CCA) (Ritchey, 1998), the system however does allow for reduction, not by reducing the number of variables involved, but by reducing the number of possible solutions through the elimination of the illogical solution combinations in a grid box. A detailed introduction to morphological modeling is given in Ritchey (2002, 2006).

Overview

General morphology was developed by Fritz Zwicky, the Swiss astrophysicist based at the California Institute of Technology. Zwicky applied MA inter alia to astronomical studies and the development of jet and rocket propulsion systems.
Illustration of the need for Morphological Analysis

Consider a complex real world problem, like those of marketing or making policies for a nation, where there are many governing factors, and most of them cannot be expressed as numerical time series data, as one would like to have for building mathematical models. The conventional approach here would be to break the system down into parts, isolate the vital parts (dropping the trivial components) for their contributions to the output and solve the simplified system for creating desired models or scenarios. The disadvantage of this approach is that real world scenarios do not behave rationally and more often than not a simplified model will break down when the contribution of trivial components becomes significant. Also significantly, the behaviour of many components will be governed by states of, and relations with other components, perhaps minor.

Morphological Analysis on the other hand, does not drop any of the components of the system itself, but works backwards from the output towards the system internals. Again, the interactions and relations get to play their parts in MP and their effects are accounted for in the analysis.

Reduction (complexity)

Example of a reduction from a boolean satisfiability problem to a vertex cover problem. Blue vertices form a vertex cover which corresponds to truth values.

In computability theory and computational complexity theory, a reduction is a transformation of one problem into another problem. Depending on the transformation used this can be used to define complexity classes on a set of problems.

Intuitively, problem A is reducible to problem B if solutions to B exist and give solutions to A whenever A has solutions. Thus, solving A cannot be harder than solving B. We write A

≤m B, usually with a subscript on the ≤ to indicate the type of reduction being used (m : mapping reduction, p : polynomial reduction).

Types and applications of reductions

As described in the example above, there are two main types of reductions used in computational complexity, the many-one reduction and the Turing reduction. Many-one reductions map instances of one problem to instances of another; Turing reductions compute the solution to one problem, assuming the other problem is easy to solve. A many-one reduction is weaker than a Turing reduction. Weaker reductions are more effective at separating problems, but they have less power, making reductions harder to design.

A problem is complete for a complexity class if every problem in the class reduces to that problem, and it is also in the class itself. In this sense the problem represents the class, since any solution to it can, in combination with the reductions, be used to solve every problem in the class.

However, in order to be useful, reductions must be easy. For example, it's quite possible to reduce a difficult-to-solve NP-complete problem like the boolean satisfiability problem to a trivial problem, like determining if a number equals zero, by having the reduction machine solve the problem in exponential time and output zero only if there is a solution. However, this does not achieve much, because even though we can solve the new problem, performing the reduction is just as hard as solving the old problem. Likewise, a reduction computing a noncomputable function can reduce an undecidable problem to a decidable one. As Michael Sipser points out in Introduction to the Theory of Computation: "The reduction must be easy, relative to the complexity of typical problems in the class [...] If the reduction itself were difficult to compute, an easy solution to the complete problem wouldn't necessarily yield an easy solution to the problems reducing to it."

Therefore, the appropriate notion of reduction depends on the complexity class being studied. When studying the complexity class NP and harder classes such as the polynomial hierarchy, polynomial-time reductions are used. When studying classes within P such as NC and NL, log-space reductions are used. Reductions are also used in computability theory to show whether problems are or are not solvable by machines at all; in this case, reductions are restricted only to computable functions.

In case of optimization (maximization or minimization) problems, we often think in terms of approximation-preserving reductions. Suppose we have two optimization problems such that instances of one problem can be mapped onto instances of the other, in a way that nearly-optimal solutions to instances of the latter problem can be transformed back to yield nearly-optimal solutions to the former. This way, if we have an optimization algorithm (or approximation algorithm) that finds near-optimal (or optimal) solutions to instances of problem B, and an efficient approximation-preserving reduction from problem A to problem B, by composition we obtain an optimization algorithm that yields near-optimal solutions to instances of problem A. Approximation-preserving reductions are often used to prove hardness of approximation results: if some optimization problem A is hard to approximate (under some complexity assumption) within a factor better than α for some α, and there is a β-approximation-preserving reduction from problem A to problem B, we can conclude that problem B is hard to approximate within factor α/β.

Examples

To show that a decision problem P is undecidable we must find a reduction from a decision problem which is already known to be undecidable to P. That reduction function must be a computable function. In particular, we often show that a problem P is undecidable by showing that the halting problem reduces to P.

The complexity classes P, NP and PSPACE are closed under polynomial-time reductions.

The complexity classes L, NL, P, NP and PSPACE are closed under log-space reduction.

Detailed example

The following example shows how to use reduction from the halting problem to prove that a language is undecidable. Suppose H(M, w) is the problem of determining whether a given Turing machine M halts (by accepting or rejecting) on input string w. This language is known to be undecidable. Suppose E(M) is the problem of determining whether the language a given Turing machine M accepts is empty (in other words, whether M accepts any strings at all). We show that E is undecidable by a reduction from H.

To obtain a contradiction, suppose R is a decider for E. We will use this to produce a decider S for H (which we know does not exist). Given input M and w (a Turing machine and some input string), define S(M, w) with the following behavior: S creates a Turing machine N that accepts only if the input string to N is w and M halts on input w, and does not halt otherwise. The decider S can now evaluate R(N) to check whether the language accepted by N is empty. If R accepts N, then the language accepted by N is empty, so in particular M does not halt on input w, so S can reject. If R rejects N, then the language accepted by N is nonempty, so M does halt on input w, so S can accept. Thus, if we had a decider R for E, we would be able to produce a decider S for the halting problem H(M, w) for any machine M and input w. Since we know that such an S cannot exist, it follows that the language E is also undecidable.

Research

Research can be defined as the search for knowledge, or as any systematic investigation, with an open mind, to establish novel facts, solve new or existing problems, prove new ideas, or develop new theories, usually using a scientific method. The primary purpose for basic research (as opposed to applied research) is discovering, interpreting, and the development of methods and systems for the advancement of human knowledge on a wide variety of scientific matters of our world and the universe.

Scientific research relies on the application of the scientific method, a harnessing of curiosity. This research provides scientific information and theories for the explanation of the nature and the properties of the world around us. It makes practical applications possible. Scientific research is funded by public authorities, by charitable organizations and by private groups, including many companies. Scientific research can be subdivided into different classifications according to their academic and application disciplines.

Artistic research, also seen as 'practice-based research', can take form when creative works are considered both the research and the object of research itself. It is the debatable body of thought which offers an alternative to purely scientific methods in research in its search for knowledge and truth.

Historical research is embodied in the historical method.

The phrase my research is also used loosely to describe a person's entire collection of information about a particular subject.

Root cause analysis

This article has multiple issues. Please help improve it or discuss these issues on the talk page.

It needs additional references or sources for verification. Tagged since October 2009.

It uses first-person or second-person inappropriately. Tagged since October 2010.

Root cause analysis (RCA) is a class of problem solving methods aimed at identifying the root causes of problems or events. The practice of RCA is predicated on the belief that problems are best solved by attempting to address, correct or eliminate root causes, as opposed to merely addressing the immediately obvious symptoms. By directing corrective measures at root causes, it is more probable that problem recurrence will be prevented. However, it is recognized that complete prevention of recurrence by one corrective action is not always possible. Conversely, there may be several effective measures (methods) that address the root cause of a problem. Thus, RCA is often considered to be an iterative process, and is frequently viewed as a tool of continuous improvement.

RCA is typically used as a reactive method of identifying event(s) causes, revealing problems and solving them. Analysis is done after an event has occurred. Insights in RCA may make it useful as a pro-active method. In that event, RCA can be used to forecast or predict probable events even before they occur. While one follows the other, RCA is a completely separate process to Incident Management.

Root cause analysis is not a single, sharply defined methodology; there are many different tools, processes, and philosophies for performing RCA analysis. However, several very-broadly defined approaches or "schools" can be identified by their basic approach or field of origin: safety-based, production-based, process-based, failure-based, and systems-based.

- Safety-based RCA descends from the fields of accident analysis and occupational safety and health.
- Production-based RCA has its origins in the field of quality control for industrial manufacturing.
- Process-based RCA is basically a follow-on to production-based RCA, but with a scope that has been expanded to include business processes.
- Failure-based RCA is rooted in the practice of failure analysis as employed in engineering and maintenance.
- Systems-based RCA has emerged as an amalgamation of the preceding schools, along with ideas taken from fields such as change management, risk management, and systems analysis.

Despite the different approaches among the various schools of root cause analysis, there are some common principles. It is also possible to define several general processes for performing RCA.

General principles of root cause analysis

- The primary aim of RCA is to identify the root cause(s) of a problem in order to create effective corrective actions that will prevent that problem from ever recurring, otherwise addressing the problem with virtual certainty of success. ("Success" is defined as the near-certain prevention of recurrence.)
- To be effective, RCA must be performed systematically, usually as part of an investigation, with conclusions and root causes identified backed up by documented evidence. Usually a team effort is required.
- There may be more than one root cause for an event or a problem, the difficult part is demonstrating the persistence and sustaining the effort required to develop them.
- The purpose of identifying all solutions to a problem is to prevent recurrence at lowest cost in the simplest way. If there are alternatives that are equally effective, then the simplest or lowest cost approach is preferred.
- Root causes identified depend on the way in which the problem or event is defined. Effective problem statements and event descriptions (as failures, for example) are helpful, or even required.
- To be effective the analysis should establish a sequence of events or timeline to understand the relationships between contributory (causal) factors, root cause(s) and the defined problem or event to prevent in the future.
- Root cause analysis can help to transform a reactive culture (that reacts to problems) into a forward-looking culture that solves problems before they occur or escalate. More importantly, it reduces the frequency of problems occurring over time within the environment where the RCA process is used.
- RCA is a threat to many cultures and environments. Threats to cultures often meet with resistance. There may be other forms of management support required to

achieve RCA effectiveness and success. For example, a "non-punitory" policy towards problem identifiers may be required.

General process for performing and documenting an RCA-based Corrective Action

Notice that RCA (in steps 3, 4 and 5) forms the most critical part of successful corrective action, because it directs the corrective action at the true root cause of the problem. The root cause is secondary to the goal of prevention, but without knowing the root cause, we cannot determine what an effective corrective action for the defined problem will be.

1. Define the problem or describe the event factually
2. Gather data and evidence, classifying that along a timeline of events to the final failure or crisis.
3. Ask "why" and identify the causes associated with each step in the sequence towards the defined problem or event.
4. Classify causes into causal factors that relate to an event in the sequence, and root causes, that if applied can be agreed to have interrupted that step of the sequence chain.
5. If there are multiple root causes, which is often the case, reveal those clearly for later optimum selection.
6. Identify corrective action(s) that will with certainty prevent recurrence of the problem or event.
7. Identify solutions that effective, prevent recurrence with reasonable certainty with consensus agreement of the group, are within your control, meet your goals and objectives and do not cause introduce other new, unforeseen problems.
8. Implement the recommended root cause correction(s).
9. Ensure effectiveness by observing the implemented recommendation solutions.
10. Other methodologies for problem solving and problem avoidance may be useful.

Root cause analysis techniques

- Barrier analysis - a technique often used in process industries. It is based on tracing energy flows, with a focus on barriers to those flows, to identify how and why the barriers did not prevent the energy flows from causing harm.
- Bayesian inference
- Change analysis - an investigation technique often used for problems or accidents. It is based on comparing a situation that does not exhibit the problem to one that does, in order to identify the changes or differences that might explain why the problem occurred.
- Current Reality Tree - A method developed by Eliahu M. Goldratt in his theory of constraints that guides an investigator to identify and relate all root causes using a cause-effect tree whose elements are bound by rules of logic (Categories of Legitimate Reservation). The CRT begins with a brief list of the undesirables things we see around us, and then guides us towards one or more root causes. This method is particularly powerful when the system is complex, there is no obvious link

between the observed undesirable things, and a deep understanding of the root cause(s) is desired.

- Failure mode and effects analysis
- Fault tree analysis
- 5 Whys ask why why why why over until exhausted
- Ishikawa diagram, also known as the fishbone diagram or cause-and-effect diagram. The Ishikawa diagram is for project managers for conducting RCA.
- Pareto analysis "80/20 rule"
- RPR Problem Diagnosis - An ITIL-aligned method for diagnosing IT problems.
- Kepner-Tregoe Approach

- Common cause analysis (CCA) common modes analysis (CMA) are evolving engineering techniques for complex technical systems to determine if common root causes in hardware, software or highly integrated systems interaction may contribute to human error or improper operation of a system. Systems are analyzed for root causes and causal factors to determine probability of failure modes, fault modes, or common mode software faults due to escaped requirements. Also ensuring complete testing and verification are methods used for ensuring complex systems are designed with no common causes that cause severe hazards. Common cause analysis are sometimes required as part of the safety engineering tasks for theme parks, commercial/military aircraft, spacecraft, complex control systems, large electrical utility grids, nuclear power plants, automated industrial controls, medical devices or other safety safety-critical systems with complex functionality.

Basic elements of root cause using Management Oversight Risk Tree (MORT) Approach Classification

Materials

Defective raw material
Wrong type for job
Lack of raw material

Man Power

Inadequate capability
Lack of Knowledge
Lack of skill
Stress
Improper motivation

Machine / Equipment

Incorrect tool selection
Poor maintenance or design
Poor equipment or tool placement
Defective equipment or tool

Environment
Orderly workplace
Job design or layout of work
Surfaces poorly maintained
Physical demands of the task
Forces of nature

Management
No or poor management involvement
Inattention to task
Task hazards not guarded properly
Other (horseplay, inattention....)
Stress demands
Lack of Process
Lack of Communication

Methods
No or poor procedures
Practices are not the same as written procedures
Poor communication

Management system
Training or education lacking
Poor employee involvement
Poor recognition of hazard
Previously identified hazards were not eliminated

Trial and error

Trial and error, or trial by error, is a general method of problem solving, fixing things, or for obtaining knowledge. "Learning doesn't happen from failure itself but rather from analyzing the failure, making a change, and then trying again."

In the field of computer science, the method is called generate and test. In elementary algebra, when solving equations, it is "guess and check".

This approach can be seen as one of the two basic approaches to problem solving and is contrasted with an approach using insight and theory. However, there are intermediate methods which for example, use theory to guide the method, an approach known as guided empricism.

Methodology

This approach is more successful with simple problems and in games, and is often resorted to when no apparent rule applies. This does not mean that the approach need be careless, for an individual can be methodical in manipulating the variables in an attempt to sort through possibilities that may result in success. Nevertheless, this method is often used by people who have little knowledge in the problem area.

Simplest applications

Ashby (1960, section 11/5) offers three simple strategies for dealing with the same basic exercise-problem; and they have very different efficiencies: Suppose there are 1000 on/off switches which have to be set to a particular combination by random-based testing, each test to take one second. [This is also discussed in Traill (1978/2006, section C1.2]. The strategies are:

- the perfectionist all-or-nothing method, with no attempt at holding partial successes. This would be expected to take more than 10^301 seconds, [i.e. 2^1000 seconds, or 3·5×(10^291) centuries!];
- a serial-test of switches, holding on to the partial successes (assuming that these are manifest) would take 500 seconds; while
- a parallel-but-individual testing of all switches simultaneously would take only one second.

Note the tacit assumption here that no intelligence or insight is brought to bear on the problem. However, the existence of different available strategies allows us to consider a separate ("superior") domain of processing — a "meta-level" above the mechanics of switch handling — where the various available strategies can be randomly chosen. Once again this is "trial and error", but of a different type. This leads us to:

Trial-and-error Hierarchies

Ashby's book develops this "meta-level" idea, and extends it into a whole recursive sequence of levels, successively above each other in a systematic hierarchy. On this basis he argues that human intelligence emerges from such organization: relying heavily on trial-and-error (at least initially at each new stage), but emerging with what we would call "intelligence" at the end of it all. Thus presumably the topmost level of the hierarchy (at any stage) will still depend on simple trial-and-error.

Traill (1978/2006) suggests that this Ashby-hierarchy probably coincides with Piaget's well-known theory of developmental stages. [This work also discusses Ashby's 1000-switch example; see §C1.2]. After all, it is part of Piagetian doctrine that children learn by first actively doing in a more-or-less random way, and then hopefully learn from the consequences — which all has a certain to Ashby's random "trial-and-error".

The basic strategy in many fields?

Traill (2008, espec. Table "S" on p.31) follows Jerne and Popper in seeing this strategy as probably underlying all knowledge-gathering systems — at least in their initial phase.

Four such systems are identified:

Darwinian evolution which "educates" the DNA of the species,
The brain of the individual (just discussed);
The "brain" of society-as-such (including the publicly-held body of science); and
The immune system.

An ambiguity: Can we have "intention" during a "trial"

In the Ashby-and-Cybernetics tradition, the word "trial" usually implies random-or-arbitrary, without any deliberate choice. However amongst non-cyberneticians, "trial" will often imply a deliberate subjective act by some adult human agent; (e.g. in a court-room, or laboratory). So that has sometimes led to confusion.

Of course the situation becomes even more confusing if one accepts Ashby's hierarchical explanation of intelligence, and its implied ability to be deliberate and to creatively design — all based ultimately on non-deliberate actions. The lesson here seems to be that one must simply be careful to clarify the meaning of one's own words, and indeed the words of others. [Incidentally it seems that consciousness is not an essential ingredient for intelligence as discussed above.

Features

Trial and error has a number of features:

- solution-oriented: trial and error makes no attempt to discover why a solution works, merely that it is a solution.
- problem-specific: trial and error makes no attempt to generalise a solution to other problems.
- non-optimal: trial and error is generally an attempt to find a solution, not all solutions, and not the best solution.
- needs little knowledge: trials and error can proceed where there is little or no knowledge of the subject.

It is possible to use trial and error to find all solutions or the best solution, when a testably finite number of possible solutions exist. To find all solutions, one simply makes a note and continues, rather than ending the process, when a solution is found, until all solutions have been tried. To find the best solution, one finds all solutions by the method just described and then comparatively evaluates them based upon some predefined set of criteria, the existence of which is a condition for the possibility of finding a best solution. (Also, when only one solution can exist, as in assembling a jigsaw puzzle, then any solution found is the only solution and so is necessarily the best.)

Examples

Trial and error has traditionally been the main method of finding new drugs, such as antibiotics. Chemists simply try chemicals at random until they find one with the desired effect. In a more sophisticated version, chemists select a narrow range of chemicals it is thought may have some effect using a technique called structure-activity relationship. (The latter case can be alternatively considered as a changing of the problem rather than of the solution strategy: instead of "What chemical will work well as an antibiotic?" the problem in the sophisticated approach is "Which, if any, of the chemicals in this narrow range will work well as an antibiotic?") The method is used widely in many disciplines, such as polymer technology to find new polymer types or families.

The scientific method can be regarded as containing an element of trial and error in its formulation and testing of hypotheses. Also compare genetic algorithms, simulated annealing and reinforcement learning - all varieties for search which apply the basic idea of trial and error.

Biological evolution is also a form of trial and error. Random mutations and sexual genetic variations can be viewed as trials and poor reproductive fitness, or lack of improved fitness, as the error. Thus after a long time 'knowledge' of well-adapted genomes accumulates simply by virtue of them being able to reproduce.

Bogosort, a conceptual sorting algorithm (that is extremely inefficient and impractical), can be viewed as a trial and error approach to sorting a list. However, typical simple examples of bogosort do not track which orders of the list have been tried and may try the same order any number of times, which violates one of the basic principles of trial and error. Trial and error is actually more efficient and practical than bogosort; unlike bogosort, it is guaranteed to halt in finite time on a finite list, and might even be a reasonable way to sort extremely short lists under some conditions.

Jumping spiders of the genus Portia use trial and error to find new tactics against unfamiliar prey or in unusual situations, and remember the new tactics. Tests show that Portia fimbriata and Portia labiata can use trial and error in an artificial environment, where the spider's objective is to cross a miniature lagoon that is too wide for a simple jump, and must either jump then swim or only swim.

Issues with trial and error

Trial and error is usually a last resort for a particular problem, as there are a number of problems with it. For one, trial and error is tedious and monotonous. Also, it is very time-consuming; chemical engineers must sift through millions of various potential chemicals before they find one that works. There is also an element of risk, in that if a certain attempt at a solution is extremely erroneous, it can produce disastrous results that may or may not be repairable. Fortunately, computers are best suited for trial and error; they do not succumb to the boredom that humans do, can test physical challenges in a virtual environment where they will not do harm, and can potentially do thousands of trial-and-error segments in the blink of an eye.

Proof (truth)

A proof is sufficient evidence or argument for the truth of a proposition.

The concept arises in a variety of areas, with both the nature of the evidence or justification and the criteria for sufficiency being area-dependent. In the area of oral and written communication such as conversation, dialog, rhetoric, etc., a proof is a persuasive perlocutionary speech act, which demonstrates the truth of a proposition. In any area of mathematics defined by its assumptions or axioms, a proof is an argument establishing a theorem of that area via accepted rules of inference starting from those axioms and other previously established theorems. The subject of logic, in particular proof theory, formalizes and studies the notion of formal proof. In the areas of epistemology and theology, the notion of justification plays approximately the role of proof, while in jurisprudence the corresponding term is evidence, with burden of proof as a concept common to both philosophy and law.

In most areas, evidence is drawn from experience of the world around us, with science obtaining its evidence from nature, law obtaining its evidence from witnesses and forensic investigation, and so on. A notable exception is mathematics, whose evidence is drawn from a mathematical world begun with postulates and further developed and enriched by theorems proved earlier.

As with evidence itself, the criteria for sufficiency of evidence are also strongly area-dependent, usually with no absolute threshold of sufficiency at which evidence becomes proof. The same evidence that may convince one jury may not persuade another. Formal proof provides the main exception, where the criteria for proofhood are ironclad and it is impermissible to defend any step in the reasoning as "obvious"; for a well-formed formula to qualify as part of a formal proof, it must be the result of applying a rule of the deductive apparatus of some formal system to the previous well-formed formulae in the proof sequence.

Proofs have been presented since antiquity. Aristotle used the observation that patterns of nature never display the machine-like uniformity of determinism as proof that chance is an inherent part of nature. On the other hand, Thomas Aquinas used the observation of the existence of rich patterns in nature as proof that nature is not ruled by chance. Augustine of Hippo provides a good case study in early uses of informal proofs in theology. He argued that given the assumption that Christ had risen, there is resurrection of the dead and he provided further arguments to prove that the death of Jesus was for the salvation of man.

Proofs need not be verbal. Before Galileo, people took the apparent motion of the Sun across the sky as proof that the Sun went round the Earth. Suitably incriminating evidence left at the scene of a crime may serve as proof of the identity of the perpetrator. Conversely, a verbal entity need not assert a proposition to constitute a proof of that proposition. For example, a signature constitutes direct proof of authorship; less directly, handwriting analysis may be submitted as proof of authorship of a document. Privileged information in a document can serve as proof that the document's author had access to that information; such access might in turn establish the location of the author at certain time, which might then provide the author with an alibi.

Eight Disciplines Problem Solving

Eight Disciplines Problem Solving is a method used to approach and to resolve problems, typically employed by quality engineers or other professionals.

D0: The Planning Phase: Plan for solving the problem and determine the prerequisites.

D1: Use a Team: Establish a team of people with product/process knowledge.

D2: Define and describe the Problem: Specify the problem by identifying in quantifiable terms the who, what, where, when, why, how and how many (5W2H) for the problem.

D3: Developing Interim Containment Plan Implement and verify Interim Actions: Define and implement containment actions to isolate the problem from any customer.

D4: Determine and Identify and Verify Root Causes and escape points: Identify all potential causes that could explain why the problem occurred. Also identify why the problem has not been noticed at the time it occurred. All causes shall be verified or proved, not determined by fuzzy brainstorming.

D5: Choose and verify Permanent Corrective Actions (PCAs) for root cause and Escape point : Through pre-production programs quantitatively confirm that the selected corrective actions will resolve the problem for the customer.

D6: Implement and validate PCAs: Define and Implement the best corrective actions.

D7: Prevent recurrence: Modify the management systems, operation systems, practices and procedures to prevent recurrence of this and all similar problems.

D8: Congratulate your Team: Recognize the collective efforts of the team. The team needs to be formally thanked by the organization.

8D has become a standard in the Auto, Assembly and other industries that require a thorough structured problem solving process using a team approach.

History

People have been using structured problem solving methodologies since the Dark Ages. No single source can claim to be the fountain of modern problem solving techniques. Ford Motor Company developed a method, while the military also developed and quantified their own process during World War II. Both of these methods revolve around the Eight Disciplines.

Ford's Perspective

The development of a Team Oriented Problem Solving strategy, based on the use of statistical methods of data analysis, was developed at Ford Motor Company. The executives of the Powertrain Organization (transmissions, chassis, engines) wanted a methodology where teams(design engineering, manufacturing engineering, and production) could work on recurring problems. In 1986, the assignment was given to develop a manual and a subsequent course that would achieve a new approach to solving tough engineering design and manufacturing problems. The manual for this methodology was documented and defined in "Team Oriented Problem Solving"(TOPS), first published in 1987. The manual and subsequent course material was piloted at World Headquarters in Dearborn, Michigan. Many changes and revisions were made based on feedback from the pilot sessions. This has been Ford's approach to problem solving ever since. It was never based on any military standard or other existing problem solving methodology. The material is extensive and the 8D titles are merely the chapter headings for each step in the process. Ford also refers to their current variant as G8D (Global 8D).

Military Usage

The US Government first standardized a process during the Second World War as Military Standard 1520 'Corrective Action and Disposition System for Nonconforming Material' . This military standard focused on nonconforming material and the disposition of the material.

The 8D Problem Solving Process is used to identify, correct and eliminate recurring problems. The methodology is useful in product and process improvement. It establishes a permanent corrective action based on statistical analysis of the problem. It focuses on the origin of the problem by determining Root Causes.

This 'Determine a Root Cause' step is a part of the military usage of the 8D's but was not a reference in the development of the 8D problem solving methodology and is not referenced or included in the TOPS manual or course.

Usage

Many disciplines are typically involved in the "8D" process, all of which can be found in various textbooks and reference materials used by Quality Assurance professionals. For example, an "Is/Is Not" worksheet is a common tool employed at D2, and a "Fishbone Diagram" or "5 Why Analysis" are common tools employed at step D4.

In the late 1990s, Ford developed a revised version of the 8D process, that they call "Global 8D" (G8D) which is the current global standard for Ford and many other companies in the automotive supply chain. The major revisions to the process are as follows:

Addition of a D0 (D-Zero) step as a gateway to the process. At D0, the team documents the symptoms that initiated the effort along with any Emergency Response Actions (ERAs) that were taken before formal initiation of the G8D. D0 also incorporates standard assessing questions meant to determine whether a full G8D is required. The assessing questions are meant to ensure that in a world of limited problem-solving resources, the efforts required for a full team-based problem-solving effort are limited to those problems that warrant these resources.

Addition of Escape Point to D4 through D6. The idea here is to consider not only the Root cause of a problem, but equally importantly, what went wrong with the control system in allowing this problem to escape. Global 8D requires the team to identify and verify this Escape Point (defined as the earliest control point in the control system following the Root Cause that should have detected the problem but failed to do so) at D4. Then, through D5 and D6, the process requires the team to choose, verify, implement, and validate Permanent Corrective Actions to address the Escape Point.

Recently, the 8D process has been employed significantly outside the auto industry. As part of Lean initiatives and Continuous Improvement Processes it is employed extensively within Food Manufacturing, High Tech and Health Care industries.

GROW model

The GROW model (or process) is a technique for problem solving or goal setting. It was developed in the United Kingdom and was used extensively in the corporate coaching market in the late 1980s and 1990s.

There have been many claims to authorship of GROW as a way of achieving goals and solving problems. While no one person can be clearly identified as the originator Graham Alexander, Alan Fine and Sir John Whitmore, who are well known in the world of coaching, made significant contributions. Max Landsberg also describes GROW in his book The Tao of Coaching

GROW is very well known in the business arena but it also has many applications in everyday life. The particular value of GROW is that it provides an effective, structured methodology which both helps set goals effectively and is a problem solving process.

It can be used by anyone without special training. While there are many methodologies that can be used to address problems, the value of GROW is that it is easily understood, straightforward to apply and very thorough. In addition it is possible to apply it to a large variety of issues in a very effective way.

Stages of GROW

There are a number of different versions of the GROW model. This version presents one view of the stages but there are others. The 'O' in this version has two meanings.

G Goal This is the end point, where the client wants to be. The goal has to be defined in such a way that it is very clear to the client when they have achieved it.

R Reality This is how far the client is away from their goal. If the client were to look at all the steps they need to take in order to achieve the goal, the Reality would be the number of those steps they have completed so far.

O Obstacles There will be Obstacles stopping the client getting from where they are now to where they want to go. If there were no Obstacles the client would already have reached their goal.

Options Once Obstacles have been identified the client need to find ways of dealing with them if they are to make progress. These are the Options.

W Way Forward The Options then need to be converted into action steps which will take the client to their goal. These are the Way Forward.

As with many simple principles any user of GROW can apply a great deal of skill and knowledge at each stage but the basic process remains as written above. There are numerous questions which the coach could use at any point and part of the skill of the coach is to know which questions to use and how much detail to uncover.

This is a very simple example of using the GROW model to achieve a goal.

This example deals with weight loss. The clients wants: ‘To bring my weight down to 120 pounds in three months and keep it down’.

That is their Goal. The GROW approach would then be to establish the Reality by stating what their weight is now. The coach would then ask awareness questions to deepen understanding of what is happening when the client tries to lose weight, thus identifying the Obstacles. These questions could include:

When you have been able to lose weight – what made the difference?

What is the difference between the times you are able to keep weight off and the times when you put it on again?

What would have to change for you to be sure you could lose the weight and keep it off?

If the client genuinely answers these questions they will discover new information about what works and does not work for them in terms of weight loss, and create some potential for change. It then becomes possible to create some strategies or Options which get around the Obstacles. These could include looking at which diets or exercise regimes work best, or finding a specific type of support. Once the client knows the strategies that are likely to work they can establish a Way Forward which involves taking action steps. This is where they commit to what they will do in the short term to put the strategies into effect. For instance, one action might be asking a particular person for support, and another might be to buy a different selection of foods.

The same principles can be applied whatever goal or problem the client has. GROW can be used on technical problems, issues regarding processes, strategy questions, interpersonal issues and many more. Almost any situation where there is something to be achieved and there is an Obstacle can be tackled with GROW. The model can also be used by a group who are all working on the same problem or goal.

The GROW principle and the Inner Game

GROW was developed out of the Inner Game theory developed by Timothy Gallwey, Gallwey was a tennis coach who noticed that he could often see what a player was doing incorrectly but that simply telling them what they should be doing did not bring about lasting change.

This is often illustrated by the example of a player who does not keep their eye on the ball. Most coaches would give instructions such as: 'Keep your eye on the ball' to try and correct this. The problem with this sort of instruction is that a player will be able to follow it for a short while but be unable to keep it in the front of their minds in the long term. This means that progress was slow. The result was that coaches and players grew increasingly frustrated at the slowness of progress but no one had better system of coaching.

So one day, instead of giving an instruction, Gallwey asked the player to say `bounce' out loud when the ball bounced and `hit' out loud when they hit it

The result was that the players started to improve without a lot of effort because they were keeping their eye on the ball. But because of the way the instruction was given they did not have a voice in their heads saying 'I must keep my eye on the ball.' They were simply playing a simple game while they were playing tennis. Once Gallwey saw how play could be improved in this way he stopped giving instructions and started asking questions that would help the player discover for himself what worked and what needed to change. This was the birth of the Inner Game.

The basic methodology of GROW came out of Gallweys work with tennis players. For example the first stage in this process would be to set a target which the player wanted to achieve. For example if a player wanted to improve his first serve Gallwey would ask how many first serves out of ten they would like to get in. This was the target or goal.

The Reality would be defined by asking the player to serve 10 balls and seeing how many first serves went in.

Gallwey would then ask awareness raising questions such as "What do you notice you are doing differently when you the ball goes in or out?" This would enable the player to discover for themselves what they were changing about their mind and body when the serve when in or out. They had then defined their Obstacles and Options. They therefor learnt for themselves what they had to change in order to meet their serving targets and they had a clear Way Forward.

From Gallwey's experience with tennis players it is possible to define a number of learning principles which can be applied to any learning situation whether sport based or not. For example:

In most learning situations the learner is rarely focused on what is happening during the process. But if they focus their attention on a relevant aspect of what is actually happening during the process, rather than what they 'should' be doing or trying to get it 'right' they will make progress much faster.

Learning happens best when the learner is focused on the present. If they are focused on the present they will not struggle to prove or remember something but rather make discoveries as they go along.

If the learner is trying to look good or using a lot of unfocused effort they will interfere with the learning process. The less interference with their learning, the faster they progress.

Coaches using the Inner Game soon realised they could apply the principles in other learning situations. GROW was developed as a structured framework to use the Inner Game principles to achieve goals. The originators saw that, just as in sport, many individuals were struggling to achieve goals because they were not learning from experience and were not aware of the knowledge within themselves that would help them.

How to Solve It

How to Solve It (1945) is a small volume by mathematician George Pólya describing methods of problem solving.

Four principles

How to Solve It suggests the following steps when solving a mathematical problem:

- First, you have to understand the problem.
- After understanding, then make a plan.
- Carry out the plan.
- Look back on your work. How could it be better?

If this technique fails, Pólya advises: "If you can't solve a problem, then there is an easier problem you can solve: find it." Or: "If you cannot solve the proposed problem, try to solve first some related problem. Could you imagine a more accessible related problem?"

First principle: Understand the problem

"Understand the problem" is often neglected as being obvious and is not even mentioned in many mathematics classes. Yet students are often stymied in their efforts to solve it, simply because they don't understand it fully, or even in part. In order to remedy this oversight, Pólya taught teachers how to prompt each student with appropriate questions, depending on the situation, such as:

What are you asked to find or show?
Can you restate the problem in your own words?
Can you think of a picture or a diagram that might help you understand the problem?
Is there enough information to enable you to find a solution?
Do you understand all the words used in stating the problem?
Do you need to ask a question to get the answer?

The teacher is to select the question with the appropriate level of difficulty for each student to ascertain if each student understands at their own level, moving up or down the list to prompt each student, until each one can respond with something constructive.

Second principle: Devise a plan

Pólya mentions that there are many reasonable ways to solve problems. The skill at choosing an appropriate strategy is best learned by solving many problems. You will find choosing a strategy increasingly easy. A partial list of strategies is included:

Guess and check
Make an orderly list
Eliminate possibilities
Use symmetry
Consider special cases
Use direct reasoning
Solve an equation

Also suggested:

Look for a pattern
Draw a picture
Solve a simpler problem
Use a model
Work backward
Use a formula
Be creative

Use your head/noggin

Third principle: Carry out the plan

This step is usually easier than devising the plan. In general, all you need is care and patience, given that you have the necessary skills. Persist with the plan that you have chosen. If it continues not to work discard it and choose another. Don't be misled; this is how mathematics is done, even by professionals.

Fourth principle: Review/extend

Pólya mentions that much can be gained by taking the time to reflect and look back at what you have done, what worked and what didn't. Doing this will enable you to predict what strategy to use to solve future problems, if these relate to the original problem.

Kepner-Tregoe Inc.

Kepner-Tregoe, Inc. is a multinational management consulting and training services company. It provides consultation and training to companies in industries such as manufacturing, electronics, chemical, pharmaceuticals, and financial services.

The company was founded in 1958 by former RAND Corporation researchers Dr. Charles Kepner and Dr. Benjamin Tregoe. They are best known for their Rational Process technique, and together wrote the book "The Rational Manager" published in 1965 and "The New Rational Manager" published in December 1997.

Initial Research

The RAND Corporation at the time were attempting to improve the effectiveness of the Air Defence system in the US, and had developed a way of simulating various types of air threats; high level attacks, low level sneak attacks and so forth. Kepner and Tregoe were working in a small research group studying the Manual Air Defence System, and for 6 months studied how groups of people process information when they see various types of air threat by watching how those groups processed the incoming information. They noticed a difference in the Commanding Officer's ability to recognise a problem when it was occurring and then the decisions that they made in terms of how quickly they recognised that they were getting into trouble and in what they decided to do about it. When Kepner & Tregoe left the RAND Corporation they took with them the research hypothesis that "some people were using a mental process that enabled them be better than others at dealing with the information that was being presented" and "the more ability that a person had to articulate how they were making a decision the better they would be". The research was anthropological - they went into the field, and had managers and CEO's identify good and poor decision makers. They interviewed them, and tried to see what the differences were, sitting in on meetings and so on. When they found that there was no difference between those who had been identified as good and poor in terms of their ability to articulate how they were going about making decisions, Kepner and Tregoe came to the conclusion that if they were able to make people more consciously aware of the process that they were using, and conscious of a good decision making process they could improve their performance, and enable them to pass this process on to someone else. Interviewing people was not very productive, but sitting in on meetings was productive, they could more easily see the sequence that people were using. At the same time as conducting this research they were developing a simple form of four part business simulation, which they used at the Hughes Aircraft Fire Control Laboratories to track what people were doing and observe the sequence in a controlled environment. They found that there is a very different sequence of events and different information needed when there is something going wrong, in order to come to a successful conclusion, compared with the information required and sequence to arrive at a sensible decision.

PDCA

PDCA (plan–do–check–act) is an iterative four-step management process typically used in business. It is also known as the Deming circle/cycle/wheel, Shewhart cycle, control circle/cycle, or plan–do–study–act (PDSA).

Meaning

The PDCA cycle

PDCA is a successive cycle which starts off small to test potential effects on processes, but then gradually leads to larger and more targeted change. Plan, Do, Check, Act are the four components of Work bench in Software testing.

PLAN

Establish the objectives and processes necessary to deliver results in accordance with the expected output (the target or goals). By making the expected output the focus, it differs from other techniques in that the completeness and accuracy of the specification is also part of the improvement.

DO

Implement the new processes, often on a small scale if possible, to test possible effects. It is important to collect data for charting and analysis for the following "CHECK" step.

CHECK

Measure the new processes and compare the results (collected in "DO" above) against the expected results (targets or goals from the "PLAN") to ascertain any differences. Charting data can make this much easier to see trends in order to convert the collected data into information. Information is what you need for the next step "ACT".

ACT

Analyze the differences to determine their cause. Each will be part of either one or more of the P-D-C-A steps. Determine where to apply changes that will include improvement. When a pass through these four steps does not result in the need to improve, refine the scope to which PDCA is applied until there is a plan that involves improvement.

About

PDCA was made popular by Dr. W. Edwards Deming, who is considered by many to be the father of modern quality control; however he always referred to it as the "Shewhart cycle". Later in Deming's career, he modified PDCA to "Plan, Do, Study, Act" (PDSA) so as to better describe his recommendations.

The concept of PDCA is based on the scientific method, as developed from the work of Francis Bacon (Novum Organum, 1620). The scientific method can be written as "hypothesis"–"experiment"–"evaluation" or plan, do and check. Shewhart described manufacture under "control"—under statistical control—as a three step process of specification, production, and inspection. He also specifically related this to the scientific method of hypothesis, experiment, and evaluation. Shewhart says that the statistician "must help to change the demand [for goods] by showing [...] how to close up the tolerance range and to improve the quality of goods". Clearly, Shewhart intended the analyst to take action based on the conclusions of the evaluation. According to Deming, during his lectures in Japan in the early 1950s, the Japanese participants shortened the steps to the now traditional plan, do, check, act. Deming preferred plan, do, study, act because "study" has connotations in English closer to Shewhart's intent than "check".

A fundamental principle of the scientific method and PDSA is iteration—once a hypothesis is confirmed (or negated), executing the cycle again will extend the knowledge further. Repeating the PDSA cycle can bring us closer to the goal, usually a perfect operation and output.

In Six Sigma programs, the PDSA cycle is called "define, measure, analyze, improve, control" (DMAIC). The iterative nature of the cycle must be explicitly added to the DMAIC procedure.

PDSA should be repeatedly implemented in spirals of increasing knowledge of the system that converge on the ultimate goal, each cycle closer than the previous. One can envision an open coil spring, with each loop being one cycle of the scientific method - PDSA, and each complete cycle indicating an increase in our knowledge of the system under study. This approach is based on the belief that our knowledge and skills are limited, but improving. Especially at the start of a project, key information may not be known; the PDSA—scientific method—provides feedback to justify our guesses (hypotheses) and increase our knowledge. Rather than enter "analysis paralysis" to get it perfect the first time, it is better to be approximately right than exactly wrong. With the improved knowledge, we may choose to refine or alter the goal (ideal state). Certainly, the PDSA approach can bring us closer to whatever goal we choose.

Rate of change, that is, rate of improvement, is a key competitive factor in today's world. PDSA allows for major 'jumps' in performance ('breakthroughs' often desired in a Western approach), as well as Kaizen (frequent small improvements associated with an Eastern approach). In the United States a PDSA approach is usually associated with a sizable project involving numerous people's time, and thus managers want to see large 'breakthrough' improvements to justify the effort expended. However, the scientific method and PDSA apply to all sorts of projects and improvement activities.

The power of Deming's concept lies in its apparent simplicity. The concept of feedback in the scientific method, in the abstract sense, is today firmly rooted in education. While apparently easy to understand, it is often difficult to accomplish on an on-going basis due to the intellectual difficulty of judging one's proposals (hypotheses) on the basis of measured results. Many people have an emotional fear of being shown "wrong", even by objective measurements. To avoid such comparisons, we may instead cite complacency, distractions, loss of focus, lack of commitment, re-assigned priorities, lack of resources, etc.

RPR Problem Diagnosis

RPR is a problem diagnosis method specifically designed to determine the root cause of IT problems.

Overview

RPR (Rapid Problem Resolution) deals with failures, incorrect output and performance issues, and its particular strengths are in the diagnosis of ongoing & recurring grey problems. The method comprises:

- Core Process
- Supporting Techniques

The Core Process defines a step-by-step approach to problem diagnosis and has three phases:

Discover

Gather & review existing information
Reach an agreed understanding

Investigate

Create & execute a diagnostic data capture plan
Analyse the results & iterate if necessary
Identify Root Cause

Fix

Translate diagnostic data
Determine & implement fix
Confirm Root Cause addressed

The Supporting Techniques detail how the objectives of the Core Process steps are achieved, and cite examples using tools and techniques that are available in every business.

Standards alignment

RPR has been fully aligned with ITIL v3 since RPR 2.01 was released in April 2008. RPR fits directly into the ITIL v3 Problem Management Process as a sub-process. Some organisations handle ongoing recurring problems within Incident Management, and RPR also fits into the ITIL v3 Incident Management Process as a sub-process.

COBIT also defines a Problem Management Process (DS10) with key activity of Perform root cause analysis. RPR is a superset of this step in that it defines a process that covers all of the activities needed to perform Problem investigation & diagnosis, including Root Cause identification.

Limitations

RPR has some limitations and considerations, including:

- RPR deals with a single symptom at a time
- RPR is not a forensic technique and so historical data alone is rarely sufficient
- The Investigate phase requires the user to experience the problem one more time

History

The method was originally developed by Advance7 in 1990 as the Rapid Problem Resolution Method, with the first fully documented version produced in 1995. Early versions included problem management guidance but this was removed over time as the method became more closely aligned to ITIL. RPR is now focused on Problem Diagnosis based on Root Cause Identification. Due to the highly practical nature of the Supporting Techniques and the ever changing IT landscape, Advance7 continues to develop RPR to keep it relevant to current IT environments.

Until November 2007 Advance7 made the RPR material available to its employees only, although a limited number of other IT professionals had been trained in the use of the method. In late 2007 the company announced its intention to make RPR training and material more widely available.

In March 2009 the TSO added a significant amount of RPR information to the ITIL Best Practice Live website within the areas dealing with Problem Management.

TRIZ

TRIZ is "a problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature". It was developed by the Soviet inventor and science fiction author Genrich Altshuller and his colleagues, beginning in 1946. In English the name is typically rendered as "the Theory of Inventive Problem Solving)", and occasionally goes by the English acronym TIPS.

Following Altshuller's insight, the Theory developed on a foundation of extensive research covering hundreds of thousands of inventions across many different fields to produce a theory which defines generalisable patterns in the nature of inventive solutions and the distinguishing characteristics of the problems that these inventions have overcome.

An important part of the Theory has been devoted to revealing patterns of evolution and one of the objectives which has been pursued by leading practitioners of TRIZ has been the development of an algorithmic approach to the invention of new systems, and the refinement of existing ones.

The Theory includes a practical methodology, tool sets, a knowledge base, and model-based technology for generating new ideas and solutions for problem solving. It is intended for application in problem formulation, system analysis, failure analysis, and patterns of system evolution.

History

TRIZ in its classical form was developed by the Soviet inventor and science fiction writer Genrich Altshuller and his associates. He started developing TRIZ in 1946 while working in the "Inventions Inspection" department of the Caspian Sea flotilla of the Soviet Navy. His job was to help with the initiation of invention proposals, to rectify and document them and prepare applications to the patent office. During this time he realised that a problem requires an inventive solution if there is a unresolved contradiction in the sense that improving one parameter impacts negatively on another. He later called these “technical contradictions".

His work on what later resulted in TRIZ was interrupted in 1950 by his arrest and sentencing to 25 years in the Gulag. According to one source the arrest was partially triggered by letters which he and Raphael Shapiro sent to Stalin, ministers and newspapers about certain decisions made by the Soviet Government, which they believed were erroneous. Altshuller and Shapiro were freed following Stalin's death in 1953 and returned to Baku.

The first paper on TRIZ titled "On the psychology of inventive creation" was published in 1956 in "Issues in Psychology" (Voprosi Psichologii) journal.

By 1969 Altshuller had reviewed about 40,000 patent abstracts in order to find out in what way the innovation had taken place and developed the concept of technical contradictions, the concept of Ideality of a system, contradiction matrix, and 40 Principles of Invention. In the years that followed he developed the concept of physical contradictions, SuField Analysis, Standard Solutions, and several Laws of Technical Systems Evolution, and numerous other theoretical and practical approaches.

In 1971 Altshuller convinced The Inventors Society to establish in Baku the first TRIZ teaching facility called the Azerbaijan Public Institute for Inventive Creation and the first TRIZ research lab called The Public Lab for Inventive Creation. Altshuller was appointed the head of the lab by the Society. The lab incubated the TRIZ movement and in the years that followed other TRIZ teaching institutes were established in all major cities of the USSR. In 1989 the TRIZ Association was formed, with Altshuller chosen as President.

Following the end of the cold war, the waves of emigrants from the former Soviet Union brought TRIZ to other countries and drew attention to it overseas. In 1995 the Altshuller Institute for TRIZ Studies was established in Boston, USA.

Basic principles of TRIZ

TRIZ presents a systematic approach for analysing the kind of challenging problems where inventiveness is needed and provides a range of strategies and tools for finding inventive solutions. One of the earliest findings of the massive research on which the theory is based is that the vast majority of problems that require inventive solutions typically reflect a need to overcome a dilemma or a trade-off between two contradictory elements. The central purpose of TRIZ-based analysis is to systematically apply the strategies and tools to find superior solutions that overcome the need for a compromise or trade-off between the two elements.

TRIZ process for creative problem solving

By the early 1970s two decades of research covering hundreds of thousands of patents had confirmed Altshuller's initial insight about the patterns of inventive solutions and one of the first analytical tools was published in the form of 40 Inventive Principles, which could account for virtually all of those patents that presented truly inventive solutions. Following this approach the "Typical solution" shown in the diagram can be found by defining the contradiction which needs to be resolved and systematically considering which of the 40 principles may be applied to provide a specific solution which will overcome the “contradiction” in the problem at hand, enabling a solution that is closer to the “ultimate ideal result”.

The combination of all of these concepts together – the analysis of the contradiction, the pursuit of an ideal solution and the search for one or more of the Principles which will overcome the contradiction, are the key elements in a process which is designed to help the inventor to engage in the process with purposefulness and focus.

One of the tools which evolved as an extension of the 40 Principles was a Contradiction Matrix in which the contradictory elements of a problem were categorized according to a list of 39 factors which could impact on each other. The combination of each pairing of these 39 elements is set out in a matrix (for example, the weight of a stationary object, the use of energy by a moving object, the ease of repair etc.) Each of the 39 elements is represented down the rows and across the columns (as the negatively affected element) and based upon the research and analysis of patents, wherever precedent solutions have been found that resolve a conflict between two of the elements the relevant cells in the matrix typically contain a sub-set of three or four Principles that have been applied most frequently in inventive solutions which resolve contradictions between those two elements.

The main objective of the contradiction matrix was to simplify the process of selecting the most appropriate Principle to resolve a specific contradiction. It was the core of all modifications of ARIZ till 1973. But in 1973, after introducing the concept of physical contradictions and creating SuField Analysis, Altshuller realized that the contradiction matrix was comparatively an inefficient tool and stopped working on it. Beginning ARIZ-71c contradiction matrix ceased to be the core of ARIZ and therefore was not a tool for solving inventive problems that Altshuller believed should be pursued. Physical contradictions and separation principles as well as SuField Analysis, etc became the core. Despite this, the 40 Principles has remained the most popular tool taught in introductory seminars and has consistently attracted the most attention amongst the tens of thousands of individuals who visit TRIZ-focused web sites in a typical month. Therefore, many of those who learn TRIZ or have attended seminars are taught quite wrongly that TRIZ is primarily composed of the 40 principles and contradiction matrix, the truth is ARIZ is the core methodology of TRIZ.

ARIZ is an algorithmic approach to finding inventive solutions by identifying and resolving contradictions. This includes the "System of Inventive Standards Solutions" which Altshuller used to replace the 40 principles and contradiction matrix, it comprises of Su-field modeling and the 76 Inventive Standards. A number of TRIZ-based computer programs have been developed whose purpose is to provide assistance to engineers and inventors in finding inventive solutions for technological problems. Some of these programs are also designed to apply another TRIZ methodology whose purpose is to reveal and forecast emergency situations and to anticipate circumstances which could result in undesirable outcomes.

One of the important branches of TRIZ is focused on analysing and predicting trends of evolution in the characteristics that existing solutions are likely to develop in successive generations of a system.

Essentials

Basic terms

- **Ideal Final Result (IFR)** - the ultimate idealistic solution of a problem when the desired result is achieved by itself;
- **Administrative Contradiction** - contradiction between the needs and abilities;
- **Technical Contradiction** - an inverse dependence between parameters/characteristics of a machine or technology;
- **Physical Contradiction** - opposite/contradictory physical requirements to an object;
- **Separation principle** - a method of resolving physical contradictions by separating contradictory requirements;
- **VePol or SuField** - a minimal technical system consisting of two material objects (substances) and a "field". "Field" is the source of energy whereas one of the substances is "transmission" and the other one is the "tool";
- **FePol** - a sort of VePol where "substances" are ferromagnetic objects;
- **Level of Invention**;
- **Standard** - a standard inventive solution of a higher level;
- **Law of Technical Systems Evolution**;
- **ARIZ** - Algorithm of Inventive Problems Solving, which combines various specialized methods of TRIZ into one universal tool;

Identifying a problem: contradictions

Altshuller believed that inventive problems stem from contradictions (one of the basic TRIZ concepts) between two or more elements, such as, "If we want more acceleration, we need a larger engine; but that will increase the cost of the car," that is, more of something desirable also brings more of something less desirable, or less of something else also desirable.

These are called Technical Contradictions by Altshuller. He also defined so-called physical or inherent contradictions: More of one thing and less of the same thing may both be desired in the same system. For instance, a higher temperature may be needed to melt a compound more rapidly, but a lower temperature may be needed to achieve a homogeneous mixture.

An "inventive situation" which challenges us to be inventive, might involve several such contradictions. Conventional solutions typically "trade" one contradictory parameter for another; no special inventiveness is needed for that. Rather, the inventor would develop a creative approach for resolving the contradiction, such as inventing an engine that produces more acceleration without increasing the cost of the engine.

Inventive principles and the matrix of contradictions

Altshuller screened patents in order to find out what kind of contradictions were resolved or dissolved by the invention and the way this had been achieved. From this he developed a set of 40 inventive principles and later a Matrix of Contradictions. Rows of the matrix indicate the 39 system features that one typically wants to improve, such as speed, weight, accuracy of measurement and so on. Columns refer to typical undesired results. Each matrix cell points to principles that have been most frequently used in patents in order to resolve the contradiction.

For instance, Dolgashev mentions the following contradiction: Increasing accuracy of measurement of machined balls while avoiding the use of expensive microscopes and elaborate control equipment. The matrix cell in row "accuracy of measurement" and column "complexity of control" points to several principles, among them the Copying Principle, which states, "Use a simple and inexpensive optical copy with a suitable scale instead of an object that is complex, expensive, fragile or inconvenient to operate." From this general invention principle, the following idea might solve the problem: Taking a high-resolution image of the machined ball. A screen with a grid might provide the required measurement. As mentioned above, Altshuler abandoned this method of defining and solving "technical" contradictions in the mid 1980's and instead used Su-field modeling and the 76 inventive standards and a number of other tools included in the algorithm for solving inventive problems, ARIZ

Laws of technical system evolution

Altshuller also studied the way technical systems have been developed and improved over time. From this, he discovered several trends (so called Laws of Technical Systems Evolution) that help engineers predict what the most likely improvements that can be made to a given product are. The most important of these laws involves the ideality of a system.

Substance-field analysis

One more technique that is frequently used by inventors involves the analysis of substances, fields and other resources that are currently not being used and that can be found within the system or nearby. TRIZ uses non-standard definitions for substances and fields. Altshuller developed methods to analyze resources; several of his invention principles involve the use of different substances and fields that help resolve contradictions and increase ideality of a technical system. For instance, videotext systems used television signals to transfer data, by taking advantage of the small time segments between TV frames in the signals.

Su-Field Analysis (structural substance-field analysis) produces a structural model of the initial technological system, exposes its characteristics, and with the help of special laws, transforms the model of the problem. Through this transformation the structure of the solution that eliminates the shortcomings of the initial problem is revealed. Su-Field Analysis is a special language of formulas with which it is possible to easily describe any technological system in terms of a specific (structural) model. A model produced in this manner is transformed according to special laws and regularities, thereby revealing the structural solution of the problem.

ARIZ - algorithm of inventive problems solving

ARIZ (Russian acronym of Алгоритм решения изобретательских задач - АРИЗ) - Algorithm of Inventive Problems Solving - is a list of about 85 step-by-step procedures to solve complicated invention problems, where other tools of TRIZ alone (Su-field analysis, 40 inventive principles, etc.) are not sufficient.

Various TRIZ software (see Invention Machine, Ideation International...) is based on this algorithm (or an improved one).

Starting with an updated matrix of contradictions, semantic analysis, subcategories of inventive principles and lists of scientific effects, some new interactive applications are other attempts to simplify the problem formulation phase and the transition from a generic problem to a whole set of specific solutions.

Use of TRIZ methods in industry

It has been reported that car companies Ford and Daimler-Chrysler, Johnson & Johnson, aeronautics companies Boeing, NASA, technology companies Hewlett Packard, Motorola, General Electric, Xerox, IBM, LG and Samsung, and Procter and Gamble and Kodak have used TRIZ methods in some projects.

Failure mode and effects analysis

A failure modes and effects analysis (FMEA) is a procedure in product development and operations management for analysis of potential failure modes within a system for classification by the severity and likelihood of the failures. A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or processes, enabling the team to design those failures out of the system with the minimum of effort and resource expenditure, thereby reducing development time and costs. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry. Failure modes are any errors or defects in a process, design, or item, especially those that affect the customer, and can be potential or actual. Effects analysis refers to studying the consequences of those failures.

Basic terms

FMEA cycle.

Failure

"The LOSS of an intended function of a device under stated conditions."

Failure mode

"The manner by which a failure is observed; it generally describes the way the failure occurs."

Failure effect

Immediate consequences of a failure on operation, function or functionality, or status of some item

Indenture levels

An identifier for item complexity. Complexity increases as levels are closer to one.

Local effect

The Failure effect as it applies to the item under analysis.

Next higher level effect

The Failure effect as it applies at the next higher indenture level.

End effect

The failure effect at the highest indenture level or total system.

Failure cause

Defects in design, process, quality, or part application, which are the underlying cause of the failure or which initiate a process which leads to failure.

Severity

"The consequences of a failure mode. Severity considers the worst potential consequence of a failure, determined by the degree of injury, property damage, or system damage that could ultimately occur."

History

Learning from each failure is both costly and time consuming, and FMEA is a more systematic method of studying failure. As such, it is considered better to first conduct some thought experiments.

Procedures for conducting FMECA were described in US Armed Forces Military Procedures document MIL-P-1629 (1949; revised in 1980 as MIL-STD-1629A). Later it was used for aerospace/rocket development to avoid errors in small sample sizes of costly rocket technology. An example of this is the Apollo Space program. It was also used as application for HACCP for the Apollo Space Program, and later the food industry in general. The primary push came during the 1960s, while developing the means to put a man on the moon and return him safely to earth. In the late 1970s the Ford Motor Company introduced

FMEA to the automotive industry for safety and regulatory consideration after the Pinto affair. They applied the same approach to processes (PFMEA) to consider potential process induced failures prior to launching production.

Although initially developed by the military, FMEA methodology is now extensively used in a variety of industries including semiconductor processing, food service, plastics, software, and healthcare. It is integrated into the Automotive Industry Action Group's (AIAG) Advanced Product Quality Planning (APQP) process to provide risk mitigation, in both product and process development phases. Each potential cause must be considered for its effect on the product or process and, based on the risk, actions are determined and risks revisited after actions are complete. Toyota has taken this one step further with its Design Review Based on Failure Mode (DRBFM) approach. The method is now supported by the American Society for Quality which provides detailed guides on applying the method.

Implementation

In FMEA, failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. A FMEA also documents current knowledge and actions about the risks of failures for use in continuous improvement. FMEA is used during the design stage with an aim to avoid future failures (sometimes called DFMEA in that case). Later it is used for process control, before and during ongoing operation of the process. Ideally, FMEA begins during the earliest conceptual stages of design and continues throughout the life of the product or service.

The outcomes of an FMEA development are actions to prevent or reduce the severity or likelihood of failures, starting with the highest-priority ones. It may be used to evaluate risk management priorities for mitigating known threat vulnerabilities. FMEA helps select remedial actions that reduce cumulative impacts of life-cycle consequences (risks) from a systems failure (fault).

It is used in many formal quality systems such as QS-9000 or ISO/TS 16949.

Using FMEA when designing

FMEA can provide an analytical approach, when dealing with potential failure modes and their associated causes. When considering possible failures in a design – like safety, cost, performance, quality and reliability – an engineer can get a lot of information about how to alter the development/manufacturing process, in order to avoid these failures. FMEA provides an easy tool to determine which risk has the greatest concern, and therefore an action is needed to prevent a problem before it arises. The development of these specifications will ensure the product will meet the defined requirements and customer needs.

The pre-work

The process for conducting an FMEA is straightforward. It is developed in three main phases, in which appropriate actions need to be defined. But before starting with an FMEA, it is important to complete some pre-work to confirm that robustness and past history are included in the analysis.

A robustness analysis can be obtained from interface matrices, boundary diagrams, and parameter diagrams. Many failures are due to noise factors and shared interfaces with other parts and/or systems, because engineers tend to focus on what they control directly.

To start it is necessary to describe the system and its function. A good understanding simplifies further analysis. This way an engineer can see which uses of the system are desirable and which are not. It is important to consider both intentional and unintentional uses. Unintentional uses are a form of hostile environment.

Then, a block diagram of the system needs to be created. This diagram gives an overview of the major components or process steps and how they are related. These are called logical relations around which the FMEA can be developed. It is useful to create a coding system to identify the different system elements. The block diagram should always be included with the FMEA.

Before starting the actual FMEA, a worksheet needs to be created, which contains the important information about the system, such as the revision date or the names of the components. On this worksheet all the items or functions of the subject should be listed in a logical manner, based on the block diagram.

Step 1: Occurrence

In this step it is necessary to look at the cause of a failure mode and the number of times it occurs. This can be done by looking at similar products or processes and the failure modes that have been documented for them. A failure cause is looked upon as a design weakness. All the potential causes for a failure mode should be identified and documented. Again this should be in technical terms. Examples of causes are: erroneous algorithms, excessive voltage or improper operating conditions. A failure mode is given an occurrence ranking (O), again 1–10. Actions need to be determined if the occurrence is high (meaning > 4 for non-safety failure modes and > 1 when the severity-number from step 1 is 1 or 0). This step is called the detailed development section of the FMEA process. Occurrence also can be defined as %. If a non-safety issue happened less than 1%, we can give 1 to it. It is based on your product and customer specification.

Step 2: Sensitivity

Determine all failure modes based on the functional requirements and their effects. Examples of failure modes are: Electrical short-circuiting, corrosion or deformation. A failure mode in one component can lead to a failure mode in another component, therefore each failure mode should be listed in technical terms and for function. Hereafter the ultimate effect of each failure mode needs to be considered. A failure effect is defined as the result of a failure mode on the function of the system as perceived by the user. In this way it is convenient to write these effects down in terms of what the user might see or experience. Examples of failure effects are: degraded performance, noise or even injury to a user. Each effect is given a sensitivity number (S) from 1 (no danger) to 10 (critical). These numbers help an engineer to prioritize the failure modes and their effects. If the sensitivity of an effect has a number 9 or 10, actions are considered to change the design by eliminating the failure mode, if possible, or protecting the user from the effect. A sensitivity rating of 9 or 10 is generally reserved for those effects which would cause injury to a user or otherwise result in litigation.

Step 3: Detection

When appropriate actions are determined, it is necessary to test their efficiency. In addition, design verification is needed. The proper inspection methods need to be chosen. First, an engineer should look at the current controls of the system, that prevent failure modes from occurring or which detect the failure before it reaches the customer. Hereafter one should identify testing, analysis, monitoring and other techniques that can be or have been used on similar systems to detect failures. From these controls an engineer can learn how likely it is for a failure to be identified or detected. Each combination from the previous 2 steps receives a detection number (D). This ranks the ability of planned tests and inspections to remove defects or detect failure modes in time. The assigned detection number measures the risk that the failure will escape detection. A high detection number indicates that the chances are high that the failure will escape detection, or in other words, that the chances of detection are low.

After these three basic steps, risk priority numbers (RPN) are calculated

Risk Priority Number (RPN)

RPN play an important part in the choice of an action against failure modes. They are threshold values in the evaluation of these actions.

After ranking the severity, occurrence and detectability the RPN can be easily calculated by multiplying these three numbers: $RPN = S \times O \times D$

This has to be done for the entire process and/or design. Once this is done it is easy to determine the areas of greatest concern. The failure modes that have the highest RPN should be given the highest priority for corrective action. This means it is not always the failure modes with the highest severity numbers that should be treated first. There could be less severe failures, but which occur more often and are less detectable.

After these values are allocated, recommended actions with targets, responsibility and dates of implementation are noted. These actions can include specific inspection, testing or quality procedures, redesign (such as selection of new components), adding more redundancy and limiting environmental stresses or operating range. Once the actions have been implemented in the design/process, the new RPN should be checked, to confirm the improvements. These tests are often put in graphs, for easy visualization. Whenever a design or a process changes, an FMEA should be updated.

A few logical but important thoughts come in mind:

Try to eliminate the failure mode (some failures are more preventable than others)
Minimize the severity of the failure
Reduce the occurrence of the failure mode
Improve the detection

Timing of FMEA

The FMEA should be updated whenever:

At the beginning of a cycle (new product/process)
Changes are made to the operating conditions
A change is made in the design
New regulations are instituted
Customer feedback indicates a problem

Uses of FMEA

- Development of system requirements that minimize the likelihood of failures.
- Development of methods to design and test systems to ensure that the failures have been eliminated.
- Evaluation of the requirements of the customer to ensure that those do not give rise to potential failures.
- Identification of certain design characteristics that contribute to failures, and minimize or eliminate those effects.
- Tracking and managing potential risks in the design. This helps avoid the same failures in future projects.
- Ensuring that any failure that could occur will not injure the customer or seriously impact a system.
- To produce world class quality products

Advantages

- Improve the quality, reliability and safety of a product/process
- Improve company image and competitiveness
- Increase user satisfaction
- Reduce system development timing and cost
- Collect information to reduce future failures, capture engineering knowledge
- Reduce the potential for warranty concerns
- Early identification and elimination of potential failure modes
- Emphasize problem prevention
- Minimize late changes and associated cost

- Catalyst for teamwork and idea exchange between functions
- Reduce the possibility of same kind of failure in future
- Reduce impact of profit margin company
- Reduce possible scrap in production

Limitations

Since FMEA is effectively dependent on the members of the committee which examines product failures, it is limited by their experience of previous failures. If a failure mode cannot be identified, then external help is needed from consultants who are aware of the many different types of product failure. FMEA is thus part of a larger system of quality control, where documentation is vital to implementation. General texts and detailed publications are available in forensic engineering and failure analysis. It is a general requirement of many specific national and international standards that FMEA is used in evaluating product integrity. If used as a top-down tool, FMEA may only identify major failure modes in a system. Fault tree analysis (FTA) is better suited for "top-down" analysis. When used as a "bottom-up" tool FMEA can augment or complement FTA and identify many more causes and failure modes resulting in top-level symptoms. It is not able to discover complex failure modes involving multiple failures within a subsystem, or to report expected failure intervals of particular failure modes up to the upper level subsystem or system.

Additionally, the multiplication of the severity, occurrence and detection rankings may result in rank reversals, where a less serious failure mode receives a higher RPN than a more serious failure mode. The reason for this is that the rankings are ordinal scale numbers, and multiplication is not defined for ordinal numbers. The ordinal rankings only say that one ranking is better or worse than another, but not by how much. For instance, a ranking of "2" may not be twice as bad as a ranking of "1," or an "8" may not be twice as bad as a "4," but multiplication treats them as though they are. See Level of measurement for further discussion.

Failure analysis

Failure analysis is the process of collecting and analyzing data to determine the cause of a failure. It is an important discipline in many branches of manufacturing industry, such as the electronics industry, where it is a vital tool used in the development of new products and for the improvement of existing products. It relies on collecting failed components for subsequent examination of the cause or causes of failure using a wide array of methods, especially microscopy and spectroscopy. The NDT or nondestructive testing methods are valuable because the failed products are unaffected by analysis, so inspection always starts using these methods.

Forensic investigation

Forensic inquiry into the failed process or product is the starting point of failure analysis. Such inquiry is conducted using scientific analytical methods such as electrical and mechanical measurements, or by analysing failure data such as product reject reports or examples of previous failures of the same kind. The methods of forensic engineering are especially valuable in tracing product defects and flaws. They may include fatigue cracks, brittle cracks produced by stress corrosion cracking or environmental stress cracking for example. Witness statements can be valuable for reconstructing the likely sequence of events and hence the chain of cause and effect. Human factors can also be assessed when the cause of the failure is determined. There are several useful methods to prevent product failures occurring in the first place, including failure mode and effects analysis (FMEA) and fault tree analysis (FTA), methods which can be used during prototyping to analyse failures before a product is marketed.

Failure theories can only be constructed on such data, but when corrective action is needed quickly, the precautionary principle demands that measures be put in place. In aircraft accidents for example, all planes of the type involved can be grounded immediately pending the outcome of the inquiry.

Another aspect of failure analysis is associated with No Fault Found (NFF) which is a term used in the field of failure analysis to describe a situation where an originally reported mode of failure can't be duplicated by the evaluating technician and therefore the potential defect can't be fixed.

NFF can be attributed to oxidation, defective connections of electrical components, temporary shorts or opens in the circuits, software bugs, temporary environmental factors, but also to the operator error. Large number of devices that are reported as NFF during the first troubleshooting session often return to the failure analysis lab with the same NFF symptoms or a permanent mode of failure.

The term Failure analysis also applies to other fields such as business management and military strategy.

Backward chaining

Backward chaining (or backward reasoning) is an inference method that can be described (in lay terms) as working backward from the goal(s). It is used in automated theorem provers, proof assistants and other artificial intelligence applications, but it has also been observed in primates.

In game theory, its application to (simpler) subgames in order to find a solution to the game is is called backward induction. In chess, it's called retrograde analysis, and it is used to generate tablebases for chess endgames for computer chess.

Backward chaining is implemented in logic programming by SLD resolution. Both rules are based on the modus ponens inference rule. It is one of the two most commonly used methods of reasoning with inference rules and logical implications – the other is forward chaining. Backward chaining systems usually employ a depth-first search strategy, e.g. Prolog.

How it works

Backward chaining starts with a list of goals (or a hypothesis) and works backwards from the consequent to the antecedent to see if there is data available that will support any of these consequents. An inference engine using backward chaining would search the inference rules until it finds one which has a consequent (Then clause) that matches a desired goal. If the antecedent (If clause) of that rule is not known to be true, then it is added to the list of goals (in order for one's goal to be confirmed one must also provide data that confirms this new rule).

For example, suppose that the goal is to conclude the color of my pet Fritz, given that he croaks and eats flies, and that the rule base contains the following four rules:
An Example of Backward Chaining.
An Example of Backward Chaining.

If X croaks and eats flies – Then X is a frog
If X chirps and sings – Then X is a canary
If X is a frog – Then X is green
If X is a canary – Then X is yellow

This rule base would be searched and the third and fourth rules would be selected, because their consequents (Then Fritz is green, Then Fritz is yellow) match the goal (to determine Fritz's color). It is not yet known that Fritz is a frog, so both the antecedents (If Fritz is a frog, If Fritz is a canary) are added to the goal list. The rule base is again searched and this time the first two rules are selected, because their consequents (Then X is a frog, Then X is a canary) match the new goals that were just added to the list. The antecedent (If Fritz croaks and eats flies) is known to be true and therefore it can be concluded that Fritz is a frog, and not a canary. The goal of determining Fritz's color is now achieved (Fritz is green if he is a frog, and yellow if he is a canary, but he is a frog since he croaks and eats flies; therefore, Fritz is green).

Note that the goals always match the affirmed versions of the consequents of implications (and not the negated versions as in modus tollens) and even then, their antecedents are then considered as the new goals (and not the conclusions as in affirming the consequent) which ultimately must match known facts (usually defined as consequents whose antecedents are always true); thus, the inference rule which is used is modus ponens.

Because the list of goals determines which rules are selected and used, this method is called goal-driven, in contrast to data-driven forward-chaining inference. The backward chaining approach is often employed by expert systems.

Programming languages such as Prolog, Knowledge Machine and ECLiPSe support backward chaining within their inference engines.

Use by primates

Kanzi, a bonobo (pygmy chimpanzee, Pan paniscus) dramatically illustrated his use of this strategy when he was being taught how to create stone tools by a human expert. Unable to replicate the manipulations of the human expert, Kanzi eventually resorted to smashing stones upon others, and simply selected shards with sharp edges, in order to produce his stone tools.

Forward chaining

Forward chaining is one of the two main methods of reasoning when using inference rules (in artificial intelligence) and can be described logically as repeated application of modus ponens. Forward chaining is a popular implementation strategy for expert systems, business and production rule systems. The opposite of forward chaining is backward chaining.

Forward chaining starts with the available data and uses inference rules to extract more data (from an end user for example) until a goal is reached. An inference engine using forward chaining searches the inference rules until it finds one where the antecedent (If clause) is known to be true. When found it can conclude, or infer, the consequent (Then clause), resulting in the addition of new information to its data.

Inference engines will iterate through this process until a goal is reached.

For example, suppose that the goal is to conclude the color of a pet named Fritz, given that he croaks and eats flies, and that the rule base contains the following four rules:

If X croaks and eats flies - Then X is a frog
If X chirps and sings - Then X is a canary
If X is a frog - Then X is green
If X is a canary - Then X is yellow

This rule base would be searched and the first rule would be selected, because its antecedent (If Fritz croaks and eats flies) matches our data. Now the consequents (Then X is a frog) is added to the data. The rule base is again searched and this time the third rule is selected, because its antecedent (If Fritz is a frog) matches our data that was just confirmed. Now the new consequent (Then Fritz is green) is added to our data. Nothing more can be inferred from this information, but we have now accomplished our goal of determining the color of Fritz.

Because the data determines which rules are selected and used, this method is called data-driven, in contrast to goal-driven backward chaining inference. The forward chaining approach is often employed by expert systems, such as CLIPS.

One of the advantages of forward-chaining over backward-chaining is that the reception of new data can trigger new inferences, which makes the engine better suited to dynamic situations in which conditions are likely to change.

Divide and conquer algorithm

In computer science, divide and conquer (D&C) is an important algorithm design paradigm based on multi-branched recursion. A divide and conquer algorithm works by recursively breaking down a problem into two or more sub-problems of the same (or related) type, until these become simple enough to be solved directly. The solutions to the sub-problems are then combined to give a solution to the original problem.

This technique is the basis of efficient algorithms for all kinds of problems, such as sorting (e.g., quicksort, merge sort), multiplying large numbers (e.g. Karatsuba), syntactic analysis (e.g., top-down parsers), and computing the discrete Fourier transform (FFTs).

On the other hand, the ability to understand and design D&C algorithms is a skill that takes time to master. As when proving a theorem by induction, it is often necessary to replace the original problem by a more general or complicated problem in order to get the recursion going, and there is no systematic method for finding the proper generalization.

The name "divide and conquer" is sometimes applied also to algorithms that reduce each problem to only one subproblem, such as the binary search algorithm for finding a record in a sorted list (or its analog in numerical computing, the bisection algorithm for root finding). These algorithms can be implemented more efficiently than general divide-and-conquer algorithms; in particular, if they use tail recursion, they can be converted into simple loops. Under this broad definition, however, every algorithm that uses recursion or loops could be regarded as a "divide and conquer algorithm". Therefore, some authors consider that the name "divide and conquer" should be used only when each problem may generate two or more subproblems. The name decrease and conquer has been proposed instead for the single-subproblem class.

Six Thinking Hats

The de Bono Hats system (also known as "Six Hats" or "Six Thinking Hats") is a thinking tool for group discussion and individual thinking. Combined with the idea of parallel thinking which is associated with it, it provides a means for groups to think together more effectively, and a means to plan thinking processes in a detailed and cohesive way. The method is attributed to Dr. Edward de Bono and is the subject of his book, Six Thinking Hats.

The paternity of this method is disputed by the School of Thinking.

The method is finding some use in the UK innovation sector, is offered by some facilitation companies and has been trialled within the UK civil service.

Underlying principles

The premise of the method is that the human brain thinks in a number of distinct ways which can be identified, deliberately accessed and hence planned for use in a structured way allowing one to develop strategies for thinking about particular issues. Dr de Bono identifies six distinct states in which the brain can be "sensitised". In each of these states the brain will identify and bring into conscious thought certain aspects of issues being considered (e.g. gut instinct, pessimistic judgment, neutral facts).

A compelling example presented is sensitivity to "mismatch" stimuli. This is presented as a valuable survival instinct, because, in the natural world, the thing that is out of the ordinary may well be dangerous. This state is identified as the root of negative judgment and critical thinking.

Six distinct states are identified and assigned a color:

- **Information: (White)** - considering purely what information is available, what are the facts?
- **Emotions (Red)** - instinctive gut reaction or statements of emotional feeling (but not any justification)
- **Bad points judgment (Black)** - logic applied to identifying flaws or barriers, seeking mismatch
- **Good points judgment (Yellow)** - logic applied to identifying benefits, seeking harmony
- **Creativity (Green)** - statements of provocation and investigation, seeing where a thought goes
- **Thinking (Blue)** - thinking about thinking

Coloured hats are used as metaphors for each state. Switching to a state is symbolized by the act of putting on a coloured hat, either literally or metaphorically. These metaphors allow for more complete and elaborate segregation of the states than the preconceptions inherent in people's current language. All of these thinking hats help for thinking more deeply. The six thinking hats indicate problems and solutions about an idea or a product you might come up with. Furthermore, Dr de Bono asserts that these states are associated with distinct chemical states of the brain — however, no details or evidence of this are presented.

Parallel thinking

In ordinary, unstructured thinking this process is unfocussed; the thinker leaps from critical thinking to neutrality to optimism and so on without structure or strategy. The Six Thinking Hats process attempts to introduce parallel thinking.

Many individuals are used to this and develop their own habits unconsciously. Sometimes these are effective, other times not. What is certain is that when thinking in a group these individual strategies will not tend to converge. As a result, discussion will tend not to converge. Due to the power of the ego and the identified predilection to black hat thinking in the majority of western culture, this can lead to very destructive meetings. Even with good courtesy and clear shared objectives in any collaborative thinking activity there is a natural tendency for "spaghetti thinking" where one person is thinking about the benefits while another considers the facts and so on. The hats allow this to be avoided so that everyone together considers the problems, or the benefits, or the facts, reducing distractions and supporting cross pollination of thought. This is achieved because everyone will put on one hat, e.g., the white hat, together, then they will all put on the next hat together. In this way all present think in the same way at the same time. The only exception is the facilitator, who will tend to keep the blue hat on all the time to make sure things progress effectively. The blue hat tends to be the outward-looking, leader/trail blazing hat that attracts the leaders of all groups.

Strategies and Programs

Having identified the six states that can be accessed, distinct programs can be created. These are sequences of hats which encompass and structure the thinking process toward a distinct goal. A number of these are included in the materials provided to support the franchised training of the six hats method; however it is often necessary to adapt them to suit an individual purpose. Also, programs are often "emergent", which is to say that the group might plan the first few hats then the facilitator will see what seems to be the right way to go.

Sequences always begin and end with a blue hat; the group agrees together how they will think, then they do the thinking, then they evaluate the outcomes of that thinking and what they should do next. Sequences (and indeed hats) may be used by individuals working alone or in groups.

Example programs

- Initial Ideas - Blue, White, Green
- Choosing between alternatives - Blue, White, Green, Yellow, Black, Red
- Identifying Solutions - Blue, White, Black, Green
- Quick Feedback - Blue, Black, Green, White
- Strategic Planning - Blue, Yellow, Black, White
- Process Improvement - Blue, White, (Other peoples views) Yellow, Black, Green, Red
- Solving Problems - Blue, White, Green, Red, Yellow, Black
- Performance Review - Blue, Red, White, Yellow, Black, Green

Types of hat

Included below is a brief description of each of the hats and the thinking processes that they represent. Their use is illustrated by examples from a typical commercial environment and also through the analysis of a simple classroom issue - "Students are talking while their teacher is talking".

White hat – Facts & Information

Participants make statements of fact, including identifying information that is absent and presenting the views of people who are not present in a factual manner. In many thinking sessions this occurs immediately after an initial blue hat, and is often an extended action with participants presenting details about their organization and the background to the purpose of the thinking session. The key information that represents the inputs to the session are presented and discussed. Key absences of information (i.e. information needs) can also be identified at this point.

Commercial examples are:

Total sales of this product are €x p.a.
Our sales data are two years old
Energy efficiency legislation is expected to impact our ability to run our business in the next five years
The number of elderly people in Europe is increasing

Examples in the referenced article are:

Students are talking while the teacher is talking
There is noise and therefore other students are distracted and can't hear the teacher
Students don't know what to do once instructions are given
Many students become distracted and off task resulting in the failure to complete work
Students are not understanding the focused lecture due to lack of concentration

Red hat – Feelings & Emotions

Participants state their feelings, exercising their gut instincts. In many cases this is a method for harvesting ideas - it is not a question of recording statements, but rather getting everyone to identify their top two or three choices from a list of ideas or items identified under another hat. This is done to help reduce lists of many options into a few to focus on by allowing each participant to vote for the ones they prefer. It is applied more quickly than the other hats to ensure it is a gut reaction feeling that is recorded. This method can use post-it notes to allow a quick system of voting, and creates a clear visual cue that creates rapid if incomplete agreement around an issue.

Alternatively it may be used to state ones gut reaction or feelings on an issue under discussion - this is more common when using the hats to review personal progress or deal with issues where there is high emotional content that is relevant to discussion.

Finally this hat can be used to request an aesthetic response to a particular design or object.

Commercial examples are:

I'm enthusiastic about getting involved in selling!
That role in the company doesn't appeal to me.
I'd like to do that but I feel uncertain about it.
I'm frustrated that we have let the situation get this bad!

Examples from the referenced article are:

The teacher feels offended
Students become frustrated because they can’t hear directions
Those talking enjoy joking around and being heard.
It represents emotional thinking of a person.

Black hat – Being Cautious

Participants identify barriers, hazards, risks and other negative connotations. This is critical thinking, looking for problems and mismatches. This hat is usually natural for people to use, the issues with it are that people will tend to use it when it is not requested and when it is not appropriate, thus stopping the flow of others. Preventing inappropriate use of the black hat is a common obstacle and vital step to effective group thinking. Another difficulty faced is that some people will naturally start to look for the solutions to raised problems — they start practising green on black thinking before it is requested.

Commercial examples are:

We will be facing strong competition in that market
What if we cannot get enough capital together to support the investment?
We might not be able to make it cheaply enough for our customers to buy it
There will be too much political opposition to this approach
There is a risk that new legislation will make this market unattractive

Examples from the referenced article are:

Time is wasted
Learning is compromised
Those speaking feel that black hat listeners do not respect them and do not wish to hear what they are saying
Flow of discussion is less clear

Yellow hat – Being Positive and Optimistic

Participants identify benefits associated with an idea or issue. This is the opposite of black hat thinking and looks for the reasons in favor of something. This is still a matter of judgment - it is an analytical process, not just blind optimism. One is looking to create

justified statements in favor of the idea or issue. It is encapsulated by the idea of "undecided positive" (whereas the black hat would be skeptical - "undecided negative").
The outputs may be statements of the benefits that could be created with a given idea, or positive statements about the likelihood of achieving it, or identifying the key supports available that will benefit this course of action

Commercial examples are:

That would be useful in market X
That would reduce the environmental impact of our activities
This approach will make our operations more efficient
We could use our existing distribution channels for this product

Examples from the referenced article are:

Everyone is able to say what is on their minds.
It can be fun.
Not only the ‘smart kids’ get to speak.
One doesn’t have to wait to share their ideas and therefore risk forgetting information.

Green hat – New Ideas

This is the hat of thinking new thoughts. It is based around the idea of provocation and thinking for the sake of identifying new possibilities. Things are said for the sake of seeing what they might mean, rather than to form a judgement. This is often carried out on black hat statements in order to identify how to get past the barriers or failings identified there (green on black thinking). Because green hat thinking covers the full spectrum of creativity, it can take many forms.

Commercial examples are:

What if we provided it for free?
Could we achieve it using technology X instead?
If we extended the course by half a day it would really help people understand
How would someone from profession X view this
Fish (green hat thinking can include random word stimulus methods)

Examples from the referenced article are:

Teacher will be more aware about the amount of time they spend talking
Teacher will try to incorporate interaction from a variety of different students rather than just the ‘smart kids’
Students will resist the urge to say whatever is on their mind. They will think about what they have to say and whether it is relevant to the topic
Students will take into account whether their comment will interfere with other people's learning

Students will think of new ways to communicate rather than talking in class, for example, talk on Messenger

Students will be able to develop ideas as a result of being creative in class

Blue hat – The Big Picture

This is the hat under which all participants discuss the thinking process. The facilitator will generally wear it throughout and each member of the team will put it on from time to time to think about directing their work together. This hat should be used at the start and end of each thinking session, to set objectives, to define the route to take to get to them, to evaluate where the group has got to, and where the thinking process is going. Having a facilitator maintain this role throughout helps ensure that the group remains focused on task and improves their chances of achieving their objectives. The blue hat is also an organization of thinking. What have we done so far? What can we do next?

Commercial examples are:

We'll follow this program of thinking to start the day - does everyone agree?

OK time to move on to some yellow hat thinking

Stop there - you are getting into debate. Lets do some black hat and surface all the issues together first

I think we need to revisit our objectives, I'm not sure that they are right in light of our work so far

Examples from the referenced article are:

Teacher learns that they need to monitor the amount of time that they spend talking within the classroom

Teacher needs to involve all students within discussions

Teacher needs to recognize that some students need thinking time before responding. Allowing these students time to compute solutions promotes wider participation and increased learning

Students realize that their talking makes the speaker feel unappreciated and disrespected

Students realize that their comments are jeopardizing the learning of other individuals

Students realize that talking out of time demonstrates a lack of self-discipline and that not all comments require sharing

Application Method

Whilst the ideas of the hats themselves provide significant benefits, there is more to the six hats method as applied within de Bono thinking systems and as trained under his franchise. In particular the pace at which the hats are used is highly relevant.

Typically in use a project will begin with an extended white hat action, as everyone gets "on the same page" creating a shared vision of the issue being addressed. Thereafter each hat is used for a few minutes at a time only, except the red hat which is limited to a very short 30 seconds or so to ensure that it is an instinctive gut reaction, rather than a form of judgement. This pace is believed to have a positive impact on the thinking process, in accordance with Malcolm Gladwell's theories on "blink" thinking.

This ensures that groups think together in a focused manner, staying on task, it also ensures that they focus their efforts on the most important elements of any issue being discussed. However, it also has the potential to create conflict if not well facilitated, since people can feel "railroaded". To avoid this it is important to notice when there is any significant difference of opinion on the thinking process or the area in which it should focus.

Summary

Using a variety of approaches within thinking and problem solving allows the issue to be addressed from a variety of angles, thus servicing the needs of all individuals concerned. The thinking hats are useful for learners as they illustrate the need for individuals to address problems from a variety of different angles. They also aid learners as they allow the individual to recognize any deficiencies in the way that they approach problem solving, thus allowing them to rectify such issues.

de Bono believed that the key to a successful use of the Six Think Hats methodology was the deliberate focusing of the discussion on a particular approach as needed during the meeting or collaboration session. For instance, a meeting may be called to review a particular problem and to develop a solution for the problem. The Six Thinking Hats method could then be used in a sequence to first of all explore the problem, then develop a set of solutions, and to finally choose a solution through critical examination of the solution set.

So the meeting may start with everyone assuming the Blue hat to discuss how the meeting will be conducted and to develop the goals and objectives. The discussion may then move to Red hat thinking in order to collect opinions and reactions to the problem. This phase may also be used to develop constraints for the actual solution such as who will be affected by the problem and/or solutions. Next the discussion may move to the (Yellow then) Green hat in order to generate ideas and possible solutions. Next the discussion may move between White hat thinking as part of developing information and Black hat thinking to develop criticisms of the solution set.

Because everyone is focused on a particular approach at any one time, the group tends to be more collaborative than if one person is reacting emotionally (Red hat) while another person is trying to be objective (White hat) and still another person is being critical of the points which emerge from the discussion (Black hat).

LogoVisual thinking

LogoVisual thinking (also LogoVisual technology and LVT) is a practical methodology that helps people think. It is used by management teams, project leaders, teachers and students as a means of tapping the diversity of groups and enabling many people to participate in effective thinking processes. It makes thinking visible and tactile by making ideas into moveable objects displayed on writeable surfaces – for instance magnetic dry-wipe shapes on whiteboards. Structured processes guide people’s thinking to achieve their intended outcomes.

LVT is both an overall concept and a methodology. It developed out of structural communication, systematics (the study of multi-term systems), and other work of J. G. Bennett in the 1960s, recent development being sponsored by Centre for Management Creativity. As a general concept it covers the region of learning and communication in which three modes of intelligence are combined for understanding: verbal, visual and haptic. It is thus related to multiple intelligences. The structure of the process supports metacognition.

Description

LVT evolved independently but in parallel with Tony Buzan’s mindmapping, Edward de Bono’s lateral thinking, Japanese affinity diagrams, Robert Horn’s visual language, Gabriele Rico's 'clustering' and many other emergent trends from the 1960s onwards. It makes the making of meaning the main focus of its technology. The technology extends verbal expression to visual arrangement and brings into play physical manipulation of 'meaning objects'. The haptic component of physical contact and action is a primary distinguishing feature of LVT.

It emphasises the logos or meaning of words in statements that are 'molecules of meaning', which can be understood autonomously and in combinations. Each molecule of meaning (MM) exists on a separate object. MMs can be placed on a visual display and moved around in relation to each other. Meaningful aggregates of MMs are replaced by higher order MMs. Use of MMs distinguishes LVT from other current techniques of display such as mindmapping because (a) MMs are statements and not single words (b) they are free to be moved about and are not fixed in position (c) they can form into any kind of pattern and not just hierarchical ones. In principle, every MM can be seen in the context of any of the other MMs in a given set.

The technological freedom of MMs enables people to suspend collapse into set forms and/or conclusions (convergent thinking), while providing structure to their explorations (divergent thinking). A complex process of thinking by a group can easily be tracked and recorded.

LVT supports process of democracy because it enables people to think together. It articulates thinking in a public shared space, in which structure is given equal attention to content. It relates strongly to dialogue and can be called a 'technology of dialogue'.

There are five standard stages in the process.

- Focus - identifying a question or theme that provides a basis for a common act of attention
- Gather - generating, articulating and displaying separate MMs as a relevant set as in a gathering
- Organise - arranging and aggregating MMs to form (separate) higher order MMs
- Integrate - systematic or aesthetic unification of these MMs into a whole system
- Realise - creative or 'willed' outcome

LVT emphasises the importance of articulate statement. Each MM is symbolic of an individual in a social setting, capable of finding many complex relations with other individuals; rather than a 'thing' that has to be fixed into a mechanical order.

In the stage of Gathering, the assembly of MMs is deliberately chaotic. This allows for complexity in aggregations.

In stage three, Organising can be of different kinds but in particular explore the tensions between using prefigured forms - classifications, hierarchies, etc. - and allowing the MMs to self-organise. The flexibility and range of Organise in LVT distinguishes it from the use of set forms as in mindmapping. The capacity to insert, remove and rearrange MMs in organising is a totally new dimension of thinking technology.

The fourth stage of Integrating draws on structural insights into complex texts, in particular the principles of ring composition as discovered by the English anthropologist Mary Douglas.

The stages move from contemplation to decision making.

The correctness of a divide and conquer algorithm is usually proved by mathematical induction, and its computational cost is often determined by solving recurrence relations.

Decision making: Part I

Decision making can be regarded as the mental processes (cognitive process) resulting in the selection of a course of action among several alternative scenarios. Every decision making process produces a final choice. The output can be an action or an opinion of choice.

Overview

Human performance in decision terms has been the subject of active research from several perspectives. From a psychological perspective, it is necessary to examine individual decisions in the context of a set of needs, preferences an individual has and values they seek. From a cognitive perspective, the decision making process must be regarded as a continuous process integrated in the interaction with the environment. From a normative perspective, the analysis of individual decisions is concerned with the logic of decision making and rationality and the invariant choice it leads to.

Yet, at another level, it might be regarded as a problem solving activity which is terminated when a satisfactory solution is reached. Therefore, decision making is a reasoning or emotional process which can be rational or irrational, can be based on explicit assumptions or tacit assumptions.

Logical decision making is an important part of all science-based professions, where specialists apply their knowledge in a given area to making informed decisions. For example, medical decision making often involves making a diagnosis and selecting an appropriate treatment. Some research using naturalistic methods shows, however, that in situations with higher time pressure, higher stakes, or increased ambiguities, experts use intuitive decision making rather than structured approaches, following a recognition primed decision approach to fit a set of indicators into the expert's experience and immediately arrive at a satisfactory course of action without weighing alternatives. Recent robust decision efforts have formally integrated uncertainty into the decision making process. However, Decision Analysis, recognized and included uncertainties with a structured and rationally justifiable method of decision making since its conception in 1964.

A major part of decision making involves the analysis of a finite set of alternatives described in terms of some evaluative criteria. These criteria may be benefit or cost in nature. Then the problem might be to rank these alternatives in terms of how attractive they are to the decision maker(s) when all the criteria are considered simultaneously. Another goal might be to just find the best alternative or to determine the relative total priority of each alternative (for instance, if alternatives represent projects competing for funds) when all the criteria are considered simultaneously. Solving such problems is the focus of multi-criteria decision analysis (MCDA) also known as multi-criteria decision making (MCDM). This area of decision making, although it is very old and has attracted the interest of many researchers and practitioners, is still highly debated as there are many

MCDA / MCDM methods which may yield very different results when they are applied on exactly the same data. This leads to the formulation of a decision making paradox.

Problem Analysis vs Decision Making

It is important to differentiate between problem analysis and decision making. The concepts are completely separate from one another. Problem analysis must be done first, then the information gathered in that process may be used towards decision making.

Problem Analysis

• Analyze performance, what should the results be against what they actually are
• Problems are merely deviations from performance standards
• Problem must be precisely identified and described
• Problems are caused by some change from a distinctive feature
• Something can always be used to distinguish between what has and hasn't been effected by a cause
• Causes to problems can be deducted from relevant changes found in analyzing the problem
• Most likely cause to a problem is the one that exactly explains all the facts

Decision Making

• Objectives must first be established
• Objectives must be classified and placed in order of importance
• Alternative actions must be developed
• The alternative must be evaluated against all the objectives
• The alternative that is able to achieve all the objectives is the tentative decision
• The tentative decision is evaluated for more possible consequences
• The decisive actions are taken, and additional actions are taken to prevent any adverse consequences from becoming problems and starting both systems (problem analysis and decision making) all over again
• There are steps that are generally followed that result in a decision model that can be used to determine an optimal production plan.

Everyday techniques

Some of the decision making techniques people use in everyday life include:

- Pros and Cons: Listing the advantages and disadvantages of each option, popularized by Plato and Benjamin Franklin
- Simple Prioritization: Choosing the alternative with the highest probability-weighted utility for each alternative (see Decision Analysis)
- Satisficing: using the first acceptable option found
- Acquiesce to a person in authority or an "expert", just following orders

- Flipism: Flipping a coin, cutting a deck of playing cards, and other random or coincidence methods
- Prayer, tarot cards, astrology, augurs, revelation, or other forms of divination

Decision-Making Stages

Developed by B. Aubrey Fisher, there are four stages that should be involved in all group decision making. These stages, or sometimes called phases, are important for the decision-making process to begin

- Orientation stage- This phase is where members meet for the first time and start to get to know each other.

- Conflict stage- Once group members become familiar with each other, disputes, little fights and arguments occur. Group members eventually work it out.

- Emergence stage- The group begins to clear up vague opinions by talking about them.

- Reinforcement stage- Members finally make a decision, while justifying themselves that it was the right decision.

Decision-Making Steps

When in an organization and faced with a difficult decision, there are several steps one can take to ensure the best possible solutions will be decided. These steps are put into seven effective ways to go about this decision making process (McMahon 2007).

- The first step - Outline your goal and outcome. This will enable decision makers to see exactly what they are trying to accomplish and keep them on a specific path.

- The second step - Gather data. This will help decision makers have actual evidence to help them come up with a solution.

- The third step - Brainstorm to develop alternatives. Coming up with more than one solution ables you to see which one can actually work.

- The fourth step - List pros and cons of each alternative. With the list of pros and cons, you can eliminate the solutions that have more cons than pros, making your decision easier.

- The fifth step - Make the decision. Once you analyze each solution, you should pick the one that has many pros (or the pros that are most significant), and is a solution that everyone can agree with.

- The sixth step - Immediately take action. Once the decision is picked, you should implement it right away.

- The seventh step - Learn from, and reflect on the decision making. This step allows you to see what you did right and wrong when coming up, and putting the decision to use.

Cognitive and personal biases

Biases can creep into our decision making processes. Many different people have made a decision about the same question (e.g. "Should I have a doctor look at this troubling breast cancer symptom I've discovered?" "Why did I ignore the evidence that the project was going over budget?") and then craft potential cognitive interventions aimed at improving decision making outcomes.

Below is a list of some of the more commonly debated cognitive biases.

- Selective search for evidence (a.k.a. Confirmation bias in psychology) (Scott Plous, 1993) – We tend to be willing to gather facts that support certain conclusions but disregard other facts that support different conclusions. Individuals who are highly defensive in this manner show significantly greater left prefrontal cortex activity as measured by EEG than do less defensive individuals.
- Premature termination of search for evidence – We tend to accept the first alternative that looks like it might work.
- Inertia – Unwillingness to change thought patterns that we have used in the past in the face of new circumstances.
- Selective perception – We actively screen-out information that we do not think is important. (See prejudice.) In one demonstration of this effect, discounting of arguments with which one disagrees (by judging them as untrue or irrelevant) was decreased by selective activation of right prefrontal cortex.
- Wishful thinking or optimism bias – We tend to want to see things in a positive light and this can distort our perception and thinking.
- Choice-supportive bias occurs when we distort our memories of chosen and rejected options to make the chosen options seem more attractive.
- Recency – We tend to place more attention on more recent information and either ignore or forget more distant information. (See semantic priming.) The opposite effect in the first set of data or other information is termed Primacy effect (Plous, 1993).
- Repetition bias – A willingness to believe what we have been told most often and by the greatest number of different sources.
- Anchoring and adjustment – Decisions are unduly influenced by initial information that shapes our view of subsequent information.
- Group think – Peer pressure to conform to the opinions held by the group.
- Source credibility bias – We reject something if we have a bias against the person, organization, or group to which the person belongs: We are inclined to accept a statement by someone we like. (See prejudice.)

- Incremental decision making and escalating commitment – We look at a decision as a small step in a process and this tends to perpetuate a series of similar decisions. This can be contrasted with zero-based decision making. (See slippery slope.)
- Attribution asymmetry – We tend to attribute our success to our abilities and talents, but we attribute our failures to bad luck and external factors. We attribute other's success to good luck, and their failures to their mistakes.
- Role fulfillment (Self Fulfilling Prophecy) – We conform to the decision making expectations that others have of someone in our position.
- Underestimating uncertainty and the illusion of control – We tend to underestimate future uncertainty because we tend to believe we have more control over events than we really do. We believe we have control to minimize potential problems in our decisions.

Reference class forecasting was developed to eliminate or reduce cognitive biases in decision making.

Post decision analysis

Evaluation and analysis of past decisions is complementary to decision making; see also mental accounting.

Cognitive styles

Influence of Briggs Myers type

According to behavioralist Isabel Briggs Myers, a person's decision making process depends to a significant degree on their cognitive style. Myers developed a set of four bi-polar dimensions, called the Myers-Briggs Type Indicator (MBTI). The terminal points on these dimensions are: thinking and feeling; extroversion and introversion; judgment and perception; and sensing and intuition. She claimed that a person's decision making style correlates well with how they score on these four dimensions. For example, someone who scored near the thinking, extroversion, sensing, and judgment ends of the dimensions would tend to have a logical, analytical, objective, critical, and empirical decision making style. However, some psychologists say that the MBTI lacks reliability and validity and is poorly constructed.

Other studies suggest that these national or cross-cultural differences exist across entire societies. For example, Maris Martinsons has found that American, Japanese and Chinese business leaders each exhibit a distinctive national style of decision making.

Optimizing vs. satisficing

Herbert Simon coined the phrase "bounded rationality" to express the idea that human decision-making is limited by available information, available time, and the information-processing ability of the mind. Simon also defined two cognitive styles: maximizers try to make an optimal decision, whereas satisficers simply try to find a solution that is "good enough". Maximizers tend to take longer making decisions due to the need to maximize performance across all variables and make tradeoffs carefully; they also tend to more often regret their decisions (perhaps because they are more able than satisficers to recognise that a decision turned out to be sub-optimal).

Combinatoral vs. positional

Styles and methods of decision making were elaborated by the founder of Predispositioning Theory, Aron Katsenelinboigen. In his analysis on styles and methods Katsenelinboigen referred to the game of chess, saying that "chess does disclose various methods of operation, notably the creation of predisposition—methods which may be applicable to other, more complex systems."

In his book Katsenelinboigen states that apart from the methods (reactive and selective) and sub-methods (randomization, predispositioning, programming), there are two major styles – positional and combinational. Both styles are utilized in the game of chess. According to Katsenelinboigen, the two styles reflect two basic approaches to the uncertainty: deterministic (combinational style) and indeterministic (positional style). Katsenelinboigen's definition of the two styles are the following.

The combinational style is characterized by

- a very narrow, clearly defined, primarily material goal, and
- a program that links the initial position with the final outcome.

In defining the combinational style in chess, Katsenelinboigen writes:

The combinational style features a clearly formulated limited objective, namely the capture of material (the main constituent element of a chess position). The objective is implemented via a well-defined and in some cases in a unique sequence of moves aimed at reaching the set goal. As a rule, this sequence leaves no options for the opponent. Finding a combinational objective allows the player to focus all his energies on efficient execution, that is, the player's analysis may be limited to the pieces directly partaking in the combination. This approach is the crux of the combination and the combinational style of play.

The positional style is distinguished by

- a positional goal and
- a formation of semi-complete linkages between the initial step and final outcome.

"Unlike the combinational player, the positional player is occupied, first and foremost, with the elaboration of the position that will allow him to develop in the unknown future. In playing the positional style, the player must evaluate relational and material parameters as independent variables. (…) The positional style gives the player the opportunity to develop a position until it becomes pregnant with a combination. However, the combination is not the final goal of the positional player—it helps him to achieve the desirable, keeping in mind a predisposition for the future development. The Pyrrhic victory is the best example of one's inability to think positionally."

The positional style serves to

a) create a predisposition to the future development of the position;
b) induce the environment in a certain way;
c) absorb an unexpected outcome in one's favor;
d) avoid the negative aspects of unexpected outcomes.

The positional style gives the player the opportunity to develop a position until it becomes pregnant with a combination. Katsenelinboigen writes:

"As the game progressed and defense became more sophisticated the combinational style of play declined. . . . The positional style of chess does not eliminate the combinational one with its attempt to see the entire program of action in advance. The positional style merely prepares the transformation to a combination when the latter becomes feasible."

Neuroscience perspective

The anterior cingulate cortex (ACC), orbitofrontal cortex (and the overlapping ventromedial prefrontal cortex) are brain regions involved in decision making processes. A recent neuroimaging study, found distinctive patterns of neural activation in these regions depending on whether decisions were made on the basis of personal volition or following directions from someone else. Patients with damage to the ventromedial prefrontal cortex have difficulty making advantageous decisions.

A recent study involving Rhesus monkeys found that neurons in the parietal cortex not only represent the formation of a decision but also signal the degree of certainty (or "confidence") associated with the decision. Another recent study found that lesions to the ACC in the macaque resulted in impaired decision making in the long run of reinforcement guided tasks suggesting that the ACC may be involved in evaluating past reinforcement information and guiding future action.

Emotion appears to aid the decision making process: Decision making often occurs in the face of uncertainty about whether one's choices will lead to benefit or harm (see also Risk). The somatic-marker hypothesis is a neurobiological theory of how decisions are made in the face of uncertain outcome. This theory holds that such decisions are aided by emotions, in the form of bodily states, that are elicited during the deliberation of future consequences and that mark different options for behavior as being advantageous or disadvantageous. This process involves an interplay between neural systems that elicit emotional/bodily states and neural systems that map these emotional/bodily states.

Although it is unclear whether the studies generalize to all processing, there is evidence that volitional movements are initiated, not by the conscious decision making self, but by the subconscious. See the Neuroscience of free will.

Group decision making

Group decision making is a situation faced when people think or are brought together to solve problems in the anticipation that they are more effective than individuals under the idea of synergy. But cohesive groups display risky behavior in decision making situations that led to the devotion of much effort, especially in the area of applied social sciences and other relevant fields of specialization.

There are several aspects of group cohesion which have a negative effect on group decision making and hence on group effectiveness. Risky-shift phenomenon, group polarisation, and group-think are negative aspects of group decision making which have drawn attention.

Group-think is one of the most dangerous traps in our decision making. It's particularly because it taps into our deep social identification mechanisms - everyone likes to feel part of a group - and our avoidance of social challenges. But consensus without conflict almost always means that other viewpoints are being ignored, and the consequences of group-think can be disastrous.

Issues facing any work group concerning decision making are: how should decisions be made? Consensus? Voting? One-person rule? Secret ballot? Consideration of the various opinions of the different individuals and deciding what action a group should take might be of help.

Formal Systems

Consensus decision-making tries to avoid "winners" and "losers". Consensus requires that a majority approve a given course of action, but that the minority agree to go along with the course of action. In other words, if the minority opposes the course of action, consensus requires that the course of action be modified to remove objectionable features.

Voting-based methods

Range voting lets each member score one or more of the available options. The option with the highest average is chosen. This method has experimentally been shown to produce the lowest Bayesian regret among common voting methods, even when voters are strategic.

Majority requires support from more than 50% of the members of the group. Thus, the bar for action is lower than with unanimity and a group of “losers” is implicit to this rule.

Plurality, where the largest block in a group decides, even if it falls short of a majority.

Delphi method is structured communication technique for groups, originally developed for collaborative forecasting but has also been used for policy making

Dotmocracy is a facilitation method that relies on the use of special forms called Dotmocracy Sheets to allow large groups to collectively brainstorm and recognize agreement on an unlimited number of ideas they have authored.

Decision making in social setting

Decision making in groups is sometimes examined separately as process and outcome. Process refers to the group interactions. Some relevant ideas include coalitions among participants as well as influence and persuasion. The use of politics is often judged negatively, but it is a useful way to approach problems when preferences among actors are in conflict, when dependencies exist that cannot be avoided, when there are no super-ordinate authorities, and when the technical or scientific merit of the options is ambiguous.

In addition to the different processes involved in making decisions, group decision support systems (GDSS) may have different decision rules. A decision rule is the GDSS protocol a group uses to choose among scenario planning alternatives.

Gathering involves all participants acknowledging each other's needs and opinions and tends towards a problem solving approach in which as many needs and opinions as possible can be satisfied. It allows for multiple outcomes and does not require agreement from some for others to act.

Sub-committee involves assigning responsibility for evaluation of a decision to a sub-set of a larger group, which then comes back to the larger group with recommendations for action. Using a sub-committee is more common in larger governance groups, such as a legislature. Sometimes a sub-committee includes those individuals most affected by a decision, although at other times it is useful for the larger group to have a sub-committee that involves more neutral participants.

Participatory, where each actor would have a say in decisions directly proportionate to the degree that particular decision affects him or her. Those not affected by a decision would have no say and those exclusively affected by a decision would have full say. Likewise, those most affected would have the most say while those least affected would have the least say.

Plurality and dictatorship are less desirable as decision rules because they do not require the involvement of the broader group to determine a choice. Thus, they do not engender commitment to the course of action chosen. An absence of commitment from individuals in the group can be problematic during the implementation phase of a decision.

There are no perfect decision making rules. Depending on how the rules are implemented in practice and the situation, all of these can lead to situations where either no decision is made, or to situations where decisions made are inconsistent with one another over time.

Moral dimension of decision making

The ethical principles of decision making vary considerably. Some common choices of principles and the methods which seem to match them include:

the most powerful person/group decides
method: dictatorship or oligarchy

everyone participates in a certain class of meta-decisions
method: parliamentary democracy

everyone participates in every decision
direct democracy, consensus decision making

There are many decision making levels having a participation element. A common example is that of institutions making decisions that affect those for whom they provide. In such cases an understanding of what participation level is involved becomes crucial to understand the process and power structures dynamics.

Control-Ethics: When organisations/institutions make decisions it is important to find the balance between the parameters of control mechanisms and the ethical principles which ensure 'best' outcome for individuals and communities affected by the decision. Controls may be set by elements such as Legislation, historical precedents, available resources, Standards, policies, procedures and practices. Ethical elements may include equity, fairness, transparency, social justice, choice, least restrictive alternative, empowerment.

Empowerment is a person's way of expressing control.

Decision making in healthcare

In the health care field, the steps of making a decision may be remembered with the mnemonic BRAND, which includes

- Benefits of the action
- Risks in the action
- Alternatives to the prospective action
- Nothing: that is, doing nothing at all
- Decision

Decision making in business and management

In general, business and management systems should be set up to allow decision making at the lowest possible level.

Several decision making models or practices for business include:

- Analytic Hierarchy Process - widely-used procedure for group decision making
- Buyer decision processes - transaction before, during, and after a purchase
- Complex systems - common behavioural and structural features that can be modelled
- Corporate finance
  The investment decision
  The financing decision
  The dividend decision
  Working capital management decisions
- Cost-benefit analysis - process of weighing the total expected costs vs. the total expected benefits
- Control-Ethics, a decision making framework that balances the tensions of accountability and 'best' outcome.
- Decision trees
- Decision analysis - the discipline devoted to prescriptive modeling for decision making under conditions of uncertainty.
- Program Evaluation and Review Technique (PERT)
- critical path analysis
- critical chain analysis
- Force field analysis - analyzing forces that either drive or hinder movement toward a goal
- Game theory - the branch of mathematics that models decision strategies for rational agents under conditions of competition, conflict and cooperation.
- Grid Analysis - analysis done by comparing the weighted averages of ranked criteria to options. A way of comparing both objective and subjective data.
- Hope and fear (or colloquially greed and fear) as emotions that motivate business and financial players, and often bear a higher weight that the rational analysis of fundamentals, as discovered by neuroeconomics research
- Linear programming - optimization problems in which the objective function and the constraints are all linear
- Min-max criterion
- Model (economics)- theoretical construct of economic processes of variables and their relationships
- Monte Carlo method - class of computational algorithms for simulating systems
- Morphological analysis - all possible solutions to a multi-dimensional problem complex
- optimization
  constrained optimization
- Paired Comparison Analysis - paired choice analysis
- Pareto Analysis - selection of a limited of number of tasks that produce significant overall effect
- Robust decision or Robust decision making - method that supports selecting the best possible choice when information is incomplete, uncertain, evolving, and inconsistent

- Satisficing - In decision-making, satisficing explains the tendency to select the first option that meets a given need or select the option that seems to address most needs rather than seeking the "optimal" solution.
- Scenario analysis - process of analyzing possible future events
- Six Thinking Hats - symbolic process for parallel thinking
- Strategic planning process - applying the objectives, SWOTs, strategies, programs process
- SWOT Analysis - Evaluation by the decision making individual or organization of Strengths, Weaknesses, Opportunities and Threats with respect to desired end state or objective.
- Trend following and other imitations of what other business deciders do, or of the current fashions among consultants.
- The use of a Decision making software that provides group decision support.

Decision-makers and influencers

In the context of marketing, there is much theory, and even more opinion, expressed about how the various 'decision-makers' and 'influencers' (those who can only influence, not decide, the final decision) interact. Large purchasing decisions are frequently taken by groups, rather than individuals, and the official buyer often does not have authority to make the decision.

Decision Support Systems

The idea of using computerised support systems is discussed by James Reason under the heading of intelligent decision support systems in his work on the topic of human error. James Reason notes that events subsequent to The Three Mile accident have not inspired great confidence in the efficacy of some of these methods. In the Davis-Besse accident, for example, both independent safety parameter display systems were out of action before and during the event.

Decision making software is essential for autonomous robots and for different forms of active decision support for industrial operators, designers and managers.

Due to the large number of considerations involved in many decisions, computer-based decision support systems (DSS) have been developed to assist decision makers in considering the implications of various courses of thinking. They can help reduce the risk of human errors. DSSs which try to realize some human/cognitive decision making functions are called Intelligent Decision Support Systems (IDSS), see for ex. "An Approach to the Intelligent Decision Advisor (IDA) for Emergency Managers, 1999". On the other hand, an active/intelligent DSS is an important tool for the design of complex engineering systems and the management of large technological and business projects, see also: "Decision engineering, an approach to Business Process Reengineering (BPR) in a strained industrial and business environment".

Multi-criteria decision analysis

Multi-Criteria Decision Analysis (MCDA) or Multi-Criteria Decision Making (MCDM) is a discipline aimed at supporting decision makers faced with making numerous and sometimes conflicting evaluations. MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process.

Background

Unlike methods that assume the availability of measurements, measurements in MCDA are derived or interpreted subjectively as indicators of the strength of various preferences. Preferences differ from decision maker to decision maker, so the outcome depends on who is making the decision and what their goals and preferences are. For example, the European Parliament may apply MCDA to help assess whether the introduction of software patents in Europe would help or harm the European software industry. Since MCDA involves a certain element of subjectiveness, the morals and ethics of the persons implementing MCDA play a significant part in the accuracy and fairness of MCDA's conclusions. The ethical point is very important when one is making a decision that seriously impacts on other people, as opposed to a personal decision.

There are many MCDA / MCDM methods in use today. However, often different methods may yield different results for exactly the same problem. In other words, when exactly the same problem data are used with different MCDA / MCDM methods, such methods may recommend different solutions even for very simple problems (i.e., ones with very few alternatives and criteria). This raises the fundamental issues of how to evaluate and compare various MCDA / MCDM methods. Choosing the best MCDA / MCDM method is itself a multi-criteria decision making problem, in which the alternatives are the methods themselves and the decision criteria are the various evaluative ways for comparing them. Finding the best MCDA / MCDM method requires using the best MCDA / MCDM method on this fundamental problem. This leads to a decision making paradox.

The choice of which model is most appropriate depends on the problem at hand and may be to some extent dependent on which model the decision maker is most comfortable with. A question with all the above methods, and also methods not included in this list or even future methods, is how to assess their effectiveness. The role of rank reversals in decision making when these methods are used on certain test problems, plays a crucial role in this regard. However, this is a highly debatable issue as the near continuous emergence of new methods indicates.

Classification

A classification is often made, based on the size of the set of strategies:

MADM (multi-attribute decision making), concerned with a finite set of alternatives. The results can be expressed in the form of a selection of the most appropriate alternative, a ranking of the alternatives from the best to the worst or a classification into predefined performance classes.

and

MODM (multi-objective decision making), concerned with choosing from a large, infinite, or uncountable number of alternatives.

MCDA's are also often classified based upon the type of aggregation or the nature of the input data.

Decision making paradox

People are fascinated by paradoxes as usually they express true statements or facts which, however, defy common intuition.

This particular paradox relates to decision making and it was first identified by Triantaphyllou and Mann in 1989. It was further elaborated in the book by Triantaphyllou on multi-criteria decision making. Since then it has been recognized in the related literature as a fundamental paradox in multi-criteria decision analysis (MCDA) / multi-criteria decision making (MCDM), and decision analysis, in general. This paradox is related to the quest for determining reliable decision making methods.

Description of this paradox

The realization for this paradox comes from the rather straightforward observation that there are numerous decision making methods (both normative and descriptive) each one of which claims to be the "best" one. Furthermore, often times these methods may yield different results when they are fed with exactly the same decision problem and data.

Finding the best decision making method leads to the formulation of a decision problem itself for which the alternatives are the decision making methods themselves. Naturally, one needs to know the best method a-priori in order to select the best method from the available ones.

In the study reported in and an interesting investigation was undertaken. Since in the beginning it was assumed that the best method is not known, the problem of selecting the best method was solved by successively using different methods. The methods used in that study were the weighted sum model (WSM), the weighted product model (WPM), and two variants of the analytic hierarchy process (AHP). It was found that when a method was used, say method X (which is one of the previous four methods), the conclusion was that another method was best (say, method Y). When method Y was used, then another method, say method Z, was suggested as being the best one, and so on.

Two evaluative criteria were used to formulate the previous decision making problem (actually, an MCDM problem). The first criterion was based on the premise that a method which claims to be accurate in multi-dimensional problems (for which different units of measurement are used to describe the alternatives), should also be accurate in single-dimensional problems. For such problems, the weighted sum model (WSM) is the widely accepted approach, thus their results were compared with the ones derived from the WSM. The second evaluative criterion was based on the following situation. Suppose some alternatives are evaluated and one of them is returned as the best alternative (say alternative A). Next, a non-optimal alternative (say alternative B) is replaced by a worse one. Under normal conditions one should expect that the same alternative as before (i.e., alternative A) is the best alternative again. This is also known in the related literature as a ranking reversal. However, this may not happen with some of the methods tested in those experiments. For weights of these two evaluative criteria, all possible combinations were considered such that their sum was always equal to 1.00.

Methods that have been verified to exhibit this paradox

The following is a partial list of multi-criteria decision making methods which have been confirmed to exhibit this paradox:,

- The analytic hierarchy process (AHP) and some of its variants.
- The weighted product model (WPM).
- The ELECTRE (outranking) method and its variants.
- The TOPSIS method.

Looking into the future

Other methods have not been tested yet but it is very likely they may exhibit the same phenomenon. Such methods include the following:

- The analytic network process (ANP).
- The PROMETHEE (outranking) method.
- Multi-attribute utility theory (MAUT).
- Dominance-based rough set approach (DRSA)
- Aggregated indices randomization method (AIRM)
- Nonstructural fuzzy decision support system (NSFDSS)
- Grey relational analysis (GRA)
- Superiority and inferiority ranking method (SIR method)
- Potentially all pairwise rankings of all possible alternatives (PAPRIKA)
- Value analysis (VA)

What is the best decision making method has always been a highly contested subject. There is always an ongoing debate on this subject. At the same time, a plethora of competing methods exists. A key role in this quest is played by the study of rank reversals in decision making.

As stated earlier, it is not uncommon such methods to yield different results when they are presented with exactly the same data. Thus, this decision making paradox is likely to persist for many years to come.

Decision analysis

Decision Analysis (DA) is the discipline comprising the philosophy, theory, methodology, and professional practice necessary to address important decisions in a formal manner. Decision analysis includes many procedures, methods, and tools for identifying, clearly representing, and formally assessing important aspects of a decision, for prescribing a recommended course of action by applying the maximum expected utility action axiom to a well-formed representation of the decision, and for translating the formal representation of a decision and its corresponding recommendation into insight for the decision maker and other stakeholders.

History and Methodology

The term decision analysis was coined in 1964 by Ronald A. Howard, who since then, as a professor at Stanford University, has been instrumental in developing much of the practice and professional application of DA.

Graphical representation of decision analysis problems commonly use influence diagrams and decision trees. Both of these tools represent the alternatives available to the decision maker, the uncertainty they face, and evaluation measures representing how well they achieve their objectives in the final outcome. Uncertainties are represented through probabilities and probability distributions. The decision maker's attitude to risk is represented by utility functions and their attitude to trade-offs between conflicting objectives can be made using multi-attribute value functions or multi-attribute utility functions (if there is risk involved). In some cases, utility functions can be replaced by the probability of achieving uncertain aspiration levels. Decision analysis advocates choosing that decision whose consequences have the maximum expected utility (or which maximize the probability of achieving the uncertain aspiration level). Such decision analytic methods are used in a wide variety of fields, including business (planning, marketing, and negotiation), environmental remediation, health care research and management, energy exploration, litigation and dispute resolution, etc.

Decision analysis is used by major corporations to make multi-billion dollar capital investments. In 2010, Chevron won the Decision Analysis Society Practice Award for its use of decision analysis in all major decisions. In a video detailing Chevron's use of decision analysis, Chevron Vice Chairman George Kirkland notes that "decision analysis is a part of how Chevron does business for a simple, but powerful, reason: it works."

Controversy

Decision researchers studying how individuals research decisions have found that decision analysis is rarely used. High-stakes decisions, made under time pressure, are not well described by decision analysis. Some decision analysts, in turn, argue that their approach is prescriptive, providing a prescription of what actions to take based on sound logic, rather than a descriptive approach, describing the flaws in the way people do make decisions. Critics cite the phenomenon of paralysis by analysis as one possible consequence of over-reliance on decision analysis in organizations.

Studies have demonstrated the utility of decision analysis in creating decision-making algorithms that are superior to "unaided intuition".

Some areas within decision analysis deal with normative results that are provably optimal for specific quantifiable decisions. For example, the optimal order scheduling in a manufacturing facility or optimal hedging strategies are purely mathematical and their results are necessarily provable. The term "decision analytic" has often been reserved for decisions that do not appear to lend themselves to mathematical optimization methods. Methods like applied information economics, however, attempt to apply more rigorous quantitative methods even to these types of decisions.

Satisficing

Satisficing, a portmanteau "combining satisfy with suffice", is a decision-making strategy that attempts to meet criteria for adequacy, rather than to identify an optimal solution. A satisficing strategy may often be (near) optimal if the costs of the decision-making process itself, such as the cost of obtaining complete information, are considered in the outcome calculus.

The word satisfice was coined by Herbert Simon in 1956. He pointed out that human beings lack the cognitive resources to maximize: we usually do not know the relevant probabilities of outcomes, we can rarely evaluate all outcomes with sufficient precision, and our memories are weak and unreliable. A more realistic approach to rationality takes into account these limitations: This is called bounded rationality.

Some consequentialist theories in moral philosophy use the concept of satisficing in the same sense, though most call for optimization instead.

Etymology

The word originated as an alternative spelling of the transitive verb "satisfy" in the 16th Century (influenced by the Latin "satisfacére"). Use of the word in this sense had become obsolete except in northern dialects of England when Simon reintroduced it as an intransitive verb with its new meaning in the mid 20th Century.

Cybernetics and artificial intelligence

In cybernetics, ''satisficing is optimization where 'all' costs, including the cost of the optimization calculations themselves and the cost of getting information for use in those calculations, are considered."

As a result, the eventual choice is usually sub-optimal in regard to the main goal of the optimization, i.e., different from the optimum in the case that the costs of choosing are not taken into account.

During a 1997 chess game against Deep Blue, Garry Kasparov, after being defeated in a game where his computer opponent adopted a satisficing position, remarked that the computer was "playing like a human." Kasparov later explained that, when playing computers, chess masters could often defeat them by predicting the most "rational" move; however, satisficing made such a prediction unreliable.

Decision making

In decision making, satisficing explains the tendency to select the first option that meets a given need or select the option that seems to address most needs rather than the "optimal" solution.

Example: A task is to sew a patch onto a pair of jeans. The best needle to do the threading is a 4 inch long needle with a 3 millimeter eye. This needle is hidden in a haystack along with 1000 other needles varying in size from 1 inch to 6 inches. Satisficing claims that the first needle that can sew on the patch is the one that should be used. Spending time searching for that one specific needle in the haystack is a waste of energy and resources.

Simon, as a further example, once explained satisficing to his students by describing a mouse searching for cheese in a maze. The mouse might begin searching for a piece of Gouda, but unable to find any would eventually be "satisfied" and could "suffice" with any piece of cheese, such as cheddar.

Satisficing occurs in consensus building when the group looks towards a solution everyone can agree on even if it may not be the best.

Example: A group spends hours projecting the next fiscal year's budget. After hours of debating they eventually reach a consensus, only to have one person speak up and ask if the projections are correct. When the group becomes upset at the question, it is not because this person is wrong to ask, but rather because they have come up with a solution that works. The projection may not be what will actually come, but the majority agrees on one number and thus the projection is good enough to close the book on the budget.

In many circumstances, the individual may be uncertain about what constitutes a satisfactory outcome. For example, an individual who only seeks a satisfactory retirement income may not know what level of wealth is required—given uncertainty about future prices—to ensure a satisfactory income. In this case, the individual can only evaluate outcomes on the basis of their probability of being satisfactory.

If the individual chooses that outcome which has the maximum chance of being satisfactory, then this individual's behavior is theoretically indistinguishable from that of an optimizing individual under certain conditions

Thus, from a decision theory point of view, the distinction between "optimizing" and "satisficing" is essentially a stylistic issue (that can nevertheless be very important in certain applications) rather than a substantive issue. What is important to determine is what should be optimized and what should be satisficed.

The following quote from Jan Odhnoff's 1965 paper is appropriate:

In my opinion there is room for both 'optimizing' and 'satisficing' models in business economics. Unfortunately, the difference between 'optimizing' and 'satisficing' is often referred to as a difference in the quality of a certain choice. It is a triviality that an optimal result in an optimization can be an unsatisfactory result in a satisficing model. The best things would therefore be to avoid a general use of these two words.

More on the "satisficing" vs "optimizing" debate can be found in Byron's 2004 edited collection of articles.

Economics

In economics, satisficing is a behavior which attempts to achieve at least some minimum level of a particular variable, but which does not necessarily maximize its value. The most common application of the concept in economics is in the behavioral theory of the firm, which, unlike traditional accounts, postulates that producers treat profit not as a goal to be maximized, but as a constraint. Under these theories, a critical level of profit must be achieved by firms; thereafter, priority is attached to the attainment of other goals.

Survey taking

As an example of satisficing, in the field of social cognition, Jon Krosnick proposed a theory of statistical survey satisficing which says that optimal question answering by a survey respondent involves a great deal of cognitive work and that some people would use satisficing to reduce that burden. Some people may shortcut their cognitive processes in two ways:

- Weak satisficing: Respondent executes all cognitive steps involved in optimizing, but less completely and with bias.
- Strong satisficing: Respondent offers responses that will seem reasonable to the interviewer without any memory search or information integration.

Likelihood to satisfice is linked to respondent ability, respondent motivation and task difficulty

Regarding survey answers, satisficing manifests in:

- choosing explicitly offered no-opinion response option
- choosing socially desirable responses
- non-differentiation when a battery of questions asks for ratings of multiple objects on the same response scale
- acquiescence response bias, which is the tendency to agree with any assertion, regardless of its content

Flipism

Flipism, sometimes written as "Flippism", is a pseudophilosophy under which all decisions are made by flipping a coin. It originally appeared in the Disney comic "Flip Decision" by Carl Barks, published in 1953. Barks called a practitioner of "Flipism" a "Flippist" (with two P's).

Flipism can be seen as a normative decision theory, although it does not fulfill the criteria of rationality.

Origin

In the comic book, Donald Duck meets Professor Batty, who persuades Donald to make decisions based on flipping a coin at every crossroad of life. "Life is but a gamble! Let flipism chart your ramble!" Donald soon gets into trouble when following this advice. He drives a one way road in the wrong direction and is fined $50. The reason for the fine is not the bad driving but letting the coin do the thinking. Indeed, there are those who view the resort to Flipism to be a disavowal of responsibility for making personal and societal decisions based upon rationality. However, in the end, flipism shows surprising efficiency in guiding some decisions.

Flipism in decision-making

Flipism is a normative decision theory in a sense that it prescribes how decisions should be made. In the cartoon, flipism shows remarkable ability to make right conclusions without any information – but only once in a while. Of course, in real life flipping a coin would only lead to random decisions. However, there is an article about benefits of some randomness in the decision-making process in certain conditions. It notes:

Though the author himself may have intended this as a rejection of the idea that rationality (in the standard sense) has some special claim to superiority as a basis for making decisions, what he may really have discovered are the potential benefits of strategic commitment to randomization.

Commitment to a non-trivial mixed strategy can be beneficial for the informed party in a potential conflict under asymmetric information, as it allows the player to manipulate his opponent's beliefs in an optimal fashion. Such a strategy also makes the player less inclined to enter into conflict when it is avoidable. Coins and "flipism" have been used to suggest mathematical outcomes to a variation of the Prisoners Dilemma.

Another way of seeing the utility of flipism in decision-making can be called revealed preferences. In the traditional form, revealed preferences mean that the preferences of consumers can be revealed by their purchasing habits. With flipism, the preferences can be revealed to the decision-maker herself. Decisions with conflicting preferences are especially difficult even in situations where there is only one decision-maker and no uncertainty. The decision options may be either all appealing or all unpleasant, and therefore the decision-maker is unable to choose. Flipism, i.e., flipping a coin can be used to find a solution. However, the decision-maker should not decide based on the coin but instead observe her own feelings about the outcome; whether it was relieving or agonizing. In this way, flipism removes the mental block related to the act of decision-making, and the post-decision preferences can be revealed before the decision is actually made. An example of revealed preferences is embodied in the Old Testament story, the Judgment of Solomon, wherein King Solomon offered to resolve a child custody dispute by ordering the baby cut in two, and upon seeing the reactions made an award.

Still a third approach is to look at flipism as the endpoint of a continuum bounded on the other side by perfectly rational decision-making. Flipism requires the minimum possible cognitive overhead to make decisions, at the price of making sub-optimized choices. Truly rational decision-making requires a tremendous investment in information and cognition to arrive at an optimum decision. However, the expected marginal value of information gathered (discounted for risk and uncertainty) is often lower than the marginal cost of the information or processing itself. The concept of bounded rationality posits that people employ cognitive parsimony, gathering only what they expect to be sufficient information to arrive at a satisfying (or "good enough") solution. Flipism is therefore a perfectly rational strategy to employ when the cost of information is very high relative to its expected value. Compare Motivated tactician.

This is a commonly recognized decision making technique used in everyday life. Other methods include:

- listing advantages and disadvantages of each option (an informal form of decision matrix);
- coin flipping, cutting a deck of playing cards, finding a quotation in a holy book, consulting the Magic 8-ball, and other random or coincidence methods;
- accepting the first option that seems like it might achieve the desired result
- astrology, augury, fortune cookies, prayer, tarot cards, revelation, Methods of divination or other forms of divination or oracular device.

Similar concepts

Alternatively, dice or another random generator may be used for decision making.

In game theory, negotiations, nuclear deterrence, diplomacy and other Conflict theory – rationality, realpolitik or realism can themselves limit strategies and results. They can limit the ability of a player to make demands or get its own way through bluff, bully, instill fear, cause apprehension, or psychologically manipulate or send a heeded warning—and therefore can increase the likelihood that an opposing party may engage in objectionable or unwelcome behavior. If one knows the lines and can predict the response, than predictability and proportionality become a restraint, not a virtue. Consequently, 'taunting a junkyard dog is OK, if you know you are beyond the reach of its tether.' Thus irrationality (real or perceived) can be an important countervailing tool or strategy, particularly as a deterrent and if it engenders hesitation, fear, negotiation and resolution, or change of course. On the other hand, alternate strategies such as honesty, building a climate of trust, respect, using intermediaries, mediation or other forms of conflict resolution, sanctions, patience, process and reasoning might still be available, as might strategies like so-called Win/win bargaining (also called "interest-based" bargaining) – which tries to reach an accord based on interests, not necessarily on positions, power, rights or distribution.

In popular culture

- Joan Didion, in her 1979 New Journalism book The White Album, refers to herself as having lived through the late 1960's by what she later realized was "dice theory", as described by Charles Manson follower Linda Kasabian, who said "Everything was to teach me something", and who, according to Didion, did not believe that chance was without pattern.
- A record company named Flippist Records in Minneapolis, MN.
- The story Flip Decision has been a subject of a linguistic research about translations from English to Finnish, and from English to the Helsinki dialect.
- Danish poet and scientist Piet Hein once wrote a poem—entitled A Psychological Tip – describing the advantages of coin flipping in decision making.
- Some of the notable characters in fiction who practice flippism (to varying degrees) include:
- The main character in the book The Dice Man by Luke Rhinehart (a.k.a author George Cockcroft) and later novelsThe Search for the Dice Man, Adventures of Wim and The Book of the Die.
- Jake Nyman, the protagonist of the film American Perfekt.
- The main antagonist, Anton Chigurh, in the novel No Country for Old Men and the film.
- The Batman villain Harvey Dent (a.k.a Two-Face).
- Leela from the Futurama series.

Attitude polarization

Attitude polarization, also known as belief polarization, is a phenomenon in which a disagreement becomes more extreme as the different parties consider evidence on the issue. It is one of the effects of confirmation bias: the tendency of people to search for and interpret evidence selectively, to reinforce their current beliefs or attitudes. When people encounter ambiguous evidence, this bias can potentially result in each of them interpreting it as in support of their existing attitudes, widening rather than narrowing the disagreement between them.

The effect is observed with issues that activate emotions, such as political "hot button" issues. For most issues, new evidence does not produce a polarization effect. For those issues where polarization is found, mere thinking about the issue, without contemplating new evidence, produces the effect. Social comparison processes have also been invoked as an explanation for the effect, which is increased by settings in which people repeat and validate each other's statements. This apparent tendency is of interest to psychologists, but also to sociologists and philosophers.

Psychological research

Since the late 1960s, psychologists have carried out a number of studies on various aspects of attitude polarization.

The effects of prior theories on subsequently considered evidence

In 1979, Charles Lord, Lee Ross and Mark Lepper carried out an important piece of research on attitude polarization. The researchers selected two groups of people; one group was strongly in favor of capital punishment, the other group was strongly opposed to capital punishment. The researchers began by measuring the strength with which people held their particular position on the death penalty. Later, both the pro- and anti-capital punishment people were put into small groups and shown one of two cards, each of which had a statement about the results of a research project written on it. For example:

Kroner and Phillips (1977) compared murder rates for the year before and the year after adoption of capital punishment in 14 states. In 11 of the 14 states, murder rates were lower after adoption of the death penalty. This research supports the deterrent effect of the death penalty.

or:

Palmer and Crandall (1977) compared murder rates in 10 pairs of neighboring states with different capital punishment laws. In 8 of the 10 pairs, murder rates were higher in the state with capital punishment. This research opposes the deterrent effect of the death penalty.

The researchers again asked people about the strength of their beliefs about the deterrence effect of the death penalty, and, this time, also asked them about the effect that the research had had on their attitudes.

In the next stage of the research, the participants were given more information about the study described on the card they received, including details of the research, critiques of the research, and the researchers' responses to those critiques. The participants' degree of commitment to their original positions were re-measured, and the participants were asked about the quality of the research and the effect the research information had on their beliefs.

Finally, the trial was rerun on all the participants using a card that supported the opposite position to that they had initially seen.

The researchers found that people tended to hold that research that agreed with their original views had been better conducted and was more convincing than research that conflicted with their original views. Whichever position they held initially, people tended to hold that position more strongly after reading about research that supported their position. Lord et al. point out that it is reasonable for people to be less critical of research that supports their current position, but it seems less rational for people to significantly increase the strength of their attitudes when they read supporting evidence. When people had read both the research that supported their current views and the research that was conflicted with their views, they tended to hold their original attitudes more strongly than before they received that information.

Role of group membership

Social psychologists have carried out research on the effect of seeing oneself as part of a group on one's attitude towards oneself, the group and positions supported or rejected by that group. To briefly summarize, the research suggests that people are likely to accept the position that they believe their group holds, even when they have only just been put into the group and have yet to meet any of the other group members.

Illusory correlation

Illusory correlation is the phenomenon of seeing the relationship one expects in a set of data even when no such relationship exists. When people form false associations between membership in a statistical minority group and rare (typically negative) behaviors, this would be a common example of illusory correlation. This happens because the variables capture the attention simply because they are novel or deviant. This is one way stereotypes form and endure. David Hamilton and Terrence Rose (1980) found that stereotypes can lead people to expect certain groups and traits to fit together, and they overestimate the frequency of when these correlations actually occur. People overestimate the core association between variables such as stereotyped groups and stereotypic behavior.

Chapman and Chapman (1971) studied the effect as it relates to psychodiagnostic signs. Their study showed that although projective testing is not helpful in the diagnosis of mental disorders, some psychologists continue to use such tests because of a perceived, illusory, correlation between test results and certain attributes. An example of a projective test is the "Draw a Person" test that asks patients to draw a person on a blank piece of paper. Some psychologists believe in a correlation between drawing a person with big eyes and paranoia. No such correlation exists, and when data that is deliberately uncorrelated is presented to college students they find the same illusory correlations that psychologists believe in.

This bias can be caused by, among other things, an event that stands out as unique. For example, "The only time I forget my pencil is when we have a test". This is most likely an illusory correlation. It could be caused by only a few other pencil-less tests, which stand out particularly well in memory.

History

"Illusory correlation" was originally coined by Chapman (1967) to describe people's tendencies to overestimate relationships between two groups when distinctive and unusual information is presented. The concept was tested experimentally by David Hamilton and Robert Gifford in 1976. Rupert Brown and Amanda Smith (1989) also tested the hypothesis by conducting a study involving the academic staff at a British university. The results revealed that the staff had overestimated the number of female seniority staff and underestimated the number of male senior staff. This reflected that the academic staff inaccurately viewed the relationship between gender and seniority, showing that illusory correlations can exist in everyday situations.

Risen, Gilovich, & Dunning (2007) proposed in their research that a single distinct situation is sufficient enough to create a stereotypical association between a minority group and unusual behaviors. Risen asked research participants to read sentences that presented both common and uncommon behaviors. An example of these behaviors involved ownership of a pet sloth or something as simple as using a packet of ketchup. The results from the studies revealed that when uncommon behaviors were read by the participants, they took longer processing the information, gave more thought as to how the behavior might apply to themselves, and were more likely to remember the behavior when compared to reading about common behaviors.

Example

David Hamilton and Robert Gifford (1976) conducted a series of experiments that demonstrated how stereotypic beliefs regarding minorities could derive from inaccurate ideas from majority group members. To test their hypothesis, Hamilton and Gifford had research participants read a series of 39 sentences, which were associated with either

Group A or B. Abstract groups were used so no previous stereotypes would influence results. Twenty-six out of the 39 sentences were associated with Group A, making it the majority, and 13 were associated with Group B, making it the minority. Positive behaviors were represented in 27 sentences and negative behaviors were described in 12. The following table summarises the information given.

Behaviors	**Group A (Majority)**	**Group B (Minority)**	**Total**
Desirable	18 (69%)	9 (69%)	27
Undesirable	8 (30%)	4 (30%)	12
Total	26	13	39

Each group had the same proportions of positive and negative behaviors, so there was no real association between behaviors and group membership. Results of the study show that positive, desirable behaviors were not seen as distinctive so people were accurate in their associations. On the other hand, when distinctive, undesirable behaviors were represented in the sentences, the participants overestimated how much the minority group exhibited the behaviors.

Explanations

Most explanations for illusory correlation involve psychological heuristics: information processing short-cuts that underlie many human judgments. One of these is availability: the ease with which an idea comes to mind. Availability is often used to estimate how likely an event is or how often it occurs. This can result in illusory correlation, because some pairings can come easily and vividly to mind even though they are not especially frequent. Representativeness is the degree of similarity between an individual and the most typical example of a category. This heuristic has been shown to underlie many illusory correlations: people may correlate sexually ambiguous interpretations of inkblots with homosexuality because those judgements resemble their idea of a typical homosexual person.

Illusory correlation can also be explained in terms of biases in hypothesis-testing behavior. People tend to test hypotheses in a one-sided way, searching for evidence consistent with their current hypothesis. A parallel effect occurs when people judge whether two events, such as illness and bad weather, are correlated. They rely heavily on the number of cases where the two go together: in this example, instances of both pain and bad weather. They pay relatively little attention to the other kinds of observation (of no pain and/or good weather).

Cognitive inertia

Cognitive inertia refers the tendency for beliefs or sets of beliefs to endure once formed. In particular, cognitive inertia describes the human inclination to rely on familiar assumptions and exhibit a reluctance and/or inability to revise those assumptions, even when the evidence supporting them no longer exists or when other evidence would question their accuracy. The term is employed in the managerial and organizational sciences to describe the commonly observed phenomenon whereby managers fail to update and revise their understanding of a situation when that situation changes, a phenomenon that acts as a psychological barrier to organizational change. The notion of cognitive inertia is related to similar ideas in the fields of social psychology and behavioral decision theory, including cognitive dissonance, belief perseverance, confirmation bias, and escalation of commitment.

One example of cognitive inertia concerns managers at the Polaroid corporation, whose belief that the company could not make money on hardware but only on consumables led them to neglect the growth in digital imaging technologies; because the trend was denied by the prevailing "mental model" of the business, the corporation failed to adapt effectively to market changes.

Not all instances of cognitive inertia result in negative outcomes. Cognitive inertia is a key component of love, trust, and friendship. For instance, if evidence showed that a friend was dishonest, the cognitive inertia of the friendship would demand much more evidence to form an opinion than that required to form an opinion of a stranger. In this fashion, cognitive inertia provides an additional level of trust in a relationship.

Wishful thinking

Wishful thinking is the formation of beliefs and making decisions according to what might be pleasing to imagine instead of by appealing to evidence, rationality or reality. Studies have consistently shown that holding all else equal, subjects will predict positive outcomes to be more likely than negative outcomes (see valence effect).

Donald Lambro described wishful thinking in terms of

"the fantasy cycle" ... a pattern that recurs in personal lives, in politics, in history – and in storytelling. When we embark on a course of action which is unconsciously driven by wishful thinking, all may seem to go well for a time, in what may be called the "dream stage". But because this make-believe can never be reconciled with reality, it leads to a "frustration stage" as things start to go wrong, prompting a more determined effort to keep the fantasy in being. As reality presses in, it leads to a "nightmare stage" as everything goes wrong, culminating in an "explosion into reality", when the fantasy finally falls apart.

Prominent examples of wishful thinking include:

Economist Irving Fisher said that "stock prices have reached what looks like a permanently high plateau" a few weeks before the Stock Market Crash of 1929, which was followed by the Great Depression.

President John F. Kennedy believed that, if overpowered by Cuban forces, the CIA-backed rebels could "escape destruction by melting into the countryside" in the Bay of Pigs Invasion.

As a logical fallacy

In addition to being a cognitive bias and a poor way of making decisions, wishful thinking is commonly held to be a specific logical fallacy in an argument when it is assumed that because we wish something to be true or false that it is actually true or false. This fallacy has the form "I wish that P is true/false, therefore P is true/false." Wishful thinking, if this were true, would underlie appeals to emotion, and would also be a red herring.

The charge of "wishful thinking" itself can be a form of circumstantial ad hominem argument, even a Bulverism.

Wishful thinking may cause blindness to unintended consequences.

Related fallacies are the negative proof and argument from ignorance fallacies ("It hasn't been proven false, so it must be true." and vice versa). For instance, a believer in UFOs may accept that most UFO photos are faked, but claim that the ones that haven't been debunked must be considered genuine.

Methods to eliminate wishful thinking

Reference class forecasting was developed to eliminate or reduce the effects of wishful thinking in decision making.

Optimism bias

Optimism bias is the demonstrated systematic tendency for people to be overly optimistic about the outcome of planned actions. This includes over-estimating the likelihood of positive events and under-estimating the likelihood of negative events. Along with the illusion of control and illusory superiority, it is one of the positive illusions to which people are generally susceptible. Excessive optimism can result in cost overruns, benefit shortfalls, and delays when plans are implemented or expensive projects are built. In extreme cases these can result in defeats in military conflicts, ultimate failure of a project or economic bubbles such as market crashes.

Experimental demonstration

Armor and Taylor review a number of studies that have found optimism bias in different kinds of judgment. These include:

- Second-year MBA students overestimated the number of job offers they would receive and their starting salary.
- Students overestimated the scores they would achieve on exams.
- Almost all newlyweds in a US study expected their marriage to last a lifetime, even while aware of the divorce statistics.
- Professional financial analysts consistently overestimated corporate earnings.

- Most smokers believe they are less at risk of developing smoking-related diseases than others who smoke.

Students in one study rated themselves as much less likely than their peers (students of the same sex at the same college) to experience negative life events such as developing a drinking problem, having a heart attack, being fired from a job, or divorcing a few years after getting married. This effect, called unrealistic personal optimism, has been replicated and extended in between-subject research. This research shows that optimistic bias is more prevalent in people with greater left-prefrontal activation.

Optimism bias does not apply universally. For example, people overestimate their chances of experiencing very rare events, including negative events.

Possible effects of overconfidence

Increased risk taking and insufficient preventive care

Optimism bias can induce people to underinvest in primary and preventive care and other risk-reducing behaviors, such as abstinence from smoking. The overconfident may also inadequately react to legal threats and incentives, undermining the deterrent effect of liability rules.
Increased risk for financial problems

Overconfidence causes many people to grossly underestimate their odds of making a payment late. Statistically, many people are quite likely to make at least one payment late due to the normal range of difficulties and delays in day-to-day life. Overconfidence bias causes these people to grossly underestimate the odds of this happening and therefore to accept grossly punitive fees and rates (e.g., an interest rate of nearly 30% on a credit card or similar line of credit) as a result of otherwise minor transgressions such as a late payment. Companies have exploited this bias by increasing interest rates to punitive rates for any late payment, even if it is to another creditor. Overconfidence bias makes these terms more acceptable to borrowers than if they were accurately calibrated.

Overconfidence bias also causes many people to substantially underestimate the probability of having serious financial or liquidity problems, such as from a sudden job loss or severe illness. This can cause them to take on excessive debt under the expectation that they will do better than average in the future and be readily able to pay it off.

Overconfidence, locus of control, and depression

Overconfidence bias may cause many people to overestimate their degree of control and their odds of success. This may be protective against depression—since Seligman and Maier's model of depression includes a sense of learned helplessness and loss of predictability and control. Depressives tend to be more accurate and less overconfident in their assessments of the probabilities of good and bad events occurring to others, but they tend to overestimate the probability of bad events happening to them. This has caused some researchers to consider that overconfidence bias may be adaptive or protective in some situations.

Optimism bias and planning

Optimism bias arises in relation to estimates of costs and benefits and duration of tasks. It must be accounted for explicitly in appraisals if these are to be realistic. Optimism bias typically results in cost overruns, benefit shortfalls, and delays when plans are implemented.

The UK government explicitly acknowledges that optimism bias is a problem in planning and budgeting and has developed measures for dealing with optimism bias in government (HM Treasury 2003). The UK Department for Transport requires project planners to use so-called optimism bias uplifts for large transport projects in order to arrive at accurate budgets for planned ventures (Flyvbjerg and Cowi 2004).

In a debate in Harvard Business Review, between Daniel Kahneman, Dan Lovallo, and Bent Flyvbjerg, Flyvbjerg (2003)—while acknowledging the existence of optimism bias—pointed out that what appears to be optimism bias may actually be strategic misrepresentation. Planners may deliberately underestimate costs and overestimate benefits in order to get their projects approved, especially when projects are large and when organizational and political pressures are high. Kahneman and Lovallo (2003) maintained that optimism bias is the main problem.

Optimism bias and reference class forecasting

Reference class forecasting was developed to eliminate or reduce optimism bias in forecasting, planning, and decision making.

Mechanisms

A brain-imaging study found that, when imagining negative future events, signals in the amygdala, an emotion centre of the brain, are weaker than when remembering past negative events. This weakened consideration of possible negative outcomes is one possible mechanism for optimism bias. The activity of brain regions that are known to malfunction in psychological depression also predict the optimism bias.

Planning fallacy

The planning fallacy is a tendency for people and organizations to underestimate how long they will need to complete a task, even when they have past experience of similar tasks over-running. The term was first proposed in a 1979 paper by Daniel Kahneman and Amos Tversky. Since then the effect has been found for predictions of a wide variety of tasks, including tax form completion, school work, furniture assembly, computer programming and origami. The bias only affects predictions about one's own tasks; when uninvolved observers predict task completion times, they show a pessimistic bias, overestimating the time taken. In 2003, Lovallo and Kahneman proposed an expanded definition as the tendency to underestimate the time, costs, and risks of future actions and at the same time overestimate the benefits of the same actions. According to this definition, the planning fallacy results in not only time overruns, but also cost overruns and benefit shortfalls.

Demonstration

In a 1994 study, 37 psychology students were asked to estimate how long it would take to finish their senior theses. The average estimate was 33.9 days. They also estimated how long it would take "if everything went as well as it possibly could" (averaging 27.4 days) and "if everything went as poorly as it possibly could" (averaging 48.6 days). The average actual completion time was 55.5 days, with only about 30% of the students completing their thesis in the amount of time they predicted.

Another study asked students to estimate when they would complete their personal academic projects. Specifically, the researchers asked for estimated times by which the students thought it was 50%, 75%, and 99% probable their personal projects would be done.

13% of subjects finished their project by the time they had assigned a 50% probability level;
19% finished by the time assigned a 75% probability level;
45% finished by the time of their 99% probability level.

A survey of Canadian tax payers, published in 1997, found that they mailed in their tax forms about a week later than they predicted. They had no misconceptions about their past record of getting forms mailed in, but expected that they would get it done more quickly next time. This illustrates a defining feature of the planning fallacy; that people recognise that their past predictions have been over-optimistic, while insisting that their current predictions are realistic.

Explanations

Kahneman and Tversky's original explanation for the fallacy was that planners focus on the most optimistic scenario for the task, rather than using their full experience of how much time similar tasks require. One explanation offered by Roger Buehler and colleagues is wishful thinking; in other words, people think tasks will be finished quickly and easily because that is what they want to be the case. In a different paper, Buehler and colleagues suggest an explanation in terms of the self-serving bias in how people interpret their past performance. By taking credit for tasks that went well but blaming delays on outside influences, people can discount past evidence of how long a task should take. One experiment found that when people made their predictions anonymously, they do not show the optimistic bias. This suggests that the people make optimistic estimates so as to create a favorable impression with others.

Some[who?] have attempted to explain the planning fallacy in terms of impression management theory.

One explanation, focalism, may account for the mental discounting of off-project risks. People formulating the plan may eliminate factors they perceive to lie outside the specifics of the project. Additionally, they may discount multiple improbable high-impact risks because each one is so unlikely to happen.

Planners tend to focus on the project and underestimate time for sickness, vacation, meetings, and other "overhead" tasks. Planners also tend not to plan projects to a detail level that allows estimation of individual tasks, like placing one brick in one wall; this enhances optimism bias and prohibits use of actual metrics, like timing the placing of an average brick and multiplying by the number of bricks. Complex projects that lack immutable goals are also subject to mission creep, scope creep, and featuritis. As described by Fred Brooks in The Mythical Man-Month, adding new personnel to an already-late project incurs a variety of risks and overhead costs that tend to make it even later; this is known as Brooks's law.

Another possible explanation is the "authorization imperative": Much of project planning takes place in a context where financial approval is needed to proceed with the project. And the planner often has a stake in getting the project approved. This dynamic may lead to a tendency on the part of the planner to deliberately underestimate the project effort required. It is easier to get forgiveness (for overruns) than permission (to commence the project if a realistic effort estimate were provided.) Such deliberate underestimation has been named strategic misrepresentation.

Methods to curb the planning fallacy

Daniel Kahneman, Amos Tversky, and Bent Flyvbjerg developed reference class forecasting to eliminate or reduce the effects of the planning fallacy in decision making.

Anchoring

Anchoring or focalism is a cognitive bias that describes the common human tendency to rely too heavily, or "anchor," on one trait or piece of information when making decisions.

Background

During normal decision-making, anchoring occurs when individuals overly rely on a specific piece of information to govern their thought-process. Once the anchor is set, there is a bias toward adjusting or interpreting other information to reflect the "anchored" information. Through this cognitive bias, the first information learned about a subject (or, more generally, information learned at an early age) can affect future decision-making and information analysis.

For example, as a person looks to buy a used car, he or she may focus excessively on the odometer reading and model year of the car, and use those criteria as a basis for evaluating the value of the car, rather than considering how well the engine or the transmission is maintained.

Focusing effect

The focusing effect (or focusing illusion) is a cognitive bias that occurs when people place too much importance on one aspect of an event, causing an error in accurately predicting the utility of a future outcome.

People focus on notable differences, excluding those that are less conspicuous, when making predictions about happiness or convenience. For example, when people were asked how much happier they believe Californians are compared to Midwesterners, Californians and Midwesterners both said Californians must be considerably happier, when, in fact, there was no difference between the actual happiness rating of Californians and Midwesterners. The bias lies in that most people asked focused on and overweighed the sunny weather and ostensible easy-going lifestyle of California and devalued and underrated other aspects of life and determinants of happiness, such as low crime rates and safety from natural disasters like earthquakes (both of which large parts of California lack).

A rise in income has only a small and transient effect on happiness and well-being, but people consistently overestimate this effect. Kahneman et al. proposed that this is a result of a focusing illusion, with people focusing on conventional measures of achievement rather than on everyday routine.

Anchoring and adjustment heuristic

Anchoring and adjustment is a psychological heuristic that influences the way people intuitively assess probabilities. According to this heuristic, people start with an implicitly suggested reference point (the "anchor") and make adjustments to it to reach their estimate. A person begins with a first approximation (anchor) and then makes incremental adjustments based on additional information.

The anchoring and adjustment heuristic was first theorized by Amos Tversky and Daniel Kahneman. In one of their first studies, the two showed that when asked to guess the percentage of African nations which are members of the United Nations, people who were first asked "Was it more or less than 10%?" guessed lower values (25% on average) than those who had been asked if it was more or less than 65% (45% on average). The pattern has held in other experiments for a wide variety of different subjects of estimation. Others have suggested that anchoring and adjustment affects other kinds of estimates, like perceptions of fair prices and good deals.

Some experts say that these findings suggest that in a negotiation, participants should begin from extreme initial positions.

As a second example, an audience is first asked to write the last two digits of their social security number and consider whether they would pay this number of dollars for items whose value they did not know, such as wine, chocolate and computer equipment. They were then asked to bid for these items, with the result that the audience members with higher two-digit numbers would submit bids that were between 60 percent and 120 percent higher than those with the lower social security numbers, which had become their anchor.

Groupthink

Groupthink is a psychological phenomenon that occurs within groups of people. Group members try to minimize conflict and reach a consensus decision without critical evaluation of alternative ideas or viewpoints. Antecedent factors such as group cohesiveness, structural faults, and situational context play into the likelihood of whether or not groupthink will impact the decision-making process

The primary socially negative cost of groupthink is the loss of individual creativity, uniqueness, and independent thinking. While this often causes groupthink to be portrayed in a negative light, because it can suppress independent thought, groupthink under certain contexts can also help expedite decisions and improve efficiency. As a social science model, groupthink has an enormous reach and influences literature in the fields of communications, political science, social psychology, management, organizational theory, and information technology.

The majority of the initial research on groupthink was performed by Irving Janis, a research psychologist from Yale University. His original definition of the term was, “A mode of thinking that people engage in when they are deeply involved in a cohesive ingroup, when the members' strivings for unanimity override their motivation to realistically appraise alternative courses of action” (Janis, 1972). Since Janis’s work, other studies have attempted to reformulate his groupthink model. 'T Hart (1998) developed a concept of groupthink as “collective optimism and collective avoidance,” while McCauley (1989) pointed to the impact of conformity and compliance pressures on groupthink decisions.

History

William H. Whyte coined the term in 1952, in Fortune magazine:

Groupthink being a coinage — and, admittedly, a loaded one — a working definition is in order. We are not talking about mere instinctive conformity — it is, after all, a perennial failing of mankind. What we are talking about is a rationalized conformity — an open, articulate philosophy which holds that group values are not only expedient but right and good as well.

Irving Janis led the initial research on the groupthink theory. His main principle of groupthink states:

The more amiability and esprit de corps there is among the members of a policy-making ingroup, the greater the danger that independent critical thinking will be replaced by groupthink, which is likely to result in irrational and dehumanizing actions against outgroups.

Janis set the foundation for the study of groupthink starting with his research in the American Soldier Project where he studied the effect of extreme stress on group cohesiveness. After this study he remained interested in the ways in which people make decisions under external threats. This interest led Janis to study a number of 'disasters' in American foreign policy, such as failure to anticipate the Japanese attack on Pearl Harbor (1941); the Bay of Pigs fiasco (1961) when the US administration sought to overthrow Fidel Castro; and the prosecution of the Vietnam War (1964–67) by President Lyndon Johnson. He concluded that in each of these cases, the decisions were made largely due to groupthink, which prevented contradictory views from being expressed and subsequently evaluated.

After the publication of Janis' book Victims of Groupthink, in 1972, the concept of groupthink was used to explain many other faulty decisions in history. These events included Nazi Germany's decision to invade the Soviet Union in 1941, the Watergate Scandal and countless others. Despite this being such a popular topic less than two dozen studies were done on the phenomenon, after the publication of Victims of Groupthink, from the years 1972-1998. This is surprising considering how many fields of interests it spans, which include political science, communications, organizational studies, social psychology, management, strategy, counseling, and marketing. This lack of research is most likely due to the fact that group research is difficult to conduct, groupthink has many independent and dependent variables, and there is no clear-cut definition of it.

Bay of Pigs Invasion case study

The United States Bay of Pigs Invasion was one of the primary political case studies that Irving Janis used in explaining the theory groupthink. The invasion plan was initiated by the Eisenhower administration, but when the Kennedy White House took over, the plan was uncritically accepted, even after the plan was beginning to get leaked. Kennedy's ingroup was overly optimistic of the CIA's plan. When some members of the Kennedy administration, such as Arthur Schlesinger Jr. and Senator J. William Fulbright, attempted to present their objections to the plan, other members ignored these objections and kept believing in the morality of their plan. The administration began to judge Schlesinger because he questioned the policy. Eventually Schlesinger began to minimize his own doubts. The CIA made many assumptions, including the weakness of Castro's army and the lack of effectiveness of Castro's air force. Kennedy's ingroup believed the CIA's assumptions, and stereotyped Castro and the Cubans. Finally, the Bay of Pigs Invasion was marked with a huge reliance on consensual validation. Kennedy came into office trusting Eisenhower's policy and continued to trust the CIA's intelligence without question. The fiasco that ensued could have been prevented if the Administration had followed the remedies to preventing groupthink.

Pearl Harbor case study

The attack on Pearl Harbor on December 7, 1941 was a prime example of groupthink. A number of factors such as shared illusions and rationalizations contributed to the lack of precaution taken by Naval officers based in Hawaii. The United States had intercepted Japanese messages and they discovered that Japan was arming itself for an offensive attack. Washington took action by warning officers stationed at Pearl Harbor, but their warning was not taken seriously. They assumed that Japan was taking measures in the event that their embassies and consulates in enemy territories were usurped.

The Navy and Army in Pearl Harbor also shared rationalizations about why an attack was unlikely. Some of them included:

"The Japanese would never dare attempt a full-scale surprise assault against Hawaii because they would realize that it would precipitate an all-out war, which the United States would surely win."

"The Pacific Fleet concentrated at Pearl Harbor was a major deterrent against air or naval attack."

"Even if the Japanese were foolhardy to send their carriers to attack the United States, we could certainly detect and destroy them in plenty of time."

"No warships anchored in the shallow water of Pearl Harbor could ever be sunk by torpedo bombs launched from enemy aircraft."

In addition, officers succumbed to social pressures and did not want to face social scrutiny by objecting to the common belief that Japan would not attack Pearl Harbor.

At the end of the day, the leading officers at Pearl Harbor reinforced each other's feeling of invulnerability and it is the reason why the United States was defenseless against Japan's attacks.

Causes

Janis prescribed three antecedent conditions to groupthink.

High group cohesiveness

Structural faults:

insulation of the group
lack of impartial leadership
lack of norms requiring methodological procedures
homogeneity of members' social backgrounds and ideology

Situational context:

highly stressful external threats
recent failures
excessive difficulties on the decision-making task
moral dilemmas

Although it is possible for a situation to contain all three of these factors, all three are not always present even when groupthink is occurring. Janis considered a high degree of cohesiveness to be the most important antecedent to producing groupthink and always present when groupthink was occurring; however, he believed high cohesiveness would not not always produce groupthink. A very cohesive group abides to all group norms; whether or not groupthink arises is dependent on what the group norms are. If the group encourages individual dissent and alternative strategies to problem solving, it is likely that groupthink will be avoided even in a highly cohesive group. This means that high cohesion will lead to groupthink only if one or both of the other antecedents is present, situational context being slightly more likely than structural faults to produce groupthink.
Symptoms

To make groupthink testable, Irving Janis devised eight symptoms indicative of groupthink (1977).

Type I: Overestimations of the group—its power and morality

- Illusions of invulnerability creating excessive optimism and encouraging risk taking.
- Unquestioned belief in the morality of the group, causing members to ignore the consequences of their actions.

Type II: Closed-mindedness

- Rationalizing warnings that might challenge the group's assumptions.
- Stereotyping those who are opposed to the group as weak, evil, biased, spiteful, impotent, or stupid.

Type III: Pressures toward uniformity

- Self-censorship of ideas that deviate from the apparent group consensus.
- Illusions of unanimity among group members, silence is viewed as agreement.
- Direct pressure to conform placed on any member who questions the group, couched in terms of "disloyalty"
- Mind guards — self-appointed members who shield the group from dissenting information.

Groupthink, resulting from the symptoms listed above, results in defective decision-making. That is, consensus-driven decisions are the result of the following practices of groupthinking

- Incomplete survey of alternatives
- Incomplete survey of objectives
- Failure to examine risks of preferred choice
- Failure to reevaluate previously rejected alternatives
- Poor information search
- Selection bias in collecting information
- Failure to work out contingency plans.

Janis argued that groupthink was responsible for the Bay of Pigs 'fiasco' and other major examples of faulty decision-making. The UK bank Northern Rock, before its nationalisation, is thought to be a recent major example of groupthink. In such real-world examples, a number of the above groupthink symptoms were displayed.

Deindividuation

Cults are also studied by sociologists in regard to groupthink and its deindividuation effects. The textbook definition describes deindividuation as the loss of self-awareness and evaluation apprehension, which occurs in group situations that foster anonymity and draw attention away from the individual.

Prevention

It has been thought that groups with the strong ability to work together will be able to solve dilemmas in a quicker and more efficient fashion than an individual. Groups have a greater amount of resources which lead them to be able to store and retrieve information more readily and come up with more alternatives solutions to a problem. There was a recognized downside to group problem solving in that it takes groups more time to come to a decision and requires that people make compromises with each other. However, it was not until the research of Irving Janis appeared that anyone really considered that a highly cohesive group could impair the group's ability to generate quality decisions. Tightly-knit groups may appear to make decisions better because they can come to a consensus quickly and at a low energy cost; however, over time this process of decision making may decrease the members' ability to think critically. It is, therefore, considered by many to be important to combat the effects of groupthink.

According to Irving Janis, decision making groups are not necessarily destined to groupthink. He devised seven ways of preventing groupthink (209-15):

- Leaders should assign each member the role of “critical evaluator”. This allows each member to freely air objections and doubts.
- Higher-ups should not express an opinion when assigning a task to a group.
- The organization should set up several independent groups, working on the same problem.
- All effective alternatives should be examined.
- Each member should discuss the group's ideas with trusted people outside of the group.

- The group should invite outside experts into meetings. Group members should be allowed to discuss with and question the outside experts.
- At least one group member should be assigned the role of Devil's advocate. This should be a different person for each meeting.

By following these guidelines, groupthink can be avoided. After the Bay of Pigs invasion fiasco, President John F. Kennedy sought to avoid groupthink during the Cuban Missile Crisis. During meetings, he invited outside experts to share their viewpoints, and allowed group members to question them carefully. He also encouraged group members to discuss possible solutions with trusted members within their separate departments, and he even divided the group up into various sub-groups, to partially break the group cohesion. Kennedy was deliberately absent from the meetings, so as to avoid pressing his own opinion.

Assumptions

As observed by Aldag and Fuller (1993), the groupthink phenomenon seems to consistently uphold the following principles:

- The purpose of group problem solving is mainly to improve decision quality
- Group problem solving is considered a rational process.

Benefits of group problem solving:

- variety of perspectives
- more information about possible alternatives
- better decision reliability
- dampening of biases
- social presence effects
- Groupthink prevents theses benefits due to structural faults and provocative situational context
- Groupthink prevention methods will produce better decisions
- “An illusion of well-being is presumed to be inherently dysfunctional.”
- Group pressures towards consensus lead to concurrence-seeking tendencies

Empirical findings

Whether groupthink occurs in a situation is largely a subjective perception. Researchers hold different opinions as to the amount of agreement needed within a group to conclude the occurrence of groupthink. Even then, researchers argue whether the agreement comes about through the social influence of groupthink, or whether the agreement is simply a result of a clear, optimal solution. There is no fixed threshold of factors at which one can definitively conclude groupthink occurred. Instead, a particular group could be considered a victim of groupthink from the perspective of one researcher while remaining un-victimized in the eyes of another researcher. It is also incredibly difficult to test groupthink in the laboratory because it removes groups from real social situations, which changes the variables conducive or inhibitive to groupthink. Because of its subjectivity, researchers have struggled to measure groupthink as a complete phenomenon. Instead, they often opt to measure particular factors of the groupthink phenomenon. These factors range from causal to effectual and focus on group and situational aspects.

Cline's study

In a study done by Cline (1990), the correlation between groupthink and group cohesiveness was measured in an attempt to predict if group cohesiveness affected the occurrence of groupthink. Participants in the groupthink conditions reported significantly greater cohesiveness in their groups than participants in nongroupthink conditions. Cline explains this correlation as a result of the participants in the groupthink conditions bonding throughout the time spent in the experiment. Participant-reported group cohesiveness increased from the pre-experimental discussion to the post experimental discussion. Within the same study, agreement versus disagreement between the participants of a group was hypothesized to vary between groups in the groupthink condition and groups in the nongroupthink condition. The hypothesis was proven valid as "groupthink groups expressed proportionately more agreement than nongroupthink groups." Levels of disagreement were similar for groupthink and nongroupthink groups. The study also hypothesized that "groupthink groups express proportionately more simple agreements and proportionately fewer substantiated agreements than nongroupthink groups." Again, the hypothesis was proven valid as groupthink groups were shown to use more simple agreements and fewer substantiated agreements than nongroupthink groups.

Schafer's and Crichlow's study

Schafer and Crichlow (1996) performed an analytical study of the antecedent factors that are conducive to a group falling into groupthink. They measured whether groupthink occurred by gauging information-processing errors within the participant groups. The antecedent conditions most strongly predicting information-processing errors (and, in turn, groupthink) are group homogeneity, recent failure, high personal stress, group insulation, and perceived short time restraint. If the members of a group are highly similar, they will be more likely to engage in groupthink as a result of similar opinions and cost-benefit analysis. If a group recently failed at a task, the members will become more reserved in their idea generation, opting to support the most popular idea in order to avoid becoming the scapegoat. This process increases the likelihood of groupthink. If the individual members of a group are experiencing high stress, they will feel anxiety towards dissenting (which would produce more stress). An anxiety toward dissent increases the probability of groupthink. If a group is separated from external influence (including the influence of other groups), they will lack exposure to innovative thinking and dissenting opinion. This lack of exposure makes it difficult for group members to introduce new trains of thought into the group, thus prompting groupthink. If a group is under a short time restriction in generating ideas, it will feel anxious about spending time debating the value of dissenting opinions. Instead, the group will more likely commit to a popular idea and attempt to refine it with the time given. This process is conducive to groupthink.

Flowers' study

Flowers (1977) analyzed the number of solutions produced to a particular problem by four different groups. The groups were characterized by low or high cohesiveness and open or closed leadership. Open and closed leadership refer to the nature of the leader—whether they were open to new suggestions and respectful dissent or closed to it (rather headstrong). Her findings relate to groupthink in the sense that groupthink is often believed to limit the number of solutions created by a group. She analyzed two factors (cohesiveness and leadership style) that are commonly known to affect the occurrence of groupthink. High cohesiveness and closed leadership were predicted to be most conducive to groupthink. If groupthink were occurring, her results would show a decreased number of solutions produced by the respective groups. Flowers' results reveal that the group with the two characteristics most conducive to groupthink (high cohesiveness and closed leadership) produced the fewest number of solutions, thus indicating an occurrence of groupthink. The group with the characteristics opposite to those conducive to groupthink (low cohesiveness and open leadership) produced the greatest number of solutions, thus indicating that the type of leadership and cohesiveness within a group have an effect on groupthink. Closed leadership creates groupthink because members' dissenting opinions and innovations are labeled illegitimate by the authority figure, allowing the group to easily dismiss them as inferior options. High cohesiveness creates groupthink because members feel stronger personal ties to each other and are therefore more hesitant to disagree with others' opinions. A hesitancy to disagree reduces dissent and leads to groupthink.

Park's meta-analysis

Park (1990) conducted a meta-analysis of the results of 16 empirical studies on groupthink. The results of the analysis contradict the findings presented above as well as several of Janis' claims about groupthink antecedents (Janis is one of the founders of the groupthink concept). Park concludes, "despite Janis' claim that group cohesiveness is the major necessary antecedent factor, no research has showed a significant main effect of cohesiveness on groupthink." Park also concludes that research on the interaction between group cohesiveness and leadership style does not support Janis' claim that cohesion and leadership style interact to produce groupthink symptoms. Park presents a summary of the results of the studies analyzed. According to Park, a study by Huseman and Drive (1979) indicates groupthink occurs in both small and large decision making groups within businesses. This results partly from group isolation within the business. Manz and Sims (1982) conducted a study showing that autonomous work groups are susceptible to groupthink symptoms in the same manner as decisions making groups within businesses. Fodor and Smith (1982) produced a study revealing that group leaders with high power motivation create atmospheres more susceptible to groupthink. Leaders with high power motivation possess characteristics similar to leaders with a "closed" leadership style—an unwillingness to respect dissenting opinion. The same study indicates that level of group cohesiveness is insignificant in predicting groupthink occurrence. Park summarizes a study performed by Callaway, Marriot, and Esser (1985) in which groups with highly dominant members "made higher quality decisions, exhibited lowered state of anxiety, took more time to reach a decision, and made more statements of disagreement/agreement." Overall, groups with highly dominant members expressed characteristics inhibitory to groupthink. If highly dominant members are considered equivalent to leaders with high power motivation, the results of Callaway, Marriot, and Esser contradict the results of Fodor and Smith. A study by Leana (1985) indicates the interaction between level of group cohesion and leadership style is completely insignificant in predicting groupthink. This finding refutes Janis' claim that the factors of cohesion and leadership style interact to produce groupthink. Park summarizes a study by McCauley (1989) in which structural conditions of the group were found to predict groupthink while situational conditions did not. The structural conditions included group insulation, group homogeneity, and promotional leadership. The situational conditions included group cohesion. These findings refute Janis' claim about group cohesiveness predicting groupthink.

Overall, studies on groupthink have largely focused on the factors (antecedents) that predict groupthink. Groupthink occurrence is often measured by number of ideas/solutions generated within a group, but there is no uniform, concrete standard by which researchers can objectively conclude groupthink occurs. The studies of groupthink and groupthink antecedents reveal a mixed body of results. Some studies indicate group cohesion and leadership style to be powerfully predictive of groupthink, while other studies indicate the insignificance of these factors. Group homogeneity and group insulation are generally supported as factors predictive of groupthink.

Real-world application

Corporate world

Swissair's collapse

In the corporate world, ineffective and suboptimal group-making decision can negatively affect the health of a company and cause a considerable amount of monetary loss. Aaron Hermann and Hussain Rammal illustrate the detrimental role of groupthink in the collapse of Swissair, a Swiss airline company that was thought to be so financially stable that it earned the title the "Flying Bank." The authors argue that, among other factors, Swissair carried two symptoms of groupthink: the belief that the group is invulnerable and the belief in the morality of the group. In addition, prior to the fiasco, the size of the company board was reduced, subsequently eliminating industrial expertise. This may have further increased the likelihood of groupthink. With the board members lacking expertise in the field and having somewhat similar background, norms, and values, the pressure to conform may have become more prominent. This phenomenon is called group homogeneity, which is an antecedent to groupthink. Together, these conditions may have contributed to the poor decision-making process that eventually led to Swissair's collapse. As illustrated by Swissair's crisis, the ramification of groupthink can be monumental in the business world.

Politics

Some experts believe that groupthink also has a strong hold on political decisions and military operations, which may result in enormous expenditures of human and material resources. These scholars, including Janis and Raven, attribute political and military fiascos, such as the Bay of Pigs invasion, Vietnam War, and the Watergate scandal, to the effect of groupthink. More recently, Dina Badie argues that the invasion of Iraq by the United States was driven by groupthink. According to Badie, groupthink was largely responsible for the shift in the U.S. administration's view on Sadam Hussein that eventually led to military action in Iraq. After 9/11, "stress, promotional leadership, and intergroup conflict" were all factors that gave way to the occurrence of groupthink. Political case studies of groupthink serve to illustrate the impact that the occurrence of groupthink can have in today's political scene.

New arena: sports

Recent literature of groupthink attempts to study the application of this concept beyond the framework of business and politics. One particularly relevant and popular arena in which groupthink is rarely studied is sports. The lack of literature in this area prompted Charles Koerber and Christopher Neck to begin a case-study investigation that examined the effect groupthink on the decision of the Major League Umpires Association (MLUA) to stage a mass resignation in 1999. The decision was a failed attempt to gain a stronger negotiating stance against Major League Baseball. Koerber and Neck suggest that three groupthink symptoms can be found in the decision-making process of the MLUA. First, the umpires overestimated the power that they had over the baseball league and the strength of their group's resolve. The union also exhibited some degree of closed-mindedness with the notion that MLB is the enemy. Lastly, there was the presence of self-censorship; some umpires who disagreed with the decision to resign failed to voice their dissent. These factors, along with other decision-making defects, led to a decision that was suboptimal and ineffective.

Criticisms and recent development

Even though groupthink has become increasing popular to the general public and relevant in many fields over the last few decades, scholars still raise some reasonable doubts about the legitimacy of the concept. Some scholars, like opt for a new model in place of groupthink. Others wish to reformulate the original model by reexamining traditional case studies of groupthink and considering new theories and empirical findings.

New models

Ubiquity model

Researcher Robert Baron (2005) contends that the connection between certain antecedents Janis believed necessary have not been demonstrated by the current collective body of research on groupthink. He believes that Janis' antecedents for groupthink is incorrect and argues that not only are they "not necessary to provoke the symptoms of groupthink, but that they often will not even amplify such symptoms." As an alternative to Janis' model, Baron proposes a ubiquity model of groupthink. This model provides a revised set of antecedents for groupthink, including social identification, salient norms, and low self-efficacy.

GGPS

Aldag and Fuller (1993) argue that the concept was based on “small and relatively restricted sample” that became too broadly generalized. Furthermore, the concept is too rigidly staged and deterministic. Empirical support for it has also not been consistent. The authors compare groupthink model to findings presented by Maslow and Piaget; they argue that, in each case, the model incites great interest and further research that, subsequently, invalidate the original concept. Aldag and Fuller thus suggest a new model called the general group problem-solving (GGPS) model, which integrates new findings from groupthink literature and alters aspects of groupthink itself. Two main differences between GGPS and groupthink is that the former is more value neutral and political oriented. Further research is necessary to assess the validity of Aldag’s and Fuller’s model.

Reexamination

Other scholars attempt to assess the merit of groupthink by reexamining case studies that Janis had originally used to buttress his model. Roderick Kramer (1998) believe that, because scholars today have a more sophisticated set of ideas about the general decision-making process and because new and relevant information about the fiascos have surfaced over the years, a reexamination of the case studies is appropriate and necessary. He argues that new evidence does not support Janis’ view that groupthink was largely responsible for President Kennedy’s and President Johnson’s decisions in the Bay of Pigs invasion and U.S. escalated military involvement in the Vietnam War, respectively. Both presidents sought the advice of experts outside of their political groups more than Janis suggested. Kramer also argues that the presidents were the final decision-makers of the fiascos; while determining which course of action to take, they relied more heavily on their own construals of the situations than on any group-consenting decision presented to them. Kramer concludes that Janis’ explanation of the two military issues is flawed and that groupthink has much less influence on group decision-making than is popularly believed to be.

Reformulation

Some of the scholars who have contributed to a new understanding of groupthink include Glen Whyte, Clark McCauley, and Marlene Turner, and Anthony Partkanis. Whyte (1998) suggests that collective efficacy play a large role in groupthink because it causes groups to become less vigilant and to favor risks, two particular factors that characterize groups affected by groupthink. McCauley recasts aspects of groupthink's preconditions by arguing that the level of attractiveness of group members is the most prominent factor in causing poor decision-making. The results of Turner's and Partkanis' (1991) study on social identity maintenance perspective and groupthink conclude that groupthink can be viewed as a “collective effort directed at warding off potentially negative views of the group.”

Together, the contributions of these scholars have brought about new understandings of groupthink that help reformulate Janis' original model.

Conclusion

Looking forward, Groupthink continues to be a popular and somewhat controversial topic in psychology research. More than twenty major studies focusing on some aspect or application of Groupthink have been published since the beginning of 2010. One of the more popular current research trends includes comparing the prevalence of groupthink in a diverse corporate environment to that of a less diverse firm. Another ongoing study by Duval frames groupthink in the context of a small group social network.

While the exact form and extent to which groupthink occurs remains subjective based off individual researchers, there is strong evidence to show that such a phenomenon exists and impacts real-world decisions on a daily basis. Groups that are engaging in groupthink target the consensus group decision and bypass alternatives without careful consideration or discussion. Greater awareness of groupthink has the potential to help minimize social damage associated with its negative consequences.

Peer pressure

Peer pressure refers to the influence exerted by a peer group in encouraging a person to change his or her attitudes, values, or behavior in order to conform to group norms. Social groups affected include membership groups, when the individual is "formally" a member (for example, political party, trade union), or a social clique. A person affected by peer pressure may or may not want to belong to these groups. They may also recognize dissociative groups with which they would not wish to associate, and thus they behave adversely concerning that group's behaviors.

In young people, youth peer pressure is considered as one of the most frequently referred to forms of peer pressure. It is particularly common because most youth spend large amounts of time in fixed groups (schools and subgroups within them) regardless of their opinion of those groups. In addition to this, they may lack the maturity to handle pressure from 'friends'. Also, young people are more willing to behave negatively towards those who are not members of their own peer groups. However, youth peer pressure can also have positive effects. For example, if one is involved with a group of people that are ambitious and working to succeed, one might feel pressured to follow suit to avoid feeling excluded from the group. Sometimes the child is pressuring themselves. They feel like they need to be in this group to be "cool" or "in." Therefore, the youth would be pressured into improving themselves, bettering them in the long run. This is most commonly seen in youths that are active in sports or other extracurricular activities where conformity with one's peer group is strongest.

Risk behavior

While socially accepted children fare the best in high school due to having the most class resources, the most opportunities and the most positive experiences, research shows that being in the popular crowd may also be a risk factor for mild turtles

to moderate deviant behavior. Popular adolescents are the most socialized into their peer groups and thus are vulnerable to peer pressures, such as behaviors usually reserved for those of a greater maturity and understanding, such as the use of drugs. Adolescence is a time of experimentation with new identities and experiences. The culture of high school often has its own social norms that are different from the outside culture. Some of these norms may not be especially positive or beneficial. Socially accepted kids are often accepted for the sheer fact that they conform well to the norms of teen culture, good and bad aspects included. Popular adolescents are more strongly associated with their peer groups in which they may together experiment with things like alcohol, cigarettes and drugs. Although there are a few risk factors correlated with popularity, deviant behavior is often only mild to moderate. Regardless, social acceptance provides more overall protective factors than risk factors.

The Third Wave

The Third Wave was an experiment to demonstrate the appeal of fascism undertaken by history teacher Ron Jones with sophomore high school students attending his Contemporary History as part of a study of Nazi Germany. The experiment took place at Cubberley High School in Palo Alto, California, during the first week of April 1967. Jones, unable to explain to his students how the German populace could claim ignorance of the extermination of the Jewish people, decided to show them instead. Jones started a movement called "The Third Wave" and convinced his students that the movement is to eliminate democracy. The fact that democracy emphasizes individuality was considered as a drawback of democracy, and Jones emphasized this main point of the movement in its motto: "Strength through discipline, strength through community, strength through action, strength through pride". The Third Wave experiment is an example of risk behavior in authoritarian and peer pressure situations.

Benign peer pressure

Management

In management, benign peer pressure refers to a technique used to boost team members' motivation, proactiveness and self goal settings. It's one useful tool in leadership. Instead of direct delegation of tasks and results demanding, employees are in this case, induced into a behaviour of self propelled performance and innovation, by comparison feelings towards their peers. There are several ways peer pressure can be induced in a working environment. Examples are: training, team meetings. Training since the team member is in contact with people with comparable roles in other organizations. Team meetings since there will be an implicit comparison between every team member especially if the meeting agenda is the presentation of results and goal status.

School

In school, benign peer pressure refers to the achieving of school discipline and internal self-discipline (inner discipline within each individual) by democratic means. It is adduced that appropriate school learning theory and educational philosophy is decisive in preventing violence, and promoting learning, order, and discipline in schools. Children should be accorded the same human rights and freedoms as adults; they should be granted responsibility for the conduct of their affairs; and they should be full participants in the life of their community. Children of all ages are entitled to participate in all decisions affecting the school, without exception. They have a full and equal vote in deciding expenditures, in hiring and firing all employees (including teachers), and in making and enforcing the rules of the community. Typically, rules are made and business is handled at a weekly School Meeting, where each student, like each staff member, has one vote: freedom on individual rights' matters and peer justice.

Neural mechanisms

Neuroimaging identifies the anterior insula and anterior cingulate as key areas in the brain determining whether people conform in their preferences in regard to its being popular with their peer group.

Explanation

An explanation of how the peer pressure process works, called "the identity shift effect," is introduced by social psychologist, Wendy Treynor, who weaves together Festinger's two seminal social-psychological theories (on dissonance, which addresses internal conflict, and social comparison, which addresses external conflict) into a unified whole. According to Treynor's original "identity shift effect" hypothesis, the peer pressure process works in the following way: One's state of harmony is disrupted when faced with the threat of external conflict (social rejection) for failing to conform to a group standard. Thus, one conforms to the group standard, but as soon as one does, eliminating this external conflict, internal conflict is introduced (because one has violated one's own standards). To rid oneself of this internal conflict (self-rejection), an "identity shift" is undertaken, where one adopts the group's standards as one's own, thereby eliminating internal conflict (in addition to the formerly eliminated external conflict), returning one to a state of harmony. Although the peer pressure process begins and ends with one in a (conflict-less) state of harmony, as a result of conflict and the conflict resolution process, one leaves with a new identity—a new set of internalized standards.

Slippery slope

In debate or rhetoric, a slippery slope (also known as thin edge of the wedge, or the camel's nose) is a classic form of argument, arguably an informal fallacy. A slippery slope argument states that a relatively small first step leads to a chain of related events culminating in some significant effect, much like an object given a small push over the edge of a slope sliding all the way to the bottom. The strength of such an argument depends on the warrant, i.e. whether or not one can demonstrate a process which leads to the significant effect. The fallacious sense of "slippery slope" is often used synonymously with continuum fallacy, in that it ignores the possibility of middle ground and assumes a discrete transition from category A to category B. Modern usage avoids the fallacy by acknowledging the possibility of this middle ground.

Slippery slope arguments

The argument takes on one of various semantical forms:

In the classical form, the arguer suggests that making a move in a particular direction starts something on a path down a "slippery slope". Having started down the metaphorical slope, it will continue to slide in the same direction (the arguer usually sees the direction as a negative direction, hence the "sliding downwards" metaphor).

Modern usage includes a logically valid form, in which a minor action causes a significant impact through a long chain of logical relationships. Note that establishing this chain of logical implication (or quantifying the relevant probabilities) makes this form logically valid. The slippery slope argument remains a fallacy if such a chain is not established.

Some claims lie in between the two. For example: "If we accept censorship on most disgusting material, the politicians may easily widen the area under censorship. This has happened often before too, with far-reaching consequences. Therefore, we should completely avoid the slippery slope of censorship." This claim is not a fallacy: some people think that there is enough evidence for the claim to be probably true, some not.

Examples

Eugene Volokh's Mechanisms of the Slippery Slope (PDF version) analyzes various types of such slippage. Volokh uses the example "gun registration may lead to gun confiscation" to describe six types of slippage:

Cost-lowering: Once all gun-owners have registered their firearms, the government will know exactly from whom to confiscate them. Gun control opponents argue against limits on the sale of automatic attack weapons because the confiscation of sportsmen's shotguns will soon follow. Meanwhile, government officials defend their inflexible enforcement of a regulation, even in circumstances that are obviously unfair, because allowing an exception would open the floodgates.

Legal rule combination: Previously the government might need to search every house to confiscate guns, and such a search would violate the Fourth Amendment to the United States Constitution. Registration would eliminate that problem.

Attitude altering: People may begin to think of gun ownership as a privilege rather than a right, and thus regard gun confiscation less seriously.

Small change tolerance, colloquially referred to as the "boiling frog": People may ignore gun registration because it constitutes just a small change, but when combined with other small changes, it could lead to the equivalent of confiscation.

Political power: The hassle of registration may reduce the number of gun owners, and thus the political power of the gun-ownership bloc.

Political momentum: Once the government has passed this gun law it becomes easier to pass other gun laws, including laws like confiscation.

Slippery slope can also be used as a retort to the establishment of arbitrary boundaries or limitations. For example, one might argue that rent prices must be kept to $1,000 or less a month to be affordable to tenants in an area of a city. A retort invoking the slippery slope could go in two different directions:

Once such price ceilings become accepted, they could be slowly lowered, eventually driving out the landlords and worsening the problem.

If a $1,000 monthly rent is affordable, why isn't $1,025 or $1,050? By lumping the tenants into one abstract entity, the argument renders itself vulnerable to a slippery slope argument. A more careful argument in favor of price ceilings would statistically characterize the number of tenants who can afford housing at various levels based on income and choose a ceiling that achieves a specific goal, such as housing 80% of the working families in the area.

Sometimes a single action does indeed induce similar latter action. For example, judiciary decisions may set legal precedents.

The slippery slope as fallacy

The heart of the slippery slope fallacy lies in abusing the intuitively appreciable transitivity of implication, claiming that A leads to B, B leads to C, C leads to D and so on, until one finally claims that A leads to Z. While this is formally valid when the premises are taken as a given, each of those contingencies needs to be factually established before the relevant conclusion can be drawn. Slippery slope fallacies occur when this is not done—an argument that supports the relevant premises is not fallacious and thus isn't a slippery slope fallacy.

Often proponents of a "slippery slope" contention propose a long series of intermediate events as the mechanism of connection leading from A to B. The "camel's nose" provides one example of this: once a camel has managed to place its nose within a tent, the rest of the camel will inevitably follow. In this sense the slippery slope resembles the genetic fallacy, but in reverse.

As an example of how an appealing slippery slope argument can be unsound, suppose that whenever a tree falls down, it has a 95% chance of knocking over another tree. We might conclude that soon a great many trees would fall, but this is not the case. There is a 5% chance that no more trees will fall, a 4.75% chance that exactly one more tree will fall (and thus a 9.75% chance of 1 or fewer additional trees falling), and so on. There is a 92.3% chance that 50 or fewer additional trees will fall. The expected value of trees that will fall is 20. In the absence of some momentum factor that makes later trees more likely to fall than earlier ones, this "domino effect" approaches zero probability.

This form of argument often provides evaluative judgments on social change: once an exception is made to some rule, nothing will hold back further, more egregious exceptions to that rule.

Note that these arguments may indeed have validity, but they require some independent justification of the connection between their terms: otherwise the argument (as a logical tool) remains fallacious.

The "slippery slope" approach may also relate to the conjunction fallacy: with a long string of steps leading to an undesirable conclusion, the chance of all the steps actually occurring in sequence is less than the chance of any one of the individual steps occurring alone.

Supporting analogies

Several common analogies support slippery slope arguments. Among these are analogies to physical momentum, to frictional forces and to mathematical induction.

Momentum or frictional analogies

In the momentum analogy, the occurrence of event A will initiate a process which will lead inevitably to occurrence of event B. The process may involve causal relationships between intermediate events, but in any case the slippery slope schema depends for its soundness on the validity of some analogue for the physical principle of momentum. This may take the form of a domino theory or contagion formulation. The domino theory principle may indeed explain why a chain of dominos collapses, but an independent argument is necessary to explain why a similar principle would hold in other circumstances.

An analogy similar to the momentum analogy is based on friction. In physics, the static co-efficient of friction is always greater than the kinetic co-efficient, meaning that it takes more force to make an object start sliding than to keep it sliding. Arguments that use this analogy assume that people's habits or inhibitions act in the same way. If a particular rule A is considered inviolable, some force akin to static friction is regarded as maintaining the status quo, preventing movement in the direction of abrogating A. If, on the other hand, an exception is made to A, the countervailing resistive force is akin to the weaker kinetic frictional force. Validity of this analogy requires an argument showing that the initial changes actually make further change in the direction of abrogating A easier.

Induction analogy

Another analogy resembles mathematical induction. Consider the context of evaluating each one of a class of events A1, A2, A3,..., An (for example, is the occurrence of the event harmful or not?). We assume that for each k, the event Ak is similar to Ak+1, so that Ak has the same evaluation as Ak+1.

Therefore every An has the same evaluation as A'1.

For example, the following arguments fit the slippery slope scheme with the inductive interpretation

If we grant a building permit to build a religious structure in our community, then there will be no bound on the number of building permits we will have to grant for religious structures and the nature of this city will change. This argument instantiates the slippery slope scheme as follows: Ak is the situation in which k building permits are issued. One first argues that the situation of k permits is not significantly different from the one with k + 1 permits. Moreover, issuing permits to build 1000 religious structures in a city of 300,000 will clearly change the nature of the community.

In most real-world applications such as the one above, the naïve inductive analogy is flawed because each building permit will not be evaluated the same way (for example, the more religious structures in a community, the less likely a permit will be granted for another).

Measuring the slippery slope

When a principle is based on direct proportion and the circumstance cannot be made to fit that principle, then the discrepancy is taken as indication of failure. The impression becomes pessimistic when there is continual failure at meeting the ideal principle, such as in a democratic or justice context. To overcome the pessimism that appears when sliding on the slippery slope of injustice, one requires a measurement of discrepancy. Then successive efforts can be compared and the slippery illusion dispelled. Scientists have used hyperbolic coordinates in technical work to deal with parameters similar to those giving the slippery slope scenario.

Attribution (psychology)

Attribution is a concept in social psychology referring to how individuals explain causes of behavior and events. Attribution theory is an umbrella term for various theories that attempt to explain these processes. Fritz Heider first proposed a theory of attribution The Psychology of Interpersonal Relations (1958). It was further developed by others such as Harold Kelley and Bernard Weiner.

Causes

Fritz Heider argued that, as an active perceiver of the events, the average person continuously or spontaneously makes causal inferences on why the events occur. For example, they make inferences about why some people succeed on a task or they make inferences about how their own behavior influences someone else. Eventually, these inferences become beliefs or expectations that allow the person to predict and understand the events that they observe and experience.

Types

Explanatory attribution

People make explanatory attributions to understand the world and seek reasons for a particular event. Explanatory attribution plays an important role in understanding what is happening around us. For example, let's say Jaimie's car tire got punctured. Jaimie will make attributions by reasoning that it was the hole on the road that made the puncture. The tire puncture might be due to Jaimie's bad driving habit but by making attributions to the poor road condition, Jaimie has successfully made sense of this unfortunate event. Without the attributional explanations, Jaimie will be very embarrassed and discomforted to believe that she caused the puncture.

Predictive attribution

Attributions not only serve as an explanation of an event but it can also predict future events. People want to know and understand why the event happened, but they also want to prevent it from happening again. Once people know why the event happened, their future is more predictable. For example, if Jaimie believes that the tire puncture is from the holes on the road, she can drive through the less holy road; if Jaimie thinks her driving habit contributed to the puncture, she can drive more carefully to avoid the similar incident. Similarly, people can use attributions to predict future events and to prevent the same incident from happening.

Interpersonal attribution

Sometimes, when your action or motives for the action are questioned, you need to explain the reasons for your action. Interpersonal attributions happen when the causes of the events involve two or more individuals. More specifically, you will always want to present yourself in the most positive light in interpersonal attributions. For example, let's say Jaimie and her boyfriend had a fight. When Jaimie explains her situation to her friends, she will say she tried everything to avoid a fight but she will blame her boyfriend that he nonetheless started a fight. This way, Jaimie is seen as a peacemaker to her friends whereas her boyfriend is seen as the one who started it all.

Theories

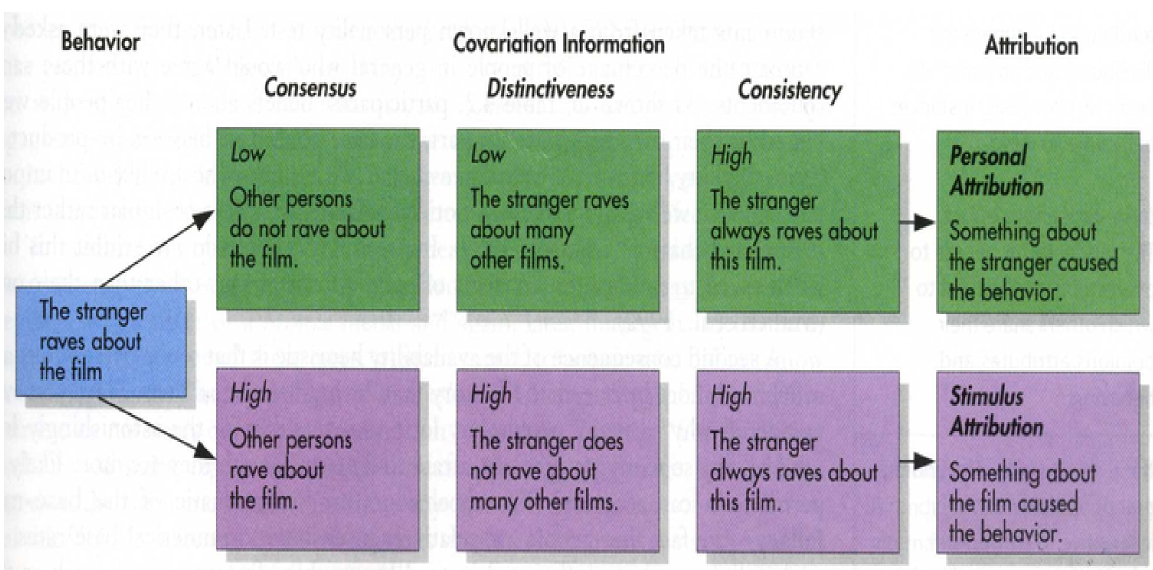
Common sense psychology

From the book The Psychology of Interpersonal Relations(1958), Fritz Heider tried to explore the nature of interpersonal relationship, and espoused the concept of what he called "common sense" or "naïve psychology". In his theory, he believed that people observe, analyze, and explain behaviors with explanations. Although people have different kinds of explanations for the events of human behaviors, Heider found it is very useful to group explanation into two categories; Internal (personal) and external (situational) attributions. When an internal attribution is made, the cause of the given behavior is assigned to the individual's characteristics such as ability, personality, mood, efforts, attitudes, or disposition. When an external attribution is made, the cause of the given behavior is assigned to the situation in which the behavior was seen such as the task, other people, or luck (that the individual producing the behavior did so because of the surrounding environment or the social situation). These two types lead to very different perceptions of the individual engaging in a behavior.

Correspondent inference theory

Correspondent inferences state that people make inferences about a person when his or her actions are freely chosen, are unexpected, and result in a small number of desirable effects. According to Edward E. Jones and Keith Davis' Correspondent Inference Theory, people make correspondent inferences by reviewing the context of behavior. It describes how people try to find out individual's personal characteristics from the behavioral evidence. People make inferences on the basis of three factors; degree of choice, expectedness of behavior, and effects of someone's behaviors.

Covariation model of attribution



When there is low consensus and distinctiveness, people make personal attributions for behaviors that are high in consistency(top row). On the other hand, people make stimulus attributions when there is high consensus and distinctiveness (bottom low).

Co-variation principle states that people attribute behavior to the factors that are present when a behavior occurs and absent when it does not. Thus, the theory assumes that people make causal attributions in a rational, logical fashion, and that they assign the cause of an action to the factor that co-varies most closely with that action. Harold Kelley's covariation model of Attribution looks to three main types of information from which to make an attribution decision about an individual's behavior. The first is consensus information, or information on how other people in the same situation and with the same stimulus behave. The second is distinctiveness information, or how the individual responds to different stimuli. The third is consistency information, or how frequent the individual's behavior can be observed with similar stimulus but varied situations. From these three sources of information observers make attribution decisions on the individual's behavior as either internal or external. Kelly’s theory and the examples of prediction are represented in the diagram.

Three dimensional model of attribution

Bernard Weiner proposed that individuals have initial affective responses to the potential consequences of the intrinsic or extrinsic motives of the actor, which in turn influence future behavior. That is, a person's own perceptions or attributions determine the amount of effort the person will engage in activities in the future. Weiner suggests that individuals exert their attribution search and cognitively evaluate casual properties on the behaviors they experience. When attributions lead to positive affect and high expectancy of future success, such attributions should result in greater willingness to approach to similar achievement tasks in the future than those attributions that produce negative affect and low expectancy of future success. Eventually, such affective and cognitive assessment influences future behavior when individuals encounter similar situations.

Weiner's achievement attribution has three categories:

1. stable theory (stable and unstable)
2. locus of control (internal and external)
3. control (controllable or uncontrollable)

Stability influence individuals' expectancy about their future; control is related with individuals' persistence on mission; causality influences emotional responses to the outcome of task.

Bias and errors in attributions

While people strive to find reasons for behaviors, they fall into many traps of biases and errors. Therefore, it’s best to know those mistakes to avoid them. As Fritz Heider says, “our perceptions of causality are often distorted by our needs and certain cognitive biases”. Here are some examples of attributional biases that people should look out for.

Fundamental attribution error

The fundamental attribution error is a cognitive bias in which people put too much emphasis on internal, dispositional factors in explaining people's behaviors rather than explaining them in terms of situational factors. In other words, people believe an action was done because of the actor's personality rather than the situation faced by the actor. For example, when a student fails to turn in a homework assignment, a teacher is too ready to assume that the student was too lazy to finish the homework, without sufficiently taking into account the situation that the student was in.

Culture bias

People in individualist cultures value individuals, personal goals, and independence.

People in collectivist cultures see individuals as members of groups such as families, work units, and nations, and tend to value conformity and interdependence.

Generally, North America and Western Europe embrace individualist culture while Asia, Latin America, and Africa embrace collectivist culture.

Research shows that culture, either individualist or collectivist, affects how people make attributions.

People from individualist cultures are more inclined to make fundamental-attribution error than people from collectivist cultures. Individualist cultures tend to attribute a person's behavior to his internal factors whereas collectivist cultures tend to attribute a person's behavior to his external factors.

Research suggests that individualist cultures engage in self-serving bias more than do collectivist cultures, ie individualist cultures tend to attribute success to internal factors and to attribute failure to external factors. In contrast, collectivist cultures engage in the opposite of self-serving bias ie self-effacing bias, which is: attributing success to external factors and blaming failure on internal factors (the individual).

Spotlight effect error

The spotlight effect error is the tendency of an individual to overestimate the extent to which others are paying attention to the individual's appearance and behavior. That is, people believe that they are in the "spotlight" and that everyone is paying attention to them, as when a person drops a cup in a restaurant and gets embarrassed, believing that everyone has seen it. "The Barry Manilow t-shirt experiment" demonstrates the spotlight effect. Students got self-conscious when they were required to wear a t-shirt with an unpopular picture to classes. The students believed more than 50 percent of their classmates would notice their shirts and judge them, when in fact fewer than 20 percent even noticed the t-shirt.

Actor/observer difference

People tend to attribute other people's behaviors to their dispositional factors while attributing own actions to situational factors. Basically, even in the same situation, people's attribution can differ depending on their role(actor or observer). For example, when a person gets a low grade on a test, he finds situational factors to justify the negative event such as saying that the teacher asked a question that she never went over in class. However, if other people get low grades on the test, he attributes the results to their internal factors such as laziness and inattentiveness in classes. The actor/observer bias is used less frequently with people one knows well such as friends and family since one knows how his/her close friends and family will behave in certain situation, leading him/her to think more about the external factors rather than internal factors.

Dispositional attributions

Dispositional attribution is a tendency to attribute people's behaviors to their dispositions that is to their personality, character and ability. For example, when a normally nice waiter is being rude to his customer, the customer will assume he has a bad temper. The customer, just by looking at the attitude that the waiter is giving him, instantly decides that the waiter is a bad person. The customer oversimplifies the situation by not taking into account all the unfortunate events that might have happened to the waiter which made him become rude at that moment. Therefore, the customer made dispositional attribution by attributing the waiter's behavior directly to his personality rather than considering situational factors that might have caused the whole "rudeness".

Self-serving bias

Self serving bias is attributing dispositional and internal factors for success and external, uncontrollable factor for failure. For example, if a person gets promoted, it is because of his/her ability and competence whereas if he/she does not get promoted, it is because his/her manager does not like him/her (external, uncontrollable factor). Originally, researchers assumed that self-serving bias is strongly related to the fact that people want to protect their self-esteem. However, alternative information processing explanation came out. That is, when the outcomes match people's expectations, they make attributions to internal factors; when the outcome does not match their expectations, they make external attributions. People also use defensive attribution to avoid feelings of vulnerability and to differentiate himself from a victim of a tragic accident.

For example, people believe in just-world hypothesis that "good things happen to good people and bad things happen to bad people" to avoid feeling vulnerable. This also leads to blaming the victim even in a tragic situation. When people hear someone died from a car accident, they reassure that the accident will never happen to them by deciding that the driver was drunk at the time of the accident. People automatically decide that it was the driver's fault drunk-driving and thus it will never happen to them. Another example of defensive attribution is optimism bias in which people believe positive events happen to them more than to the others and that negative events happen to them less than to the others. Too much optimism leads people to ignore some warnings and precautions given to them. For example, smokers believe they are less likely than other smokers to get a lung cancer.

Application of attribution

Learned helplessness

Learned helplessness was first found in animals when psychologists Martin Seligman and Steven F. Maier discovered that the classically conditioned dogs that got electrical shocks made no attempt to escape the situation. The dogs were placed in a box divided into two sections by a low barrier. Since one side of the box was electrified and the other was not, the dogs could easily avoid electrical shocks by hopping to the other side. However, the dogs just stayed in the electrified side, helpless to change the situation. This learned helplessness also applies to human beings. People feel helpless when they feel powerless to change their situation. This happens when people attribute negative results to their internal, stable and global factors leading them to think they have no control over their situation. Making no attempt to avoid or better the situation will often exacerbate the situations that people are faced and may lead them to clinical depression and related mental illnesses.

Perceptual salience and attribution

When people try to make attributions about another's behavior, their information focuses on the individual. Their perception of that individual is lacking most of the external factors which might affect the individual. The gaps tend to be skipped over and the attribution is made based on the perception information most salient. The most salient perceptual information dominates a person's perception of the situation.

For individuals making behavioral attributions about themselves, the situation and external environment are entirely salient, but their own body and behavior are less so. This leads to the tendency to make an external attribution in regards to one's own behavior.

Criticism

Attribution theory has been criticized as being mechanistic and reductionist for assuming that people are rational, logical and systematic thinkers. It turns out however that they are cognitive misers and motivated tacticians as demonstrated by the Fundamental attribution error. It also fails to address the social, cultural and historical factors that shape attributions of cause. This has been addressed extensively by discourse analysis, a branch of psychology that prefers to use qualitative methods including the use of language to understand psychological phenomena. The linguistic categorization theory for example demonstrates how language influences our attribution style.

Bounded rationality

Bounded rationality is the idea that in decision making, rationality of individuals is limited by the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make decisions. It was proposed by Herbert Simon as an alternative basis for the mathematical modeling of decision making, as used in economics and related disciplines; it complements rationality as optimization, which views decision making as a fully rational process of finding an optimal choice given the information available. Another way to look at bounded rationality is that, because decision-makers lack the ability and resources to arrive at the optimal solution, they instead apply their rationality only after having greatly simplified the choices available. Thus the decision-maker is a satisficer, one seeking a satisfactory solution rather than the optimal one. Simon used the analogy of a pair of scissors, where one blade is the "cognitive limitations" of actual humans and the other the "structures of the environment"; minds with limited cognitive resources can thus be successful by exploiting pre-existing structure and regularity in the environment.

Some models of human behavior in the social sciences assume that humans can be reasonably approximated or described as "rational" entities (see for example rational choice theory). Many economics models assume that people are on average rational, and can in large enough quantities be approximated to act according to their preferences. The concept of bounded rationality revises this assumption to account for the fact that perfectly rational decisions are often not feasible in practice due to the finite computational resources available for making them.

Models of bounded rationality

The term is thought to have been coined by Herbert Simon. In Models of Man, Simon points out that most people are only partly rational, and are emotional/irrational in the remaining part of their actions. In another work, he states "boundedly rational agents experience limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information" (Williamson, p. 553, citing Simon). Simon describes a number of dimensions along which "classical" models of rationality can be made somewhat more realistic, while sticking within the vein of fairly rigorous formalization. These include:

- limiting what sorts of utility functions there might be.
- recognizing the costs of gathering and processing information.
- the possibility of having a "vector" or "multi-valued" utility function.

Simon suggests that economic agents employ the use of heuristics to make decisions rather than a strict rigid rule of optimization. They do this because of the complexity of the situation, and their inability to process and compute the expected utility of every alternative action. Deliberation costs might be high and there are often other concurrent economic activities also requiring decisions.

Daniel Kahneman proposes bounded rationality as a model to overcome some of the limitations of the rational-agent models in economic literature.

As decision makers have to make decisions about how and when to decide, Ariel Rubinstein proposed to model bounded rationality by explicitly specifying decision-making procedures. This puts the study of decision procedures on the research agenda.

Gerd Gigerenzer argues that most decision theorists who have discussed bounded rationality have not really followed Simon's ideas about it. Rather, they have either considered how people's decisions might be made sub-optimal by the limitations of human rationality, or have constructed elaborate optimising models of how people might cope with their inability to optimize. Gigerenzer instead proposes to examine simple alternatives to a full rationality analysis as a mechanism for decision making, and he and his colleagues have shown that such simple heuristics frequently lead to better decisions than the theoretically optimal procedure.

From a computational point of view, decision procedures can be encoded in algorithms and heuristics. Edward Tsang argues that the effective rationality of an agent is determined by its computational intelligence. Everything else being equal, an agent that has better algorithms and heuristics could make "more rational" (more optimal) decisions than one that has poorer heuristics and algorithms.

Predispositioning Theory

Predispositioning Theory in the field of decision theory and systems theory is a theory, that focused on the intermediate stage between a complete order and a complete disorder.

Predispositioning Theory was founded by Aron Katsenelinboigen (1927–2005), a Professor in Wharton School who dealt with indeterministic systems such as chess, business, economics, and other fields of knowledge and also made an essential step forward in elaboration of styles and methods of decision-making.

Predispositioning Theory

Predispositioning Theory is focused on the intermediate stage between a complete order and a complete disorder. According to Katsenelinboigen, the system develops gradually, going through several stages, starting with incomplete and inconsistent linkages between its elements and ending with complete and consistent ones.

“Mess. The zero phase can be called a mess because it contains no linkages between the system's elements. Such a definition of mess as ‘a disorderly, un-tidy, or dirty state of things’ we find in Webster's New World Dictionary. (…)

Chaos. Mess should not be confused with the next phase, chaos, as this term is understood today. Arguably, chaos is the first phase of indeterminism that displays sufficient order to talk of the general problem of system development. The chaos phase is characterized by some ordering of accumulated statistical data and the emergence of the basic rules of interactions of inputs and outputs (not counting boundary conditions). Even such a seemingly limited ordering makes it possible to fix systemic regularities of the sort shown by Feigenbaum numbers and strange attractors.

(…) Different types of orderings in the chaos phase may be brought together under the notion of directing, for they point to a possible general direction of system development and even its extreme states. But even if a general path is known, enormous difficulties remain in linking algorithmically the present state with the final one and in operationalizing the algorithms. These oblectives are realized in the next two large phases that I call predispositioning and programming. (…) Programming. When linkages between states are established through reactive procedures, either by table functions or analytically, it is often assumed that each state is represented only by essentials. For instance, the production function in economics ties together inputs and outputs in physical terms. When a system is represented as an equilibrium or an optimization model, the original and conjugated parameters are stated explicitly; in economics, they are products (resources) and prices, respectively.9 Deterministic economic models have been extensively formalized; they assume full knowledge of inputs, outputs, and existing technologies. (…) Predispositioning (…) exhibits less complete linkages between system's elements than programming but more complete than chaos."

Methods like programming and randomness are well-known and developed while the methodology for the intermediate stages lying between complete chaos and complete order as well as their philosophical conceptualization have never been discussed explicitly and no methods of their measurements were elaborated. According to Katsenelinboigen, operative sub-methods of dealing with the system are programming, predispositioning, and randomness. They correspond to three stages of systems development. Programming is a formation of complete and consistent linkages between all the stages of the systems' development. Predispositioning is a formation of semi-efficient linkages between the stages of the system's development. In other words, predispositioning is a method responsible for creation of a predisposition.

Randomness is a formation of inconsistent linkages between the stages of the system's development. In this context, for instance, Darwinism emphasizes the exclusive role of chance occurrences in the system's development since it gives top priority to randomness as a method. Conversely, creationism states that the system develops in a comprehensive fashion, i.e. that programming is the only method involved in the development of the system. As Aron Katsenelinboigen notices, both schools neglect the fact that the process of the system's development includes a variety of methods which govern different stages, depending on the systems' goals and conditions.

Unfortunately, predispositioning as a method as well as a predisposition as an intermediate stage have never been discussed by scholars, though there were some interesting intuitive attempts to deal with the formation of a predisposition. The game of chess, at this point, was one of the most productive fields in the study of predispositioning as a method. Owing to chess' focus on the positional style, it elaborated a host of innovative strategies and tactics that Katsenelinboigen analyzed and systematized and made them a basis for his theory. To sum up, the main focus of Predispositioning Theory is on the intermediate stage of systems development, the stage that Katsenelinboigen proposed to call a Predisposition. This stage is distinguished by semi-complete and semi-consistent linkages between its elements. The most vital question when dealing with semi-complete and semi-consistent stages of the system is the question of its evaluation. To this end, Katsenelinboigen elaborated his structure of values, using the game of chess as a model.

Structure of values

According to Katsenelinboigen's Predispositioning Theory, in the chess game pieces are evaluated from two basic points of view – their weight in a given position on the chessboard and their weight independent to any particular position. Based on the degree of conditionality, the values are:

- Fully unconditional
- Unconditional
- Semi-conditional
- Conditional

According to Katsenelinboigen, game pieces in chess are evaluated from two basic points of view: their weight with regard to a certain situation on the chessboard and their weight without regard to any particular situation, only to the position of the pieces. The latter are defined by Katsenelinboigen as semi-unconditional values, formed by the sole condition of the rules of piece interaction. The semiunconditional values of the pieces (such as queen 9, rook 5, bishop 3, knight 3, and pawn 1) appear as a result of the rules of interaction of a piece with the opponent's king. All other conditions, such as starting conditions, final goal, and a program that links the initial condition to the final state, are not taken into account. The degree of conditionality is increased by applying preconditions, and the presence of all four preconditions fully forms conditional values.

Katsenelinboigen outlines two extreme cases of the spectrum of values—fully conditional and fully unconditional—and says that, in actuality, they are ineffectual in evaluating the material and so are sometimes replaced by semiconditional or semiunconditional valuations, which are distinguished by their differing degrees of conditionality. He defines fully conditional values as those based on complete and consistent linkages among all four preconditions."

The conditional values are formed by the four basic conditions:

- starting conditions
- final goal
- a program that links the initial conditions with the final state

- rules of interaction

The degree of unconditionality is predicated by the necessity to evaluate things under uncertainty (when the future is unknown) and conditions cannot be specified.

Applying his concept of values to social systems, Katsenelinboigen shows how the degree of unconditionality forms morality and law. According to him, the moral values represented in the Torah as the Ten Commandments are analogous to semi-unconditional values in a chess game, for they are based exclusively on the rules of interactions.

"The difference between these two approaches is clearly manifested in the various translations of the Torah. For instance, The Holy Scriptures (1955), a new translation based on the masoretic text (a vast body of the textual criticism of the Hebrew Bible), translates the commandment as 'Thou shalt not commit murder.' In The Holy Bible, commonly known as the authorized (King James) version (The Gideons International, 1983), this commandment is translated as 'Thou shalt not kill.' (...) The difference between unconditional and semi-unconditional evaluations will become more prominent if we use the same example of 'Thou shalt not kill and 'Thou shalt not murder' to illustrate the conduct of man in accordance with his precepts. In an extreme case, one who follows 'Thou shalt not kill' will allow him¬self to be killed before he kills another. These views are held by one of the Hindu sects in Sri Lanka (the former Ceylon). To the best of my knowledge, the former prime minister of Ceylon, Solomon Bandaranaike (1899-1959), belonged to this sect. He did not allow himself to kill an attacker and was murdered. As he lay bleeding to death, he did crawl over to the murderer and knock the pistol from his hand before it could be used against his wife, Sirimavo Bandaranaike. She later became the prime minister of Ceylon-Sri Lanka."

But how does one ascribe weights to certain parameters, establishes the degree of conditionality, etc.? How does the evaluative process go in indeterministic systems?
The role of subjectivity

Katsenelinboigen states that the evaluative category for indeterministic systems is based on subjectivity. "This pioneering approach to the evaluative process is the subject of Katsenelinboigen's work on indeterministic systems. The roots of one's subjective evaluation lie in the fact that the executor cannot be separated from the evaluator, who evaluates the system in accordance with his or her own particular ability to develop it. This can be observed in chess, in which the same position is evaluated differently by different chess players, or in literature with regard to hermeneutics."

Katsenelinboigen writes:

The subjective element arises not because the set of positional parameters and their valuations are formed based on a player's intuition. Rather, the choice of relevant parameters depends on the actual executor of the position, that is, the particular strengths and weaknesses of a given player. The role of the executor becomes vital because the actual realization of the position is not known beforehand, so future moves will have to be made based on the contingent situation at hand.

Katsenelinboigen clearly explains why subjectivity of the managerial decision is inevitable:

"The original subjective evaluation of the situation by the decision-maker is critical in the creative strategic management. Subjectivity of the managerial decisions is inevitable due to the intrinsically indeterministic nature of the strategic management, meaning that the subjectivity arises not just because of the lack of scientific foundation in business management. The effective approach to the strategic decision-making, as demonstrated in the game of chess, presupposes that each player has a unique, individual vision of his strategic position. To make it more systematic, one should not substitute the player's intuition with some objective laws that relate essential and positional parameters, but rather complement the intuition with the statistical analysis."

To sum up, subjectivity becomes an important factor in evaluating a predisposition. The roots of one's subjective evaluation lie in the fact that the executor cannot be separated from the evaluator who evaluates the system in accordance with his own particular ability to develop it.

The structure of values plays an essential part in calculus of predisposition.

Calculus of Predispositions

Calculus of Predispositions, a basic part of Predispositioning Theory, belongs to the indeterministic procedures. "The key component of any indeterministic procedure is the evaluation of a position. Since it is impossible to devise a deterministic chain linking the inter-mediate state with the outcome of the game, the most complex component of any indeterministic method is assessing these intermediate stages. It is precisely the function of predispositions to assess the impact of an intermediate state upon the future course of development." According to Katsenelinboigen, calculus of predispositions is another method of computing probability. Both methods may lead to the same results and, thus, can be interchangeable. However, it is not always possible to interchange them since computing via frequencies requires availability of statistics, possibility to gather the data as well as having the knowledge of the extent to which one can interlink the system's constituent elements. Also, no statistics can be obtained on unique events and, naturally, in such cases the calculus of predispositions becomes the only option. The procedure of calculating predispositions is linked to two steps – dissection of the system on its constituent elements and integration of the analyzed parts in a new whole. According to Katsenelinboigen, the system is structured by two basic types of parameters – material and positional. The material parameters constitute the skeleton of the system. Relationships between them form positional parameters. The calculus of predispositions primarily deals with:

- analyzing the system's material and positional parameters as independent variables and

- measuring them in unconditional valuations.

In order to quantify the evaluation of a position we need new techniques, which I have grouped under the heading of calculus of predispositions. This calculus is based on a weight function, which represents a variation on the well-known criterion of optimality for local extremum. This criterion incorporates material parameters and their conditional valuations. The following key elements distinguish the modified weight function from the criterion of optimality:

First and foremost, the weight function includes not only material parameters as independent (controlling) variables, but also positional (relational) parameters.

The valuations of material and positional parameters composing the weight function are, to a certain extent, unconditional; that is, they are independent of the specific conditions, but do take into account the rules of the game and statistics (experience)."

To conclude, there are some basic differences between frequency-based and predispositions-based methods of computing probability.

- The frequency-based method is grounded in statistics and frequencies of events.
- The predispositions-based method approaches a system from the point of view of its predisposition. It is used when no statistics is available.
- The predispositions-based method is used for the novel and unique situations.

According to Katsenelinboigen, the two methods of computing probability may complement each other if, for instance, are applied to a multilevel system with the increasing complexity of its composition at higher levels.

Pyrrhic victory

A Pyrrhic victory is a victory with devastating cost to the victor; it carries the implication that another such victory will ultimately cause defeat.

Origin

The phrase is named after King Pyrrhus of Epirus, whose army suffered irreplaceable casualties in defeating the Romans at Heraclea in 280 BC and Asculum in 279 BC during the Pyrrhic War. After the latter battle, Plutarch relates in a report by Dionysius:

The armies separated; and, it is said, Pyrrhus replied to one that gave him joy of his victory that one more such victory would utterly undo him. For he had lost a great part of the forces he brought with him, and almost all his particular friends and principal commanders; there were no others there to make recruits, and he found the confederates in Italy backward. On the other hand, as from a fountain continually flowing out of the city, the Roman camp was quickly and plentifully filled up with fresh men, not at all abating in courage for the loss they sustained, but even from their very anger gaining new force and resolution to go on with the war. – Plutarch

In both of Pyrrhus's victories, the Romans suffered greater casualties than Pyrrhus did. However, the Romans had a much larger supply of men from which to draw soldiers, so their casualties did less damage to their war effort than Pyrrhus's casualties did to his.

The report is often quoted as "Another such victory and I come back to Epirus alone," or "If we are victorious in one more battle with the Romans, we shall be utterly ruined."

Although it is most closely associated with a military battle, the term is used by analogy in fields such as business, politics, law, literature, and sports to describe any similar struggle which is ruinous for the victor. For example, the theologian Reinhold Niebuhr, writing of the need for coercion in the cause of justice, warned, "Moral reason must learn how to make coercion its ally without running the risk of a Pyrrhic victory in which the ally exploits and negates the triumph." Further, in Beauharnais v. Illinois, a United States Supreme Court decision involving a charge under an Illinois statute proscribing group libel, Justice Black, in his dissent, warned that "[i]f minority groups hail this holding as their victory, they might consider the possible relevancy of this ancient remark: 'Another such victory and I am undone.'"

Confirmation bias

Confirmation bias (also called confirmatory bias or myside bias) is a tendency for people to favor information that confirms their preconceptions or hypotheses regardless of whether the information is true.[Note 1] As a result, people gather evidence and recall information from memory selectively, and interpret it in a biased way. The biases appear in particular for emotionally significant issues and for established beliefs. For example, in reading about gun control, people usually prefer sources that affirm their existing attitudes. They also tend to interpret ambiguous evidence as supporting their existing position. Biased search, interpretation and/or recall have been invoked to explain attitude polarization (when a disagreement becomes more extreme even though the different parties are exposed to the same evidence), belief perseverance (when beliefs persist after the evidence for them is shown to be false), the irrational primacy effect (a stronger weighting for data encountered early in an arbitrary series) and illusory correlation (in which people falsely perceive an association between two events or situations).

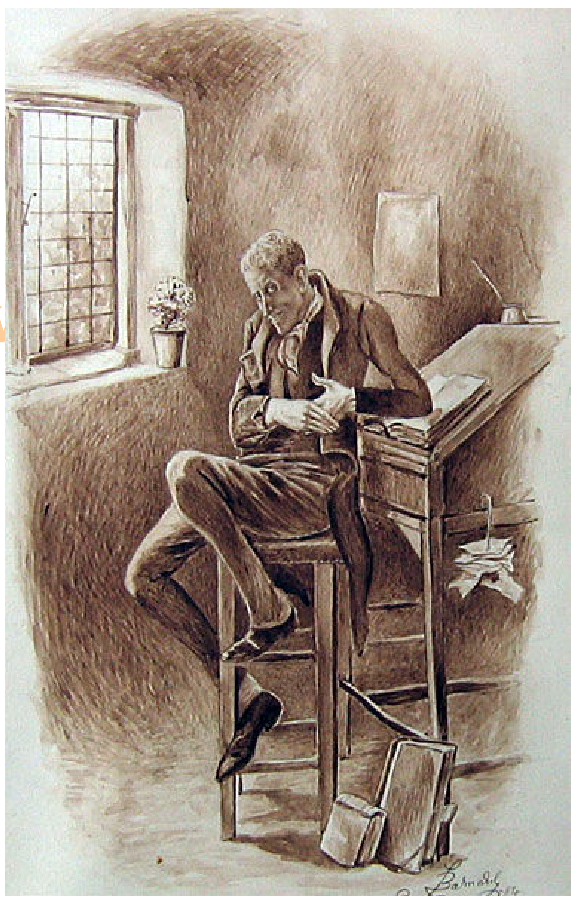
A series of experiments in the 1960s suggested that people are biased towards confirming their existing beliefs. Later work explained these results in terms of a tendency to test ideas in a one-sided way, focusing on one possibility and ignoring alternatives. In combination with other effects, this strategy can bias the conclusions that are reached. Explanations for the observed biases include wishful thinking and the limited human capacity to process information. Another proposal is that people show confirmation bias because they are pragmatically assessing the costs of being wrong, rather than investigating in a neutral, scientific way.

Confirmation biases contribute to overconfidence in personal beliefs and can maintain or strengthen beliefs in the face of contrary evidence. Hence they can lead to disastrous decisions, especially in organizational, military, political and social contexts.

Types

Confirmation biases are effects in information processing, distinct from the behavioral confirmation effect, also called "self-fulfilling prophecy", in which people behave so as to make their expectations come true. Some psychologists use "confirmation bias" to refer to any way in which people avoid rejecting a belief, whether in searching for evidence, interpreting it, or recalling it from memory. Others restrict the term to selective collection of evidence.

Biased search for information



A drawing of a man sitting on a stool at a writing desk
Confirmation bias has been described as an internal "yes man", echoing back a person's beliefs like Charles Dickens' character Uriah Heep.

Experiments have repeatedly found that people tend to test hypotheses in a one-sided way, by searching for evidence consistent with the hypothesis they hold at a given time. Rather than searching through all the relevant evidence, they ask questions that are phrased so that an affirmative answer supports their hypothesis. They look for the consequences that they would expect if their hypothesis were true, rather than what would happen if it were false. For example, someone who is trying to identify a number using yes/no questions and suspects that the number is 3 might ask, "Is it an odd number?" People prefer this sort of question, called a "positive test", even when a negative test such as "Is it an even number?" would yield exactly the same information. However, this does not mean that people seek tests that are guaranteed to give a positive answer. In studies where subjects could select either such pseudo-tests or genuinely diagnostic ones, they favored the genuinely diagnostic.

The preference for positive tests is not itself a bias, since positive tests can be highly informative. However, in conjunction with other effects, this strategy can confirm existing beliefs or assumptions, independently of whether they are true. In real-world situations, evidence is often complex and mixed. For example, various contradictory ideas about someone could each be supported by concentrating on one aspect of his or her behavior. Thus any search for evidence in favor of a hypothesis is likely to succeed. One illustration of this is the way the phrasing of a question can significantly change the answer. For example, people who are asked, "Are you happy with your social life?" report greater satisfaction than those asked, "Are you unhappy with your social life?"

Even a small change in the wording of a question can affect how people search through available information, and hence the conclusions they reach. This was shown using a fictional child custody case. Subjects read that Parent A was moderately suitable to be the guardian in multiple ways. Parent B had a mix of salient positive and negative qualities: a close relationship with the child but a job that would take him or her away for long periods. When asked, "Which parent should have custody of the child?" the subjects looked for positive attributes and a majority chose Parent B. However, when the question was, "Which parent should be denied custody of the child?" they looked for negative attributes, but again a majority answered Parent B, implying that Parent A should have custody.

Similar studies have demonstrated how people engage in biased search for information, but also that this phenomenon may be limited by a preference for genuine diagnostic tests, where they are available. In an initial experiment, subjects had to rate another person on the introversion-extroversion personality dimension on the basis of an interview. They chose the interview questions from a given list. When the interviewee was introduced as an introvert, the subjects chose questions that presumed introversion, such as, "What do you find unpleasant about noisy parties?" When the interviewee was described as extroverted, almost all the questions presumed extroversion, such as, "What would you do to liven up a dull party?" These loaded questions gave the interviewees little or no opportunity to falsify the hypothesis about them. However, a later version of the experiment gave the subjects less presumptive questions to choose from, such as, "Do you shy away from social interactions?" Subjects preferred to ask these more diagnostic questions, showing only a weak bias towards positive tests. This pattern, of a main preference for diagnostic tests and a weaker preference for positive tests, has been replicated in other studies.

Another experiment gave subjects a particularly complex rule-discovery task involving moving objects simulated by a computer. Objects on the computer screen followed specific laws, which the subjects had to figure out. They could "fire" objects across the screen to test their hypotheses. Despite making many attempts over a ten hour session, none of the subjects worked out the rules of the system. They typically sought to confirm rather than falsify their hypotheses, and were reluctant to consider alternatives. Even after seeing evidence that objectively refuted their working hypotheses, they frequently continued doing the same tests. Some of the subjects were instructed in proper hypothesis-testing, but these instructions had almost no effect.

Biased interpretation

"Smart people believe weird things because they are skilled at defending beliefs they arrived at for non-smart reasons."
—Michael Shermer

Confirmation biases are not limited to the collection of evidence. Even if two individuals have the same information, the way they interpret it can be biased.

A team at Stanford University ran an experiment with subjects who felt strongly about capital punishment, with half in favor and half against. Each of these subjects read descriptions of two studies; a comparison of U.S. states with and without the death penalty, and a comparison of murder rates in a state before and after the introduction of the death penalty. After reading a quick description of each study, the subjects were asked whether their opinions had changed. They then read a much more detailed account of each study's procedure and had to rate how well-conducted and convincing that research was. In fact, the studies were fictional. Half the subjects were told that one kind of study supported the deterrent effect and the other undermined it, while for other subjects the conclusions were swapped.

The subjects, whether proponents or opponents, reported shifting their attitudes slightly in the direction of the first study they read. Once they read the more detailed descriptions of the two studies, they almost all returned to their original belief regardless of the evidence provided, pointing to details that supported their viewpoint and disregarding anything contrary. Subjects described studies supporting their pre-existing view as superior to those that contradicted it, in detailed and specific ways. Writing about a study that seemed to undermine the deterrence effect, a death penalty proponent wrote, "The research didn't cover a long enough period of time", while an opponent's comment on the same study said, "No strong evidence to contradict the researchers has been presented". The results illustrated that people set higher standards of evidence for hypotheses that go against their current expectations. This effect, known as "disconfirmation bias", has been supported by other experiments.

An MRI scanner allowed researchers to examine how the human brain deals with unwelcome information.

A study of biased interpretation took place during the 2004 US presidential election, and involved subjects who described themselves as having strong feelings about the candidates. They were shown apparently contradictory pairs of statements, either from Republican candidate George W. Bush, Democratic candidate John Kerry or a politically neutral public figure. They were also given further statements that made the apparent contradiction seem reasonable. From these three pieces of information, they had to decide whether or not each individual's statements were inconsistent. There were strong differences in these evaluations, with subjects much more likely to interpret statements by the candidate they opposed as contradictory.

In this experiment, the subjects made their judgments while in a magnetic resonance imaging (MRI) scanner which monitored their brain activity. As subjects evaluated contradictory statements by their favored candidate, emotional centers of their brains were aroused. This did not happen with the statements by the other figures. The experimenters inferred that the different responses to the statements were not due to passive reasoning errors. Instead, the subjects were actively reducing the cognitive dissonance induced by reading about their favored candidate's irrational or hypocritical behavior.

Biased interpretation is not restricted to emotionally significant topics. In another experiment, subjects were told a story about a theft. They had to rate the evidential importance of statements arguing either for or against a particular character being responsible. When they hypothesized that character's guilt, they rated statements supporting that hypothesis as more important than conflicting statements.

Biased memory

Even if someone has sought and interpreted evidence in a neutral manner, they may still remember it selectively to reinforce their expectations. This effect is called "selective recall", "confirmatory memory" or "access-biased memory". Psychological theories differ in their predictions about selective recall. Schema theory predicts that information matching prior expectations will be more easily stored and recalled. Some alternative approaches say that surprising information stands out more and so is more memorable. Predictions from both these theories have been confirmed in different experimental contexts, with no theory winning outright.

In one study, subjects read a profile of a woman which described a mix of introverted and extroverted behaviors. They later had to recall examples of her introversion and extroversion. One group was told this was to assess the woman for a job as a librarian, while a second group were told it was for a job in real estate sales. There was a significant difference between what these two groups recalled, with the "librarian" group recalling more examples of introversion and the "sales" groups recalling more extraverted behavior. A selective memory effect has also been shown in experiments that manipulate the desirability of personality types. In one of these, a group of subjects were shown evidence that extraverted people are more successful than introverts. Another group were told the opposite. In a subsequent, apparently unrelated, study, they were asked to recall events from their lives in which they had been either introverted or extraverted. Each group of subjects provided more memories connecting themselves with the more desirable personality type, and recalled those memories more quickly.

One study showed how selective memory can maintain belief in extrasensory perception (ESP). Believers and disbelievers were each shown descriptions of ESP experiments. Half of each group were told that the experimental results supported the existence of ESP, while the others were told they did not. In a subsequent test, subjects recalled the material accurately, apart from believers who had read the non-supportive evidence. This group remembered significantly less information and some of them incorrectly remembered the results as supporting ESP.

Related effects

Polarization of opinion

When people with opposing views interpret new information in a biased way, their views can move even further apart. This is called "attitude polarization". The effect was demonstrated by an experiment that involved drawing a series of red and black balls from one of two concealed "bingo baskets". Subjects knew that one basket contained 60% black and 40% red balls; the other, 40% black and 60% red. The experimenters looked at what happened when balls of alternating color were drawn in turn, a sequence that does not favor either basket. After each ball was drawn, subjects in one group were asked to state out loud their judgments of the probability that the balls were being drawn from one or the other basket. These subjects tended to grow more confident with each successive draw—whether they initially thought the basket with 60% black balls or the one with 60% red balls was the more likely source, their estimate of the probability increased. Another group of subjects were asked to state probability estimates only at the end of a sequence of drawn balls, rather than after each ball. They did not show the polarization effect, suggesting that it does not necessarily occur when people simply hold opposing positions, but rather when they openly commit to them.

Strong opinions on an issue such as gun ownership can bias how someone interprets new evidence.

A less abstract study was the Stanford biased interpretation experiment in which subjects with strong opinions about the death penalty read about mixed experimental evidence. Twenty-three percent of the subjects reported that their views had become more extreme, and this self-reported shift correlated strongly with their initial attitudes. In later experiments, subjects also reported their opinions becoming more extreme in response to ambiguous information. However, comparisons of their attitudes before and after the new evidence showed no significant change, suggesting that the self-reported changes might not be real. Based on these experiments, Deanna Kuhn and Joseph Lao concluded that polarization is a real phenomenon but far from inevitable, only happening in a small minority of cases. They found that it was prompted not only by considering mixed evidence, but by merely thinking about the topic.

Charles Taber and Milton Lodge argued that the Stanford team's result had been hard to replicate because the arguments used in later experiments were too abstract or confusing to evoke an emotional response. The Taber and Lodge study used the emotionally charged topics of gun control and affirmative action. They measured the attitudes of their subjects towards these issues before and after reading arguments on each side of the debate. Two groups of subjects showed attitude polarization; those with strong prior opinions and those who were politically knowledgeable. In part of this study, subjects chose which information sources to read, from a list prepared by the experimenters. For example they could read the National Rifle Association's and the Brady Anti-Handgun Coalition's arguments on gun control. Even when instructed to be even-handed, subjects were more likely to read arguments that supported their existing attitudes. This biased search for information correlated well with the polarization effect.

Persistence of discredited beliefs

"[B]eliefs can survive potent logical or empirical challenges. They can survive and even be bolstered by evidence that most uncommitted observers would agree logically demands some weakening of such beliefs. They can even survive the total destruction of their original evidential bases."
—Lee Ross and Craig Anderson

Confirmation biases can be used to explain why some beliefs remain when the initial evidence for them is removed. This belief perseverance effect has been shown by a series of experiments using what is called the "debriefing paradigm": subjects examine faked evidence for a hypothesis, their attitude change is measured, then they learn that the evidence was fictitious. Their attitudes are then measured once more to see if their belief returns to its previous level.

A typical finding is that at least some of the initial belief remains even after a full debrief. In one experiment, subjects had to distinguish between real and fake suicide notes. The feedback was random: some were told they had done well while others were told they had performed badly. Even after being fully debriefed, subjects were still influenced by the feedback. They still thought they were better or worse than average at that kind of task, depending on what they had initially been told.

In another study, subjects read job performance ratings of two firefighters, along with their responses to a risk aversion test. These fictional data were arranged to show either a negative or positive association between risk-taking attitudes and job success. Even if these case studies had been true, they would have been scientifically poor evidence. However, the subjects found them subjectively persuasive. When the case studies were shown to be fictional, subjects' belief in a link diminished, but around half of the original effect remained. Follow-up interviews established that the subjects had understood the debriefing and taken it seriously. Subjects seemed to trust the debriefing, but regarded the discredited information as irrelevant to their personal belief.

Preference for early information

Experiments have shown that information is weighted more strongly when it appears early in a series, even when the order is unimportant. For example, people form a more positive impression of someone described as "intelligent, industrious, impulsive, critical, stubborn, envious" than when they are given the same words in reverse order. This irrational primacy effect is independent of the primacy effect in memory in which the earlier items in a series leave a stronger memory trace. Biased interpretation offers an explanation for this effect: seeing the initial evidence, people form a working hypothesis that affects how they interpret the rest of the information.

One demonstration of irrational primacy involved colored chips supposedly drawn from two urns. Subjects were told the color distributions of the urns, and had to estimate the probability of a chip being drawn from one of them. In fact, the colors appeared in a pre-arranged order. The first thirty draws favored one urn and the next thirty favored the other. The series as a whole was neutral, so rationally, the two urns were equally likely. However, after sixty draws, subjects favored the urn suggested by the initial thirty.

Another experiment involved a slide show of a single object, seen as just a blur at first and in slightly better focus with each succeeding slide. After each slide, subjects had to state their best guess of what the object was. Subjects whose early guesses were wrong persisted with those guesses, even when the picture was sufficiently in focus that other people could readily identify the object.

Illusory association between events

Illusory correlation is the tendency to see non-existent correlations in a set of data. This tendency was first demonstrated in a series of experiments in the late 1960s. In one experiment, subjects read a set of psychiatric case studies, including responses to the Rorschach inkblot test. They reported that the homosexual men in the set were more likely to report seeing buttocks, anuses or sexually ambiguous figures in the inkblots. In fact the case studies were fictional and, in one version of the experiment, had been constructed so that the homosexual men were less likely to report this imagery. In a survey, a group of experienced psychoanalysts reported the same set of illusory associations with homosexuality.

Another study recorded the symptoms experienced by arthritic patients, along with weather conditions over a 15-month period. Nearly all the patients reported that their pains were correlated with weather conditions, although the real correlation was zero.

This effect is a kind of biased interpretation, in that objectively neutral or unfavorable evidence is interpreted to support existing beliefs. It is also related to biases in hypothesis-testing behavior. In judging whether two events, such as illness and bad weather, are correlated, people rely heavily on the number of positive-positive cases: in this example, instances of both pain and bad weather. They pay relatively little attention to the other kinds of observation (of no pain and/or good weather). This parallels the reliance on positive tests in hypothesis testing. It may also reflect selective recall, in that people may have a sense that two events are correlated because it is easier to recall times when they happened together.

Example Days	Rain	No rain
Arthritis	14	6
No arthritis	7	2

In the above fictional example, arthritic symptoms are more likely on days with no rain. However, people are likely to focus on the relatively large number of days which have both rain and symptoms. By concentrating on one cell of the table rather than all four, people can misperceive the relationship, in this case associating rain with arthritic symptoms.

History

Engraved head-and-shoulders portrait of Francis Bacon wearing a hat and ruff.

Francis Bacon

Informal observation

Before psychological research on confirmation bias, the phenomenon had been observed anecdotally by writers, including the Greek historian Thucydides (c. 460 BC – c. 395 BC), Italian poet Dante Alighieri (1265–1321), English philosopher and scientist Francis Bacon (1561–1626), and Russian author Leo Tolstoy (1828–1910). Thucydides, in the History of the Peloponnesian War wrote, "it is a habit of mankind ... to use sovereign reason to thrust aside what they do not fancy." In the Divine Comedy, St. Thomas Aquinas cautions Dante when they meet in Paradise, "opinion—hasty—often can incline to the wrong side, and then affection for one's own opinion binds, confines the mind." Bacon, in the Novum Organum, wrote,

The human understanding when it has once adopted an opinion ... draws all things else to support and agree with it. And though there be a greater number and weight of instances to be found on the other side, yet these it either neglects or despises, or else by some distinction sets aside or rejects[.]

Bacon said that biased assessment of evidence drove "all superstitions, whether in astrology, dreams, omens, divine judgments or the like". In his essay "What Is Art?", Tolstoy wrote,

I know that most men—not only those considered clever, but even those who are very clever, and capable of understanding most difficult scientific, mathematical, or philosophic problems—can very seldom discern even the simplest and most obvious truth if it be such as to oblige them to admit the falsity of conclusions they have formed, perhaps with much difficulty—conclusions of which they are proud, which they have taught to others, and on which they have built their lives.

Wason's research on hypothesis-testing

The term "confirmation bias" was coined by English psychologist Peter Wason. For an experiment published in 1960, he challenged subjects to identify a rule applying to triples of numbers. At the outset, they were told that (2,4,6) fits the rule. Subjects could generate their own triples and the experimenter told them whether or not each triple conformed to the rule.

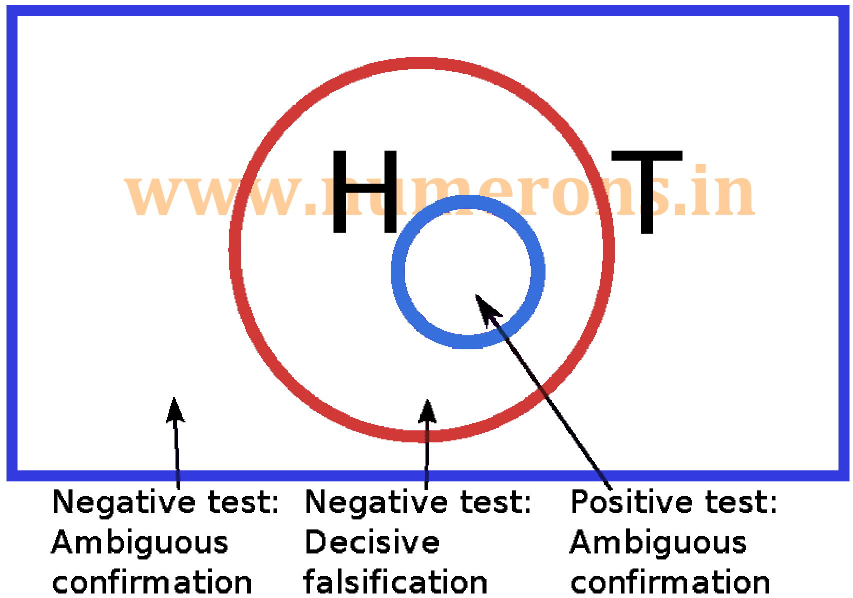
While the actual rule was simply "any ascending sequence", the subjects had a great deal of difficulty in arriving at it, often announcing rules that were far more specific, such as "the middle number is the average of the first and last". The subjects seemed to test only positive examples—triples that obeyed their hypothesized rule. For example, if they thought the rule was, "Each number is two greater than its predecessor", they would offer a triple that fit this rule, such as (11,13,15) rather than a triple that violates it, such as (11,12,19).

Wason accepted falsificationism, according to which a scientific test of a hypothesis is a serious attempt to falsify it. He interpreted his results as showing a preference for confirmation over falsification, hence the term "confirmation bias".[Note 3] Wason also used confirmation bias to explain the results of his selection task experiment. In this task, subjects are given partial information about a set of objects, and have to specify what further information they would need to tell whether or not a conditional rule ("If A, then B") applies. It has been found repeatedly that people perform badly on various forms of this test, in most cases ignoring information that could potentially refute the rule.

Klayman and Ha's critique

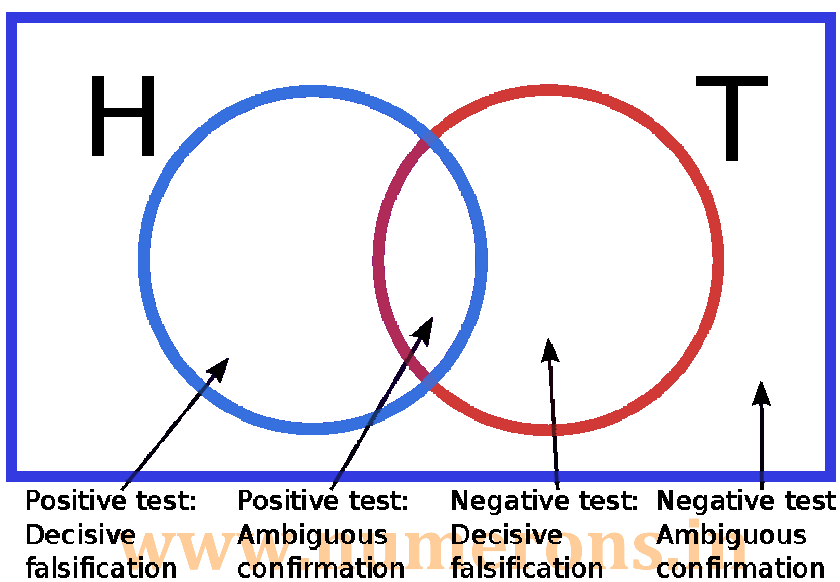
A 1987 paper by Joshua Klayman and Young-Won Ha argued that the Wason experiments had not actually demonstrated a bias towards confirmation. Instead, Klayman and Ha interpreted the results in terms of a tendency to make tests that are consistent with the working hypothesis. They called this the "positive test strategy". This strategy is an example of a heuristic: a reasoning shortcut that is imperfect but easy to compute. Klayman and Ha used Bayesian probability and information theory as their standard of hypothesis-testing, rather than the falsificationism used by Wason. According to these ideas, each answer to a question yields a different amount of information, which depends on the person's prior beliefs. Thus a scientific test of a hypothesis is one that is expected to produce the most information. Since the information content depends on initial probabilities, a positive test can either be highly informative or uninformative. Klayman and Ha argued that when people think about realistic problems, they are looking for a specific answer with a small initial probability. In this case, positive tests are usually more informative than negative tests. However, in Wason's rule discovery task the answer—three numbers in ascending order—is very broad, so positive tests are unlikely to yield informative answers. Klayman and Ha supported their analysis by citing an experiment that used the labels "DAX" and "MED" in place of "fits the rule" and "doesn't fit the rule". This avoided implying that the aim was to find a low-probability rule. Subjects had much more success with this version of the experiment.

Within the universe of all possible triples, those that fit the true rule are shown schematically as a circle. The hypothesized rule is a smaller circle enclosed within it.



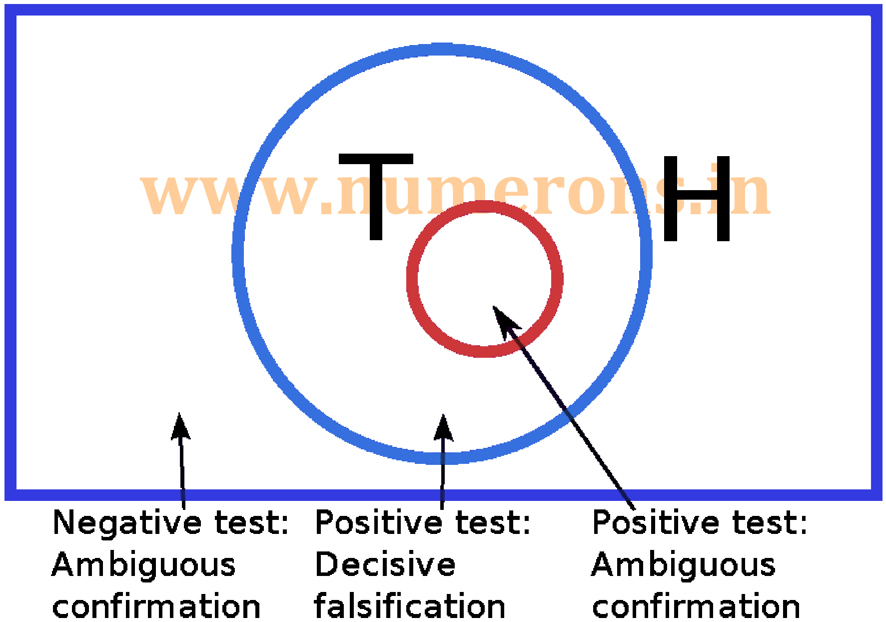
If the true rule (T) encompasses the current hypothesis (H), then positive tests (examining an H to see if it is T) will not show that the hypothesis is false.

Two overlapping circles represent the true rule and the hypothesized rule. Any observation falling in the non-overlapping parts of the circles shows that the two rules are not exactly the same. In other words, those observations falsify the hypothesis.



If the true rule (T) overlaps the current hypothesis (H), then either a negative test or a positive test can potentially falsify H.

The triples fitting the hypothesis are represented as a circle within the universe of all triples. The true rule is a smaller circle within this.



When the working hypothesis (H) includes the true rule (T) then positive tests are the only way to falsify H.

In light of this and other critiques, the focus of research moved away from confirmation versus falsification to examine whether people test hypotheses in an informative way, or an uninformative but positive way. The search for "true" confirmation bias led psychologists to look at a wider range of effects in how people process information.

Explanations

Confirmation bias is often described as a result of automatic processing. Individuals do not use deceptive strategies to fake data, but forms of information processing that take place more or less unintentionally. According to Robert Maccoun, most biased evidence processing occurs unintentionally through a combination of both "hot" (i.e., motivated) and "cold" (i.e., cognitive) mechanisms.

Cognitive explanations for confirmation bias are based on limitations in people's ability to handle complex tasks, and the shortcuts, called "heuristics", that they use. For example, people may judge the reliability of evidence by using the availability heuristic, i.e. how readily a particular idea comes to mind. It is also possible that people can only focus on one thought at a time, so find it difficult to test alternative hypotheses in parallel. Another heuristic is the positive test strategy identified by Klayman and Ha, in which people test a hypothesis by examining cases where they expect a property or event to occur. This heuristic avoids the difficult or impossible task of working out how diagnostic each possible question will be. However, it is not universally reliable, so people can overlook challenges to their existing beliefs.

Motivational explanations involve an effect of desire on belief, sometimes called "wishful thinking". It is known that people prefer pleasant thoughts over unpleasant ones in a number of ways: this is called the "Pollyanna principle". Applied to arguments or sources of evidence, this could explain why desired conclusions are more likely to be believed true. According to experiments that manipulate the desirability of the conclusion, people demand a high standard of evidence for unpalatable ideas and a low standard for preferred ideas. In other words, they ask, "Can I believe this?" for some suggestions and, "Must I believe this?" for others. Although consistency is a desirable feature of attitudes, an excessive drive for consistency is another potential source of bias because it may prevent people from neutrally evaluating new, surprising information. Social psychologist Ziva Kunda combines the cognitive and motivational theories, arguing that motivation creates the bias, but cognitive factors determine the size of the effect.

Explanations in terms of cost-benefit analysis assume that people do not just test hypotheses in a disinterested way, but assess the costs of different errors. Using ideas from evolutionary psychology, James Friedrich suggests that people do not primarily aim at truth in testing hypotheses, but try to avoid the most costly errors. For example, employers might ask one-sided questions in job interviews because they are focused on weeding out unsuitable candidates. Yaacov Trope and Akiva Liberman's refinement of this theory assumes that people compare the two different kinds of error: accepting a false hypothesis or rejecting a true hypothesis. For instance, someone who underestimates a friend's honesty might treat him or her suspiciously and so undermine the friendship. Overestimating the friend's honesty may also be costly, but less so. In this case, it would be rational to seek, evaluate or remember evidence of their honesty in a biased way. When someone gives an initial impression of being introverted or extraverted, questions that match that impression come across as more empathic. This suggests that when talking to someone who seems to be an introvert, it is a sign of better social skills to ask, "Do you feel awkward in social situations?" rather than, "Do you like noisy parties?" The connection between confirmation bias and social skills was corroborated by a study of how college students get to know other people. Highly self-monitoring students, who are more sensitive to their environment and to social norms, asked more matching questions when interviewing a high-status staff member than when getting to know fellow students.

Consequences

In finance

Confirmation bias can lead investors to be overconfident, ignoring evidence that their strategies will lose money. In studies of political stock markets, investors made more profit when they resisted bias. For example, participants who interpreted a candidate's debate performance in a neutral rather than partisan way were more likely to profit. To combat the effect of confirmation bias, investors can try to adopt a contrary viewpoint "for the sake of argument". One such technique involves imagining that their investments have collapsed and asking why this might happen.

In physical and mental health

Raymond Nickerson, a psychologist, blames confirmation bias for the ineffective medical procedures that were used for centuries before the arrival of scientific medicine. If a patient recovered, medical authorities counted the treatment as successful, rather than looking for alternative explanations such as that the disease had run its natural course. Biased assimilation is a factor in the modern appeal of alternative medicine, whose proponents are swayed by positive anecdotal evidence but treat scientific evidence hyper-critically.

Cognitive therapy was developed by Aaron T. Beck in the early 1960s and has become a popular approach. According to Beck, biased information processing is a factor in depression. His approach teaches people to treat evidence impartially, rather than selectively reinforcing negative outlooks. Phobias and hypochondria have also been shown to involve confirmation bias for threatening information.

In politics and law

A woman and a man reading a document in a courtroom

Mock trials allow researchers to examine confirmation biases in a realistic setting.

Nickerson argues that reasoning in judicial and political contexts is sometimes subconsciously biased, favoring conclusions that judges, juries or governments have already committed to. Since the evidence in a jury trial can be complex, and jurors often reach decisions about the verdict early on, it is reasonable to expect an attitude polarization effect. The prediction that jurors will become more extreme in their views as they see more evidence has been borne out in experiments with mock trials. Both inquisitorial and adversarial criminal justice systems are affected by confirmation bias.

Confirmation bias can be a factor in creating or extending conflicts, from emotionally charged debates to wars: by interpreting the evidence in their favor, each opposing party can become overconfident that it is in the stronger position. On the other hand, confirmation bias can result in people ignoring or misinterpreting the signs of an imminent or incipient conflict. For example, psychologists Stuart Sutherland and Thomas Kida have each argued that US Admiral Husband E. Kimmel showed confirmation bias when playing down the first signs of the Japanese attack on Pearl Harbor.

A two-decade study of political pundits by Philip E. Tetlock found that, on the whole, their predictions were not much better than chance. Tetlock divided experts into "foxes" who maintained multiple hypotheses, and "hedgehogs" who were more dogmatic. In general, the hedgehogs were much less accurate. Tetlock blamed their failure on confirmation bias—specifically, their inability to make use of new information that contradicted their existing theories.

In the paranormal

One factor in the appeal of psychic "readings" is that listeners apply a confirmation bias which fits the psychic's statements to their own lives. By making a large number of ambiguous statements in each sitting, the psychic gives the client more opportunities to find a match. This is one of the techniques of cold reading, with which a psychic can deliver a subjectively impressive reading without any prior information about the client. Investigator James Randi compared the transcript of a reading to the client's report of what the psychic had said, and found that the client showed a strong selective recall of the "hits".

As a "striking illustration" of confirmation bias in the real world, Nickerson mentions numerological pyramidology: the practice of finding meaning in the proportions of the Egyptian pyramids. There are many different length measurements that can be made of, for example, the Great Pyramid of Giza and many ways to combine or manipulate them. Hence it is almost inevitable that people who look at these numbers selectively will find superficially impressive correspondences, for example with the dimensions of the Earth.

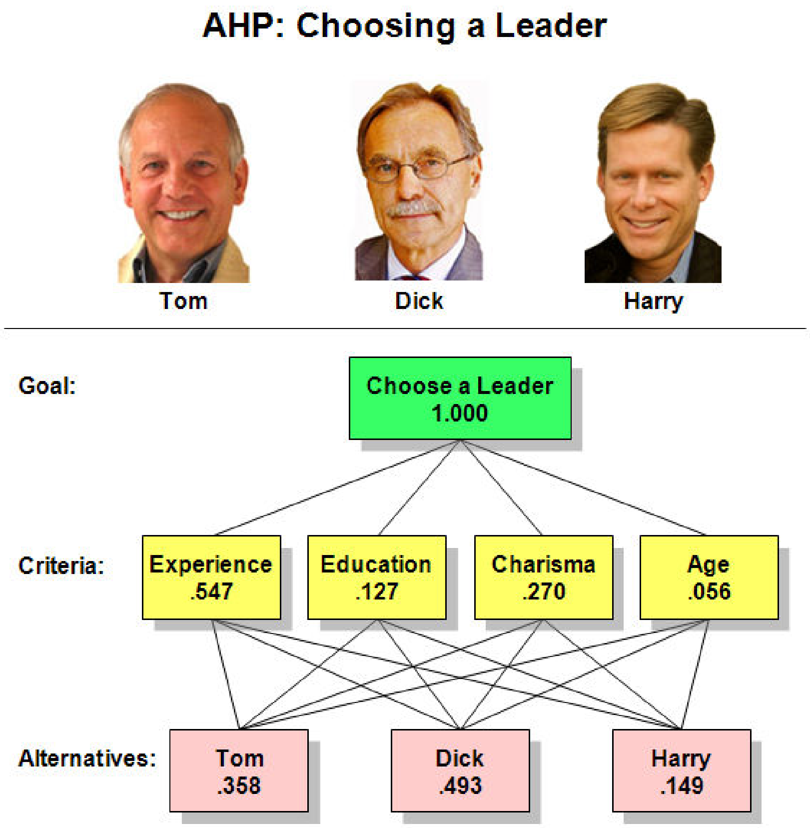
In scientific procedure

A distinguishing feature of scientific thinking is the search for falsifying as well as confirming evidence. However, many times in the history of science, scientists have resisted new discoveries by selectively interpreting or ignoring unfavorable data. Previous research has shown that the assessment of the quality of scientific studies seems to be particularly vulnerable to confirmation bias. It has been found several times that scientists rate studies that report findings consistent with their prior beliefs more favorably than studies reporting findings inconsistent with their previous beliefs. However, assuming that the research question is relevant, the experimental design adequate and the data are clearly and comprehensively described, the found results should be of importance to the scientific community and should not be viewed prejudicially—regardless of whether they conform to current theoretical predictions. Confirmation bias may thus be especially harmful to objective evaluations regarding nonconforming results, since biased individuals may regard opposing evidence to be weak in principle and give little serious thought to revising their beliefs. Scientific innovators often meet with resistance from the scientific community, and research presenting controversial results frequently receives harsh peer review. In the context of scientific research, confirmation biases can sustain theories or research programs in the face of inadequate or even contradictory evidence; the field of parapsychology has been particularly affected. An experimenter's confirmation bias can potentially affect which data are reported. Data that conflict with the experimenter's expectations may be more readily discarded as unreliable, producing the so-called file drawer effect. To combat this tendency, scientific training teaches ways to avoid bias. Experimental designs involving randomization and double blind trials, along with the social process of peer review, are thought to mitigate the effect of individual scientists' biases, although it has been argued that such biases can play a role in the peer review process itself.

In self-image

Social psychologists have identified two tendencies in the way people seek or interpret information about themselves. Self-verification is the drive to reinforce the existing self-image and self-enhancement is the drive to seek positive feedback. Both are served by confirmation biases. In experiments where people are given feedback that conflicts with their self-image, they are less likely to attend to it or remember it than when given self-verifying feedback. They reduce the impact of such information by interpreting it as unreliable. Similar experiments have found a preference for positive feedback, and the people who give it, over negative feedback.

Analytic Hierarchy Process



A simple AHP hierarchy, with final priorities. The goal is to select the most suitable leader from a field of three candidates. The factors to be considered are Experience, Education, Charisma, and Age. According to the judgments of the decision makers, Dick is the strongest candidate, followed by Tom, then Harry. Their decision process is described in depth in an appendix to this article.

The Analytic Hierarchy Process (AHP) is a structured technique for dealing with complex decisions. Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem—it is a process of organizing decisions that people are already dealing with, but trying to do in their heads.

Based on mathematics and psychology, the AHP was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

It has particular application in group decision making, and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education.

Several firms supply computer software to assist in using the process.

Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand.

Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations.

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques.

In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action.

Uses and applications

While it can be used by individuals working on straightforward decisions, the Analytic Hierarchy Process (AHP) is most useful where teams of people are working on complex problems, especially those with high stakes, involving human perceptions and judgments, whose resolutions have long-term repercussions. It has unique advantages when important elements of the decision are difficult to quantify or compare, or where communication among team members is impeded by their different specializations, terminologies, or perspectives.

Decision situations to which the AHP can be applied include:

- Choice - The selection of one alternative from a given set of alternatives, usually where there are multiple decision criteria involved.
- Ranking - Putting a set of alternatives in order from most to least desirable
- Prioritization - Determining the relative merit of members of a set of alternatives, as opposed to selecting a single one or merely ranking them
- Resource allocation - Apportioning resources among a set of alternatives
- Benchmarking - Comparing the processes in one's own organization with those of other best-of-breed organizations

- Quality management - Dealing with the multidimensional aspects of quality and quality improvement
- Conflict resolution - Settling disputes between parties with apparently incompatible goals or positions

The applications of AHP to complex decision situations have numbered in the thousands, and have produced extensive results in problems involving planning, resource allocation, priority setting, and selection among alternatives. Other areas have included forecasting, total quality management, business process re-engineering, quality function deployment, and the Balanced Scorecard. Many AHP applications are never reported to the world at large, because they take place at high levels of large organizations where security and privacy considerations prohibit their disclosure. But some uses of AHP are discussed in the literature. Recently these have included:

- Deciding how best to reduce the impact of global climate change (Fondazione Eni Enrico Mattei)
- Quantifying the overall quality of software systems (Microsoft Corporation)
- Selecting university faculty (Bloomsburg University of Pennsylvania)
- Deciding where to locate offshore manufacturing plants (University of Cambridge)
- Assessing risk in operating cross-country petroleum pipelines (American Society of Civil Engineers)
- Deciding how best to manage U.S. watersheds (U.S. Department of Agriculture)

AHP is sometimes used in designing highly specific procedures for particular situations, such as the rating of buildings by historic significance. It was recently applied to a project that uses video footage to assess the condition of highways in Virginia. Highway engineers first used it to determine the optimum scope of the project, then to justify its budget to lawmakers.

Education and scholarly research

Though using the Analytic Hierarchy Process requires no specialized academic training, it is considered an important subject in many institutions of higher learning, including schools of engineering and graduate schools of business. It is a particularly important subject in the quality field, and is taught in many specialized courses including Six Sigma, Lean Six Sigma, and QFD.

The value of the AHP is recognized in developed and developing countries around the world. China is a good example — nearly a hundred Chinese universities offer courses in AHP, and many doctoral students choose AHP as the subject of their research and dissertations. Over 900 papers have been published on the subject in China, and there is at least one Chinese scholarly journal devoted exclusively to AHP.

The International Symposium on the Analytic Hierarchy Process (ISAHP) holds biennial meetings of academics and practitioners interested in the field. A wide range of topics are covered. Those in 2005 ranged from Establishing Payment Standards for Surgical

Specialists, to Strategic Technology Roadmapping, to Infrastructure Reconstruction in Devastated Countries. At the 2007 meeting in Valparaiso, Chile, over 90 papers were presented from 19 countries, including the U.S., Germany, Japan, Chile, Malaysia, and Nepal. A similar number of papers were presented at the 2009 symposium in Pittsburgh, Pennsylvania, when 28 countries were represented. Subjects of the papers included Economic Stabilization in Latvia, Portfolio Selection in the Banking Sector, Wildfire Management to Help Mitigate Global Warming, and Rural Microprojects in Nepal.

Using the Analytic Hierarchy Process

A typical device for entering judgments in an AHP group decision making session

As can be seen in the material that follows, using the AHP involves the mathematical synthesis of numerous judgments about the decision problem at hand. It is not uncommon for these judgments to number in the dozens or even the hundreds. While the math can be done by hand or with a calculator, it is far more common to use one of several computerized methods for entering and synthesizing the judgments. The simplest of these involve standard spreadsheet software, while the most complex use custom software, often augmented by special devices for acquiring the judgments of decision makers gathered in a meeting room.

The procedure for using the AHP can be summarized as:

- Model the problem as a hierarchy containing the decision goal, the alternatives for reaching it, and the criteria for evaluating the alternatives.
- Establish priorities among the elements of the hierarchy by making a series of judgments based on pairwise comparisons of the elements. For example, when comparing potential real-estate purchases, the investors might say they prefer location over price and price over timing.

- Synthesize these judgments to yield a set of overall priorities for the hierarchy. This would combine the investors' judgments about location, price and timing for properties A, B, C, and D into overall priorities for each property.
- Check the consistency of the judgments.
- Come to a final decision based on the results of this process.

These steps are more fully described below.

Model the problem as a hierarchy

The first step in the Analytic Hierarchy Process is to model the problem as a hierarchy. In doing this, participants explore the aspects of the problem at levels from general to detailed, then express it in the multileveled way that the AHP requires. As they work to build the hierarchy, they increase their understanding of the problem, of its context, and of each other's thoughts and feelings about both.

Hierarchies defined

A hierarchy is a stratified system of ranking and organizing people, things, ideas, etc., where each element of the system, except for the top one, is subordinate to one or more other elements. Though the concept of hierarchy is easily grasped intuitively, it can also be described mathematically. Diagrams of hierarchies are often shaped roughly like pyramids, but other than having a single element at the top, there is nothing necessarily pyramid-shaped about a hierarchy.

Human organizations are often structured as hierarchies, where the hierarchical system is used for assigning responsibilities, exercising leadership, and facilitating communication. Familiar hierarchies of "things" include a desktop computer's tower unit at the "top," with its subordinate monitor, keyboard, and mouse "below."

In the world of ideas, we use hierarchies to help us acquire detailed knowledge of complex reality: we structure the reality into its constituent parts, and these in turn into their own constituent parts, proceeding down the hierarchy as many levels as we care to. At each step, we focus on understanding a single component of the whole, temporarily disregarding the other components at this and all other levels. As we go through this process, we increase our global understanding of whatever complex reality we are studying.

Think of the hierarchy that medical students use while learning anatomy—they separately consider the musculoskeletal system (including parts and subparts like the hand and its constituent muscles and bones), the circulatory system (and its many levels and branches), the nervous system (and its numerous components and subsystems), etc., until they've covered all the systems and the important subdivisions of each. Advanced students continue the subdivision all the way to the level of the cell or molecule. In the end, the students understand the "big picture" and a considerable number of its details. Not only that, but they understand the relation of the individual parts to the whole. By working hierarchically, they've gained a comprehensive understanding of anatomy.

Similarly, when we approach a complex decision problem, we can use a hierarchy to integrate large amounts of information into our understanding of the situation. As we build this information structure, we form a better and better picture of the problem as a whole.

Hierarchies in the AHP

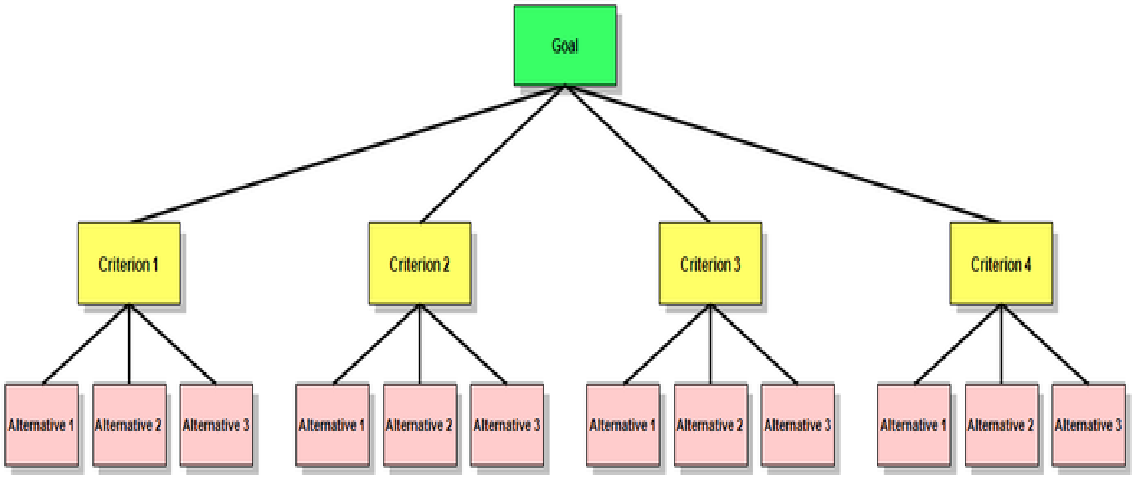
An AHP hierarchy is a structured means of modeling the decision at hand. It consists of an overall goal, a group of options or alternatives for reaching the goal, and a group of factors or criteria that relate the alternatives to the goal. The criteria can be further broken down into subcriteria, sub-subcriteria, and so on, in as many levels as the problem requires. A criterion may not apply uniformly, but may have graded differences like a little sweetness is enjoyable but too much sweetness can be harmful. In that case the criterion is divided into subcriteria indicating different intensities of the criterion, like: little, medium, high and these intensities are prioritized through comparisons under the parent criterion, sweetness. Published descriptions of AHP applications often include diagrams and descriptions of their hierarchies; some simple ones are shown throughout this article. More complex AHP hierarchies have been collected and reprinted in at least one book. More complex hierarchies can be found in this article's talk page.

The design of any AHP hierarchy will depend not only on the nature of the problem at hand, but also on the knowledge, judgments, values, opinions, needs, wants, etc. of the participants in the decision making process. Constructing a hierarchy typically involves significant discussion, research, and discovery by those involved. Even after its initial construction, it can be changed to accommodate newly-thought-of criteria or criteria not originally considered to be important; alternatives can also be added, deleted, or changed.

To better understand AHP hierarchies, consider a decision problem with a goal to be reached, three alternative ways of reaching the goal, and four criteria against which the alternatives need to be measured.

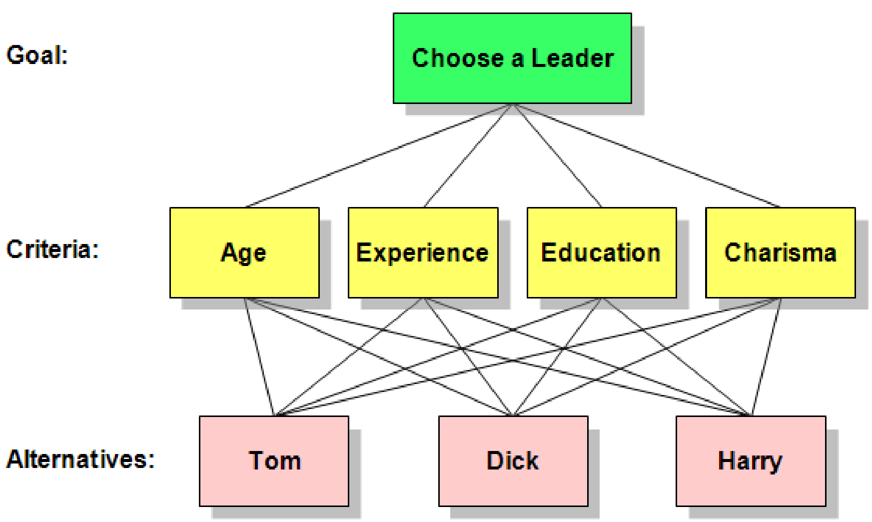
Such a hierarchy can be visualized as a diagram like the one immediately below, with the goal at the top, the three alternatives at the bottom, and the four criteria in between. There are useful terms for describing the parts of such diagrams: Each box is called a node. A node that is connected to one or more nodes in a level below it is called a parent node. The nodes to which it is so connected are called its children.

Applying these definitions to the diagram below, the Goal is the parent of the four Criteria, and the four Criteria are children of the Goal. Each Criterion is a parent of the three Alternatives. Note that there are only three Alternatives, but in the diagram, each of them is repeated under each of its parents.



A simple AHP hierarchy. There are three Alternatives for reaching the Goal, and four Criteria to be used in deciding among them.

To reduce the size of the drawing required, it is common to represent AHP hierarchies as shown in the diagram below, with only one node for each alternative, and with multiple lines connecting the alternatives and the criteria that apply to them. To avoid clutter, these lines are sometimes omitted or reduced in number. Regardless of any such simplifications in the diagram, in the actual hierarchy each alternative is connected to every one of its parent nodes.



AHP hierarchy for choosing a leader. There is one goal, three candidates and four criteria for choosing among them.

Evaluate the hierarchy

Once the hierarchy has been constructed, the participants analyze it through a series of pairwise comparisons that derive numerical scales of measurement for the nodes. The criteria are pairwise compared against the goal for importance. The alternatives are pairwise compared against each of the criteria for preference. The comparisons are processed mathematically, and priorities are derived for each node.

Consider the "Choose a Leader" example above. An important task of the decision makers is to determine the weight to be given each criterion in making the choice of a leader. Another important task is to determine the weight to be given to each candidate with regard to each of the criteria. The AHP not only lets them do that, but it lets them put a meaningful and objective numerical value on each of the four criteria.

Establish priorities

This section explains priorities, shows how they are established, and provides a simple example.

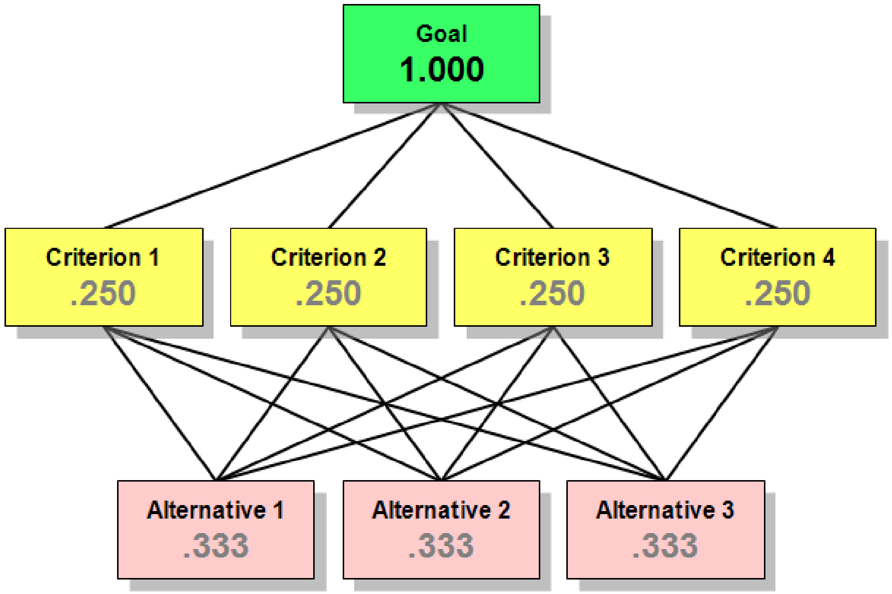
Priorities defined and explained

Priorities are numbers associated with the nodes of an AHP hierarchy. They represent the relative weights of the nodes in any group.

Like probabilities, priorities are absolute numbers between zero and one, without units or dimensions. A node with priority .200 has twice the weight in reaching the goal as one with priority .100, ten times the weight of one with priority .020, and so forth. Depending on the problem at hand, "weight" can refer to importance, or preference, or likelihood, or whatever factor is being considered by the decision makers.

Priorities are distributed over a hierarchy according to its architecture, and their values depend on the information entered by users of the process. Priorities of the Goal, the Criteria, and the Alternatives are intimately related, but need to be considered separately.

By definition, the priority of the Goal is 1.000. The priorities of the Alternatives always add up to 1.000. Things can become complicated with multiple levels of Criteria, but if there is only one level, their priorities also add to 1.000. All this is illustrated by the priorities in the example below.

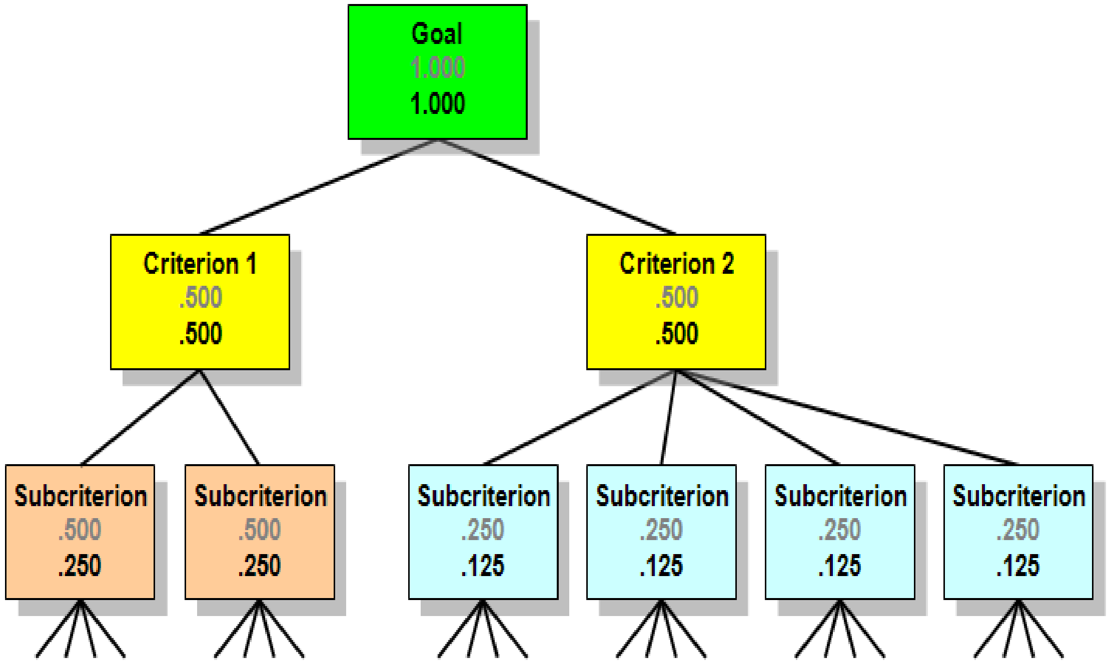


Simple AHP hierarchy with associated default priorities.

Observe that the priorities on each level of the example—the Goal, the Criteria, and the Alternatives—all add up to 1.000.

The priorities shown are those that exist before any information has been entered about weights of the criteria or alternatives, so the priorities within each level are all equal. They are called the hierarchy's default priorities. If a fifth Criterion were added to this hierarchy, the default priority for each Criterion would be .200. If there were only two Alternatives, each would have a default priority of .500.

Two additional concepts apply when a hierarchy has more than one level of criteria: local priorities and global priorities. Consider the hierarchy shown below, which has several Subcriteria under each Criterion.



A more complex AHP hierarchy, with local and global default priorities. In the interest of clarity, the decision alternatives do not appear in the diagram.

The local priorities, shown in gray, represent the relative weights of the nodes within a group of siblings with respect to their parent. You can easily see that the local priorities of each group of Criteria and their sibling Subcriteria add up to 1.000. The global priorities, shown in black, are obtained by multiplying the local priorities of the siblings by their parent's global priority. The global priorities for all the subcriteria in the level add up to 1.000.

The rule is this: Within a hierarchy, the global priorities of child nodes always add up to the global priority of their parent. Within a group of children, the local priorities add up to 1.000.

So far, we have looked only at default priorities. As the Analytical Hierarchy Process moves forward, the priorities will change from their default values as the decision makers input information about the importance of the various nodes. They do this by making a series of pairwise comparisons.

Practical examples

Experienced practitioners know that the best way to understand the AHP is to work through cases and examples. Two detailed case studies, specifically designed as in-depth teaching examples, are provided as appendices to this article:

- Simple step-by-step example with four Criteria and three Alternatives: Choosing a leader for an organization.

- More complex step-by-step example with ten Criteria/Subcriteria and six Alternatives: Buying a family car.

Some of the books on AHP contain practical examples of its use, though they are not typically intended to be step-by-step learning aids. One of them contains a handful of expanded examples, plus about 400 AHP hierarchies briefly described and illustrated with figures. Many examples are discussed, mostly for professional audiences, in papers published by the International Symposium on the Analytic Hierarchy Process.

Criticisms

The AHP is included in most operations research and management science textbooks, and is taught in numerous universities; it is used extensively in organizations that have carefully investigated its theoretical underpinnings. While the general consensus is that it is both technically valid and practically useful, the method does have its critics. Most of the criticisms involve a phenomenon called rank reversal, discussed in the following section.

Rank reversal

Decision making involves ranking alternatives in terms of criteria or attributes of those alternatives. It is an axiom of some decision theories that when new alternatives are added to a decision problem, the ranking of the old alternatives must not change — that "rank reversal" must not occur.

The reasonableness of this axiom for all applications is questionable, since there are real-world examples where adding new alternatives can change the rank of the old ones. There are also situations where it is not reasonable for the rank of existing alternatives to change when a new alternative that is not as good as any of the existing alternatives is added for consideration.

The 2000 U.S. presidential election is an example of a decision that can be understood as involving rank reversal. Ralph Nader was an 'irrelevant' alternative, in that he was dominated by both the Democrat and Republican candidates. However, since he may have attracted more votes from those who would have voted Democratic rather than Republican, his presence caused the ranks to reverse. Put another way, if Nader were not in the race, it is conceivable that Al Gore would have won. The same could be said for the impact that Ross Perot had on George Bush's loss in 1992.

There are two schools of thought about rank reversal. One maintains that new alternatives that introduce no additional attributes should not cause rank reversal under any circumstances. The other maintains that there are some situations in which rank reversal can reasonably be expected. The original formulation of AHP allowed rank reversals. In 1993, Forman introduced a second AHP synthesis mode, called the ideal synthesis mode, to address choice situations in which the addition or removal of an 'irrelevant' alternative should not and will not cause a change in the ranks of existing alternatives. The current version of the AHP can accommodate both these schools — its Ideal Mode preserves rank, while its Distributive Mode allows the ranks to change. Either mode is selected according to the problem at hand.

Rank reversal and the AHP are extensively discussed in a 2001 paper in Operations Research, as well as a chapter entitled Rank Preservation and Reversal, in the current basic book on AHP. The latter presents published examples of rank reversal due to adding copies and near copies of an alternative, due to intransitivity of decision rules, due to adding phantom and decoy alternatives, and due to the switching phenomenon in utility functions. It also discusses the Distributive and Ideal Modes of the AHP.

Decision Making: Part II

Business Decision Mapping

Business Decision Mapping (BDM) is a technique for making decisions, particularly for the kind of decisions that often need to be made in business. It involves using diagrams to help articulate and work through the decision problem, from initial recognition of the need through to communication of the decision and the thinking behind it.

BDM is designed for use in making deliberative decisions - those made based on canvassing and weighing up the arguments. It is also qualitative - although numbers may be involved, the main considerations are qualitatively specified and there is no calculation-based route to the right decision. In these two key elements, BDM is similar to the natural or typical way of making decisions.

However, it differs from typical, informal decision making by providing a structured, semi-formal framework, and using visual language, taking advantage of our ability to grasp and make sense of information faster and more easily when it is graphically presented.

BDM is centered on the creation of a decision map - a single diagram that brings together in one organized structure all the fundamental elements of a decision, and that functions as a focus of collaboration.

BDM aims to support the decision process, making it easier, more reliable and more accountable. It addresses some major problems that can afflict business decision making the way it is generally done, including stress, anxiety, time pressure, lost thinking and inefficiency. By mapping the decision problem, the options, the arguments and all relevant evidence visually using BDM, the decision maker can avoid holding a large amount of information in his or her head, is able to make a more complete and transparent analysis and can generate a record of the thinking behind the final decision.

Related methodologies

Business Decision Mapping is related to:

Argument mapping, the graphical representation of the structure of an argument, often used in the teaching of reasoning and critical thinking.

Dialogue mapping, a method for building shared understanding through a structured representation of group communication, developed by Jeff Conklin of the CogNexus Institute. Dialogue mapping and Business Decision Mapping use the 'grammar' of IBIS, a well-established methodology developed by Horst Rittel for tackling wicked problems.

Mind mapping, in which a diagram is used to structure and classify ideas by linking them radially around a central key word or idea. There are no formal restrictions on the type of links used.

Minto Pyramid Principle, a process for organizing ideas in order to write compelling business documents, developed by Barbara Minto.

Choice architecture

Choice architecture describes the way in which decisions are influenced by how the choices are presented (in order to influence the outcome), and is a term used by Cass Sunstein and economist Richard Thaler in the 2008 book Nudge: Improving Decisions about Health, Wealth, and Happiness. Parallels are drawn between choice architecture and traditional architecture.

'Choice architecture' concept

Several ways of presenting choices and the way that presentation affects outcomes are explored in Nudge. The book proposes that default outcomes of a situation can be arranged to be the outcome desired by the person or organization presenting the choice. According to the authors this is an underused method. For example a greater supply of transplant organs could be created by a system of presumed consent followed by an opt-out process rather than opt-in. Another principle suggested is laying out various outcomes of a decision in a way that is easy for the choice-maker to understand.

Choice Architecture as outlined in Nudge has a broad remit, from personal decision making, to medical options, to social policy. There have been comparisons with many theorists, including the work of B. J. Fogg on computers as persuasive technologies, and the concept of permission marketing as described by Seth Godin. Choice Architecture is similar in spirit to the concept of "heresthetics," or manipulation that changes outcomes without changing people's underlying preferences. This concept has been explored by political scientist William H. Riker.

Thaler and Sunstein are former colleagues at the University of Chicago of US President, Barack Obama, and have been described as "informal advisors" by ABC News.

Terminology

choice architect The person who frames the options, for example someone who chooses how allied products are displayed in a supermarket.

libertarian paternalism The idea that it is both possible and legitimate for private and public institutions to affect behavior while also respecting freedom of choice.

Choice modelling

Choice modelling attempts to model the decision process of an individual or segment in a particular context. Choice modelling may also be used to estimate non-market environmental benefits and costs.

Choice Models are able to predict with great accuracy how individuals would react in a particular situation. Unlike a poll or a survey, predictions are able to be made over large numbers of scenarios within a context, to the order of many trillions of possible scenarios.

Choice Modelling is believed to be the most accurate and general purpose tool currently available for making probabilistic predictions about human decision making behaviour. In addition Choice Modelling is regarded as the most suitable method for estimating consumers' willingness to pay for quality improvements in multiple dimensions.. The Nobel Prize for economics was awarded to a principal exponent of the Choice Modelling theory, Daniel McFadden.

Related terms for choice modelling

A number of terms exist that are either subsets of, part of the process or definition of, or overlap with other areas of econometrics that may be broadly termed Choice Modelling. As with any emerging technology, there are varying claims as to the correct lexicon.

These include:

- Stated preference discrete choice modelling
- Discrete choice
- Choice experiment
- Choice set
- Conjoint analysis
- Controlled experiments

Theoretical background

Modelling was developed in parallel by economists and cognitive psychologists. The origins of choice modeling can be traced to Thurstone's research into food preferences in the 1920s and to random utility theory.

To some degree, all decisions involve choice. Individuals choose among different alternatives; commuters choose between alternative routes and methods of transport, shoppers choose between competing products for their attributes such as price, quality and quantity.

Choice modelling posits that with human choice there is an underlying rational decision process and that this process has a functional form. Depending on the behavioural context, a specific functional form may be selected as a candidate to model that behaviour. The multinomial logit or MNL model form is commonly used as it is a good approximation to the economic principle of utility maximisation. That is, human beings strive to maximise their total utility. The multinomial logit form describes total utility as a linear addition (or subtraction) of the component utilities in a context. Once the functional form of the decision process has been established, the parameters of a specific model may be estimated from available data using multiple regression, in the case of MNL. Other functional forms may be used or combined, such as binary logit, probit or EBA with appropriate statistical tests to determine the goodness of fit of the model to a hold out data set.

Methods used in choice modeling

Choice modeling comprises a number of specific techniques that contribute to its power. Some or all of these may be used in the construction of a Choice Model.

Orthogonality

For model convergence, and therefore parameter estimation, it is often necessary that the data have little or no collinearity. The reasons for this have more to do with information theory than anything else. To understand why this is, take the following example:

Imagine a car dealership that sells both luxury cars and used low-end vehicles. Using the utility maximisation principle and an MNL model form, we hypothesise that the decision to buy a car from this dealership is the sum of the individual contribution of each of the following to the total utility.

- Price
- Marque (BMW, Chrysler, Mitsubishi)
- Origin (German, American)
- Performance

Using multinomial regression on the sales data however will not tell us what we want to know. The reason is that much of the data is collinear since cars at this dealership are either:

high performance, expensive German cars
low performance, cheap American cars

There is not enough information, nor will there ever be enough, to tell us whether people are buying cars because they are European, because they are a BMW or because they are high performance. The reason is that these three attributes always co-occur and in this case are perfectly correlated . That is: all BMW's are made in Germany and are of high performance. These three attributes: origin, marque and performance are said to be collinear or non-orthogonal.

These types of data, the sales figures, are known as revealed preference data, or RP data, because the data 'reveals' the underlying preference for cars. We can infer someone's preference through their actions, i.e. the car they actually bought. All data mining uses RP data. RP data is vulnerable to collinearity since the data is effectively from the wild world of reality. The presence of collinearity implies that there is missing information, as one or more of the collinear factors is redundant and adds no new information. This weakness of data mining is that the critical missing data that may explain choices, is simply never observed.

We can ensure that attributes of interest are orthogonal by filtering the RP data to remove correlations. This may not always be possible, however using stated preference methods, orthogonality can be ensured through appropriate construction of an experimental design.

Experimental design

In order to maximise the information collected in Stated Preference Experiments, an experimental design (below) is employed. An experimental design in a Choice Experiment is a strict scheme for controlling and presenting hypothetical scenarios, or choice sets to respondents. For the same experiment, different designs could be used, each with different properties. The best design depends on the objectives of the exercise.

It is the experimental design that drives the experiment and the ultimate capabilities of the model. Many very efficient designs exist in the public domain that allow near optimal experiments to be performed.

For example the Latin square 1617 design allows the estimation of all main effects of a product that could have up to 1617 (approximately 295 followed by eighteen zeros) configurations. Furthermore this could be achieved within a sample frame of only around 256 respondents.

Below is an example of a much smaller design. This is 34 main effects design.

0	0	0	0
0	1	1	2
0	2	2	1
1	0	1	1
1	1	2	0
1	2	0	2
2	0	2	2

2	1	0	1
2	2	1	0

This design would allow the estimation of main effects utilities from 81 (34) possible product configurations. A sample of around 20 respondents could model the main effects of all 81 possible product configurations with statistically significant results.

Some examples of other experimental designs commonly used:

- Balanced incomplete block designs (BIBD)
- Random designs
- Main effects
- Two way effects
- Full factorial

More information on experimental designs may be found here.

Stated preference

A major advance in choice modelling has been the use of Stated Preference data. With RP data we are at the whim of the interrelated nature of the real world. With SP data, since we are directly asking humans about their preferences for products and services, we are also at liberty to construct the very products as we wish them to evaluate.

This allows great freedom in the creative construction many improbable but plausible hypothetical products. It also allows complete militation against collinearity through experimental design.

If instead of using the RP sales data as in the previous example, we were to show respondents various cars and ask "Would you buy this car?"", we could model the same data. However, instead of simply using the cars we actually sold, we allowed ourselves the freedom to create hypothetical cars, we could escape the problems of collinearity and discover the true utilities for the attributes of marque, origin and performance. This is known as a Choice Experiment.

For example one could create the following unlikely, however plausible scenarios.

a low performance BMW that was manufactured in the US. "Would you buy this car?", or;
a high performance Mitsubishi manufactured in Germany. "How about this car?"

Information theory tells us that a data set generated from this exercise would at least allow the discrimination between 'origin' as a factor in choice.

A more formal derivation of an appropriate experimental design would consequently ensure that no attributes were collinear and would therefore guarantee that there was enough information in the collected data for all attribute effects to be identified.

Because individuals do not have to back up their choices with real commitments when they answer the survey, to some extent, they would behave inconsistently when the situation really happens, a common problem with all SP methods.

However, because Choice Models are Scale Invariant this effect is equivalent for all estimates and no individual estimate is biased with respect to another.

SP models may therefore be accurately scaled with the introduction of Scale Parameters from real world observations, yielding extremely accurate predictive models.

Preferences as choice trade-offs

It has long been known that simply asking human beings to rate or choose their preferred item from a scalar list will generally yield no more information than the fact that human beings want all the benefits and none of the costs. The above exercise if executed as a quantitative survey would tell us that people would prefer high performance cars at no cost. Again information theory tells us that there is no context-specific information here.

Instead, a choice experiment requires that individuals be forced to make a trade-off between two or more options, sometimes also allowing 'None or Neither' as a valid response. This presentation of alternatives requires that the at least some respondents compare: the cheaper, lower performance car against the more expensive, higher performance car. This datum provides the key missing information necessary to separate and independently measure the utility of performance and price.

Sampling and block allocation

- Stated Preference data must be collected in highly specific fashion to avoid temporal, learning and segment biases. Techniques include:
- random without replacement block allocation; to ensure balanced sampling of scenarios
- in-block order randomisation; to avoid temporal and learning biases
- independent segment based allocation; to ensure balanced scenarios across segments of interest
- block allocation balancing; to ensure that non-completes do not affect overal sample balance

Model generation

The typical outputs from a choice model are:

a model equation

a set of estimates of the marginal utilities for each of the attributes of interest; in the above example these would be (Marque, Origin, Price and Performance). In the case of an MNL model form, the marginal utilities have a specific quantitative meaning and are directly related to the marginal probability that the attribute causes an effect on the dependent variable which in the above example would be propensity to buy.

variance statistics for each of the utilities estimated.

Choice modeling in practice

Superficially, a Choice Experiment resembles a market research survey; Respondents are recruited to fill out a survey, data is collected and the data is analysed. However two critical steps differentiate a Choice Experiment from a Questionnaire:

An experimental design must be constructed. This is a non-trivial task.
Data must be analysed with a model form, MNL, Mixed Logit, EBA, Probit etc...

The Choice Experiment itself may be performed via hard copy with pen and paper, however increasingly the on-line medium is being used as it has many advantages over the manual process, including cost, speed, accuracy and ability to perform more complex studies such as those involving multimedia or dynamic feedback.

Despite the power and general applicability of Choice Modeling, the practical execution is far more complex than running a general survey. The model itself is a delicate tool and potential sources of bias that are ignored in general market research surveys need to be controlled for in choice models.

Strengths of choice modelling

Forces respondents to consider trade-offs between attributes;

- Makes the frame of reference explicit to respondents via the inclusion of an array of attributes and product alternatives;
- Enables implicit prices to be estimated for attributes;
- Enables welfare impacts to be estimated for multiple scenarios;
- Can be used to estimate the level of customer demand for alternative 'service product' in non-monetary terms; and
- Potentially reduces the incentive for respondents to behave strategically.

Choice modelling versus traditional quantitative market research

Choice Experiments may be used in nearly every case where a hard estimate of current and future human preferences needs to be determined.

Many other market research techniques attempt to use ratings and ranking scales to elicit preference information.

Ratings

Major problems with ratings questions that do not occur with Choice Models are:

- no trade-off information. A risk with ratings is that respondents tend not to differentiate between perceived 'good' attributes and rate them all as attractive.
- variant personal scales. Different individuals value a '2' on a scale of 1 to 5 differently. Aggregation of the frequencies of each of the scale measures has no theoretical basis.
- no relative measure. How does and analyst compare something rated a 1 to something rated a 2. Is one twice as good as the other? Again there is no theoretical way of aggregating the data.

Ranking

Rankings do introduce an element of trade-off in the response as no two items may occupy the same ranking position. Order preference is captured; however, relative importance is not.

Choice Models however do not suffer from these problems and furthermore are able to provide direct numerical predictions about the probability an individual will make a particular choice.

Maximum difference scaling

Maximum Difference Preference Scaling (or MaxDiff as it is commonly known) is a well-regarded alternative to ratings and ranking. It asks people to choose their most and least preferred options from a range of alternatives. By integrating across the choice probabilities, utility scores for each alternative can be estimated on a ratio scale.

Uses of choice modelling

Choice modelling is particularly useful for:

- Predicting uptake and refining New Product Development
- Estimating the implied willingness to pay (WTP) for goods and services
- Product or service viability testing
- Variations of product attributes
- Understanding brand value and preference
- Demand estimates and optimum pricing

- Brand value

Choice modeling is a standard technique in travel demand modeling. A classical reference is Ben Akiva and Lerman (1989) , and Cascetta (2009) ; more recent methodological developments are described in Train (2003) .

Early applications of discrete choice theory to marketing are described in Anderson et. al. (1992)

Recent developments include a Bayesian approach to discrete choice modeling as set out in Rossi, Allenby, and McCulloch (2009)

Decision downloading

Decision downloading refers to communicating a decision to those who have not been involved in the decision-making process.

The term “decision downloading” is used to set apart those special situations in which decision-makers communicate a decision that has already been made. The communicators cannot, for whatever reason, keep everyone informed in real-time about the decision-making process.

Types of "downloaders"

Decision downloaders can be classified into three groups: robust, restricted, and remedial.

Robust downloaders discuss:

a) how the decision was made b) why it was made c) what alternatives were considered d) how it fits in with the organizational mission e) how it impacts the organization f) how it impacts employees.

Restricted downloaders discuss some of the above issues, while remedial downloaders discuss few of them.

Robust decision downloaders have a different frame of reference than their less effective counterparts. They view themselves more as educators than cheerleaders. They recognize that education cannot be “once and done”. They know employees learn at different rates, in different ways and from different of sources.

Typical decision downloading situations

An executive team has been engaged in merger talks with another company. By mutual agreement, they cannot talk about the possible merger, even to employees. Presenting the offer to shareholders and other interested parties becomes a decision downloading situation.

Union and management are locked into contentious negotiations that involve changes in compensation, work rules, and benefits packages. By agreed-upon rules, the offers and counteroffers are not openly discussed with union employees. After months of give-and-take, they agree on contract language and want to put it to a vote. Announcing the agreement becomes a decision downloading situation.

An executive-level task force has been established with the principle objective of finding a creative way to reduce health care costs. After months of discussions with various vendors, they decide on an approach that minimizes the company health care expenses, preserves quality levels but involves modest increases in employee contribution levels. Announcing the plan becomes a decision downloading situation.

In each situation, the decision-makers—either by choice or by prior agreement—do not involve others in the decision-making process. Discussions leading to the decision are often deep, nuanced and sometimes contentious. The decisions are frequently complex, often difficult to understand, and sometimes controversial. Simply put, the nature of the decision-making process and the features of the decision itself often make any subsequent communications about the decision extraordinarily difficult. All too often, the subsequent communications are an afterthought borne out of psychological exhaustion from the decision-making process itself. Consequently, decision-makers frequently stumble through what we call the "decision downloading process". No wonder researchers have found that only 50% of all decisions ever get implemented and sustained.

Origin

The term was coined by Phillip G. Clampitt and M. Lee Williams in an article published in the MIT Sloan Management Review, Winter 2007.

Causes of poor decision downloading

The causes of poor decision downloading include:

- Failure to Clarify Responsibilities. Decision-makers sometimes fail to clarify who has responsibility for communicating the decision.
- Desire to Quickly Inform. Decision-makers may restrict communication to the informational highlights because they are motivated by a desire to promptly inform everyone. They tend to focus on the results of the decision-making process, not on the relevant facts, the options weighed, the manner by which decisions were made, and the uncertainty surrounding conclusions.
- Interest in Protecting Employees. Decision-makers may want to protect employees from all the nitty-gritty details of the decision-making process.

Consequences of decision downloading styles

Researchers have reported that:

- Employees who experience robustly downloaded decisions are more than twice as likely to be supportive of the decision compared to those who are forced to cope with a remedially downloaded one.
- Robustly downloaded decisions engender greater employee job satisfaction, commitment to the organization, and identity with the organization than either of the other modes.
- Robustly downloaded decisions cultivate employee perceptions that the organization is well managed and headed in the right direction.

Criticism

Since this is a relatively new concept there have not been replications of the original research.

Decision engineering

Decision engineering framework

Decision Engineering is a framework that unifies a number of best practices for organizational decision making. It is based on the recognition that, in many organizations, decision making could be improved if a more structured approach were used. Decision engineering seeks to overcome a decision making "complexity ceiling", which is characterized by a mismatch between the sophistication of organizational decision making practices and the complexity of situations in which those decisions must be made. As such, it seeks to solve some of the issues identified around complexity theory and organizations. In this sense, Decision Engineering represents a practical application of the field of complex systems, which helps organizations to navigate the complex systems in which they find themselves.

Despite the availability of advanced process, technical, and organizational decision making tools, decision engineering proponents believe that many organizations continue to make poor decisions. In response, decision engineering seeks to unify a number of decision making best practices, creating a shared discipline and language for decision making that crosses multiple industries, both public and private organizations, and that is used worldwide.

To accomplish this ambitious goal, decision engineering applies an engineering approach, building on the insight that it is possible to design the decision itself using many principles previously used for designing more tangible objects like bridges and buildings. This insight was previously applied to the engineering of software—another kind of intangible engineered artifact—with significant benefits.

As in previous engineering disciplines, the use of a visual design language representing decisions is emerging as an important element of decision engineering, since it provides an intuitive common language readily understood by all decision participants. Furthermore, a visual metaphor improves the ability to reason about complex systems as well as to enhance collaboration.

In addition to visual decision design, there are two other aspects of engineering disciplines that aid mass adoption. These are: 1) the creation of a shared language of design elements and 2) the use of a common methodology or process, as illustrated in the diagram above.

Motivation

The need for a unified methodology of decision making is driven by a number of factors that organizations face as they make difficult decisions in a complex internal and external environment.

Recognition of the broad-based inability of current methods to solve decision making issues in practice comes from several sources, including government sources and industries such as telecommunications, media, the automotive industry, and pharmaceuticals.

Examples:

The outcomes of decisions are becoming more complex, going well beyond next quarter's revenues or other tangible outcomes to multiple goals that must be satisfied together, some of which are often intangible:

The car is becoming an expression of identity, values, and personal control in ways that move far beyond traditional segmentation and branding. For example, fuel efficiency will be only one consideration for a socially responsible vehicle (SRV). What percent of the parts are recyclable? What is the vehicle's total carbon footprint? Are there child labor inputs? Toxic paints, glues, or plastics? How transparent is the supply chain? Is the seller accountable for recycling? What methods are used? Are fair labor practices employed?
— Shoshana Zuboff, The GM Solution: Life Boats, Not Life Support. Business Week, November 18, 2008

Global increase in complexity:

We live in a dynamic world in which the pace, scope, and complexity of change are increasing. The continued march of globalization, the growing number of independent actors, and advancing technology have increased global connectivity, interdependence and complexity, creating greater uncertainties, systemic risk and a less predictable future. These changes have led to reduced warning times and compressed decision cycles.

— Director of National Intelligence, Vision 2015: A Globally Networked and Integrated Intelligence Enterprise Also see this Vision 2015 summary

Transferring engineering principles

Unlike other decision making tools and methodologies, decision engineering seeks to bring to bear a number of engineering practices to the process of creating a decision. These include requirements analysis, specification, scenario planning, quality assurance, security, and the use of design principles as described above. During the decision execution phase, outputs produced during the design phase can be used in a number of ways; monitoring approaches like business dashboards and assumption based planning are used to track the outcome of a decision and to trigger replanning as appropriate. One view of how some of these elements combine is shown in the diagram at the start of this article.

Like related engineering disciplines before it, decision engineering promises improvements in the quality of decisions made, the ability to make them more quickly, the ability to align organizational resources more effectively around a change in decisions, and lowers the risks associated with decisions. Furthermore, a designed decision can be reused and modified as new information is obtained.
Bringing numerical methods to the desktop

Although many elements of decision engineering, such as Sensitivity analysis, are mature disciplines, they are not in wide use by strategic planners. Decision engineering seeks to create a visual language that serves to facilitate communication between them and quantitative experts, allowing broader utilization of these and other numerical and technical approaches.

Origins

It is interesting to note that, despite decades of development of decision support system and methodologies (like decision analysis), these are still less popular than spreadsheets as primary tools for decision making. Decision engineering seeks to bridge this gap, creating a critical mass of users of a common methodology and language for the core entities included in a decision, such as assumptions, external values, facts, data, and conclusions. If a pattern from previous industries holds, such a methodology will also facilitate technology adoption, by clarifying common maturity models and road maps that can be shared from one organization to another.

The decision engineering approach is multidisciplinary, unifying findings on cognitive bias and decision making, situational awareness, critical and creative thinking, collaboration and organizational design, with engineering technologies.

Decision engineering is considered an improvement upon current organizational decision making practices, which include the use of spreadsheets (difficult to QA, hard to collaborate and discuss), text (sequential in nature, so is not a good fit for how information flows through a decision structure), and verbal argument. The movement from these largely informal structures to one in which a decision is documented in a well understood, visual language, echoes the creation of common blueprint methodologies in construction, with promise of similar benefits.

Decision engineering is both a very new and also a very old discipline. Many of its elements—such as the language of assessing assumptions, using logic to support an argument, the necessity of critical thinking to evaluate a decision, and understanding the impacts of bias—are ancient. Yet the realization that these elements can form a coherent whole that provides significant benefits to organizations by focusing on a common methodology is relatively new.

Visual decision design

Because it makes visible the otherwise invisible reasoning structures used in complex decisions, the design aspect of decision engineering draws from other conceptual representation technologies like mind mapping, conceptual graphs, and semantic networks. The basic idea is that a visual metaphor enhances intuitive thinking, inductive reasoning, and pattern recognition—important cognitive skills usually less accessible in a verbal or text discussion. A business decision map can be seen as one approach to a formal decision language to support decision engineering. See, e.g., Waring, 2010.

Explicit representation of intangibles

Decision engineering recognizes that many aspects of decision making are based on intangible elements, including opportunity costs, employee morale, intellectual capital, brand recognition and other forms of business value that are not captured in traditional quantitative or financial models. Value network analysis—most notably Value network maps—are therefore relevant here.

Notes

Enterprise Decision Management (EDM) is a closely related discipline that focuses on automating decisions across an enterprise. Decision Engineering is from this point of view a superset of EDM, since it encompasses both manual and automated decision making processes, unifying them into a common methodology that, when effective, breaks down barriers between quantitative analysis / analytics tools and departments and those with a more qualitative / strategic / management focus.

The term "Decision engineering" is used in several industries with more specific meaning than the framework described here. For instance, the Australian Software Research Centre has an IT evaluation approach called Decision Engineering; Idea focuses on emergency management under the heading of "Decision Engineering Analysis"; and the National University of Singapore includes an organization called the Decision Engineering Group. Each of these has a meaning that is distinct from what is discussed in the present article.

In behavioral economics, "Decision engineering" can mean the deliberate manipulation of consumer choices, as in this Journal of Consumer Research study: People choose healthy meals, if given more choice: Study. In this use of the term, Decision Engineering is roughly analogous to Soft paternalism - a quite different meaning than is covered in the present article, referring as it does to the engineering of decisions made by consumers, rather than the use of engineering principles to aid in complex decision making. Although distinctly different, this practice draws on much of the same decision-making research as does decision engineering (such as, for the example, the work of Richard Thaler as described in this article about Barak Obama's University of Chicago connections to this school of thought).

Cost engineering applies engineering principles to measure the costs associated with engineering projects. Cost engineering is sometimes grouped into the broader context of other engineering decisions, such as product engineering and design optimization, in which context it is sometimes referred to as "Decision Engineering". This can be distinguished from the broader framework of this article, which goes beyond the arena of engineering decisions to all decisions faced by organizations.

Operations research is a largely quantitative approach to decision making that attempts to identify optimal or near-optimal solutions to decision making problems.

Decision theory

Decision theory in economics, psychology, philosophy, mathematics, and statistics is concerned with identifying the values, uncertainties and other issues relevant in a given decision, its rationality, and the resulting optimal decision. It is very closely related to the field of game theory.

Normative and descriptive decision theory

Most of decision theory is normative or prescriptive, i.e., it is concerned with identifying the best decision to take, assuming an ideal decision maker who is fully informed, able to compute with perfect accuracy, and fully rational. The practical application of this prescriptive approach (how people ought to make decisions) is called decision analysis, and aimed at finding tools, methodologies and software to help people make better decisions. The most systematic and comprehensive software tools developed in this way are called decision support systems.

Since people usually do not behave in ways consistent with axiomatic rules, often their own, leading to violations of optimality, there is a related area of study, called a positive or descriptive discipline, attempting to describe what people will actually do. Since the normative, optimal decision often creates hypotheses for testing against actual behaviour, the two fields are closely linked. Furthermore it is possible to relax the assumptions of perfect information, rationality and so forth in various ways, and produce a series of different prescriptions or predictions about behaviour, allowing for further tests of the kind of decision-making that occurs in practice.

In recent decades, there has been increasing interest in what is sometimes called 'behavioral decision theory' and this has contributed to a re-evaluation of what rational decision-making requires (see for instance Anand, 1993).

What kinds of decisions need a theory?

Choice under uncertainty

This area represents the heart of decision theory. The procedure now referred to as expected value was known from the 17th century. Blaise Pascal invoked it in his famous wager (see below), which is contained in his Pensées, published in 1670. The idea of expected value is that, when faced with a number of actions, each of which could give rise to more than one possible outcome with different probabilities, the rational procedure is to identify all possible outcomes, determine their values (positive or negative) and the probabilities that will result from each course of action, and multiply the two to give an expected value. The action to be chosen should be the one that gives rise to the highest total expected value. In 1738, Daniel Bernoulli published an influential paper entitled Exposition of a New Theory on the Measurement of Risk, in which he uses the St. Petersburg paradox to show that expected value theory must be normatively wrong. He also gives an example in which a Dutch merchant is trying to decide whether to insure a cargo being sent from Amsterdam to St Petersburg in winter, when it is known that there is a 5% chance that the ship and cargo will be lost. In his solution, he defines a utility function and computes expected utility rather than expected financial value (see for a review).

In the 20th century, interest was reignited by Abraham Wald's 1939 paper pointing out that the two central procedures of sampling–distribution based statistical-theory, namely hypothesis testing and parameter estimation, are special cases of the general decision problem. Wald's paper renewed and synthesized many concepts of statistical theory, including loss functions, risk functions, admissible decision rules, antecedent distributions, Bayesian procedures, and minimax procedures. The phrase "decision theory" itself was used in 1950 by E. L. Lehmann.

The revival of subjective probability theory, from the work of Frank Ramsey, Bruno de Finetti, Leonard Savage and others, extended the scope of expected utility theory to situations where subjective probabilities can be used. At this time, von Neumann's theory of expected utility proved that expected utility maximization followed from basic postulates about rational behavior.

The work of Maurice Allais and Daniel Ellsberg showed that human behavior has systematic and sometimes important departures from expected-utility maximization. The prospect theory of Daniel Kahneman and Amos Tversky renewed the empirical study of economic behavior with less emphasis on rationality presuppositions. Kahneman and Tversky found three regularities — in actual human decision-making, "losses loom larger than gains"; persons focus more on changes in their utility–states than they focus on absolute utilities; and the estimation of subjective probabilities is severely biased by anchoring.

Castagnoli and LiCalzi (1996), Bordley and LiCalzi (2000) recently showed that maximizing expected utility is mathematically equivalent to maximizing the probability that the uncertain consequences of a decision are preferable to an uncertain benchmark (e.g., the probability that a mutual fund strategy outperforms the S&P 500 or that a firm outperforms the uncertain future performance of a major competitor.). This reinterpretation relates to psychological work suggesting that individuals have fuzzy aspiration levels (Lopes & Oden), which may vary from choice context to choice context. Hence it shifts the focus from utility to the individual's uncertain reference point.

Pascal's Wager is a classic example of a choice under uncertainty. The uncertainty, according to Pascal, is whether or not God exists. Belief or non-belief in God is the choice to be made. However, the reward for belief in God if God actually does exist is infinite. Therefore, however small the probability of God's existence, the expected value of belief exceeds that of non-belief, so it is better to believe in God. (There are several criticisms of the argument.)

Intertemporal choice

This area is concerned with the kind of choice where different actions lead to outcomes that are realised at different points in time. If someone received a windfall of several thousand dollars, they could spend it on an expensive holiday, giving them immediate pleasure, or they could invest it in a pension scheme, giving them an income at some time in the future. What is the optimal thing to do? The answer depends partly on factors such as the expected rates of interest and inflation, the person's life expectancy, and their confidence in the pensions industry. However even with all those factors taken into account, human behavior again deviates greatly from the predictions of prescriptive decision theory, leading to alternative models in which, for example, objective interest rates are replaced by subjective discount rates.

Competing decision makers

Some decisions are difficult because of the need to take into account how other people in the situation will respond to the decision that is taken. The analysis of such social decisions is more often treated under the label of game theory, rather than decision theory, though it involves the same mathematical methods. From the standpoint of game theory most of the problems treated in decision theory are one-player games (or the one player is viewed as playing against an impersonal background situation). In the emerging socio-cognitive engineering, the research is especially focused on the different types of distributed decision-making in human organizations, in normal and abnormal/emergency/crisis situations.

Signal detection theory is based on decision theory.

Complex decisions

Other areas of decision theory are concerned with decisions that are difficult simply because of their complexity, or the complexity of the organization that has to make them. In such cases the issue is not the deviation between real and optimal behaviour, but the difficulty of determining the optimal behaviour in the first place. The Club of Rome, for example, developed a model of economic growth and resource usage that helps politicians make real-life decisions in complex situations.

Paradox of choice

Observed in many cases is the paradox that more choices may lead to a poorer decision or a failure to make a decision at all. It is sometimes theorized to be caused by analysis paralysis, real or perceived, or perhaps from rational ignorance. A number of researchers including Sheena S. Iyengar and Mark R. Lepper have published studies on this phenomenon. This analysis was popularized by Barry Schwartz in his 2004 book, The Paradox of Choice.

Statistical decision theory

Several statistical tools and methods are available to organize evidence, evaluate risks, and aid in decision making. The risks of Type I and type II errors can be quantified (estimated probability, cost, expected value, etc.) and rational decision making is improved.

Probability theory

The Advocates of probability theory point to:

the work of Richard Threlkeld Cox for justification of the probability axioms,

the Dutch book paradoxes of Bruno de Finetti as illustrative of the theoretical difficulties that can arise from departures from the probability axioms, and

the complete class theorems, which show that all admissible decision rules are equivalent to the Bayesian decision rule for some utility function and some prior distribution (or for the limit of a sequence of prior distributions). Thus, for every decision rule, either the rule may be reformulated as a Bayesian procedure, or there is a (perhaps limiting) Bayesian rule that is sometimes better and never worse.

Alternatives to probability theory

The proponents of fuzzy logic, possibility theory, Dempster–Shafer theory and info-gap decision theory maintain that probability is only one of many alternatives and point to many examples where non-standard alternatives have been implemented with apparent success; notably, probabilistic decision theory is sensitive to assumptions about the probabilities of various events, while non-probabilistic rules such as minimax are robust, in that they do not make such assumptions.

General criticism

A general criticism of decision theory based on a fixed universe of possibilities is that it considers the "known unknowns", not the "unknown unknowns": it focuses on expected variations, not on unforeseen events, which some argue (as in black swan theory) have outsized impact and must be considered – significant events may be "outside model". This line of argument, called the ludic fallacy, is that there are inevitable imperfections in modeling the real world by particular models, and that unquestioning reliance on models blinds one to their limits.

For instance, a simple model of daily stock market returns may include extreme moves such as Black Monday (1987), but might not model the market breakdowns following the September 11 attacks.

Emotions in decision making

Recent research suggests that emotions are just as influential as cognitive processes when it comes to decision making. This is interesting because emotions are often considered irrational occurrences that may distort reasoning (Barnes and Thagard, 1996). According to Sayegh, et al. (2004), the conventional way of thinking about decision making is to banish emotion from its decisions entirely. They say the decision makers should act using a "cool head" where decisions should come only from rational and cognitive processes to obtain the best results. The implications of emotions during decision making processes have only recently been discussed in some detail. With the growing body of knowledge on emotions in decision making, researchers have proposed various theories to help further our understanding of what influences the decisions that we make.

Loewenstein, et al. (2001) suggest the role of 'anticipatory' and 'anticipated' emotions in decision making processes. According to them, "anticipatory emotions are immediate visceral reactions" like fear, anxiety, dread about uncertainties, often felt during decision making whereas "anticipated emotions" such as disappointment or regret are typically "not experienced in the immediate present but are expected to be experienced as a result of a decision." According to Bagozzi, et al. (2003) anticipated emotions plays an important role to determine the actions of the decision makers, when dealing with a judgement, like what to choose and why choose it.

How emotions during decision making affect the decision

A study done by Isen and Shalker (1982) showed how one's emotion affects his/her cognitive process. A group of sixty students were randomly assigned to groups and the researchers intentionally generated different conditions for each group. All students were asked to evaluate slides shown to them as pleasant, unpleasant or ambiguous. Evaluations by students who were assigned to "successful" conditions were higher than those by students who were not assigned to any condition. On the other hand, "failure" students showed lower evaluation on all the slides compared with unconditioned students. Isen and Shalker (1982) concluded that "good mood provides access to positive associations in memory and that these weigh in the evaluation". The study also stated that one's mood strongly affects decisions especially on ambiguous objects which could be either positive or negative (Isen & Shalker 1982).

Another research done by Isen and Patric (1983) put forth the theory of "mood maintenance" which states that happy decision-makers are reluctant to gamble. In other words, happy people decide against gambling, since they would not want to undermine the happy feeling.

Alternately, the influence of negative feelings at the time of decision making was studied by Raghunathan and Tuan Pham (1999). They conducted three experiments in gambling decisions and job selection decisions, where unhappy subjects were found to prefer high-risk/high-reward options unlike anxious subjects who preferred low-risk/low-reward options. They stated that "anxiety and sadness convey distinct types of information to the decision-maker and prime different goals." It was found that "while anxiety primes an implicit goal of uncertainty reduction, sadness primes an implicit goal of reward replacement" (Raghunathan & Tuan Pham 1999). Thus emotions cannot simply be classified as positive or negative as we need to consider the consequences of the emotions in ultimate decision making.

State-dependent remembering in decision making

Another important factor is memory of events in decision making. Isen and Shalker (1982) illustrated how one's mood works as "a retrieval cue" whereby happy feelings make positive materials come to mind which in turn have great impact on one's decision. The same is true of negative feelings. Bower (1981) referred to it as "state-dependent remembering" which was echoed by Sayegh, et al. (2004). Both papers stated that emotions and feelings cannot be extracted from the human mind. The emotions felt in a particular situation will be recorded in the emotional memory and can be activated when the person faces a similar situation or has to make a difficult decision in a short period of time. Often the decision maker is unaware of previous experiences in similar situations.

Somatic Marker Hypothesis

The somatic marker hypothesis is a very relevant theory when discussing emotions in decision making. It states that bioregulatory signals such as feelings and emotions provide the principal guide for decisions where individuals, when dealing with a judgement, will assess the severity of the outcomes, their probability of occurrence and their emotional quality to provide their decision (Bechara, et al., 2000). According to Dunn, et al. (2006) "the somatic marker hypothesis proposes that 'somatic marker' biasing signals from the body are represented and regulated in the emotion circuitry of the brain, particularly the ventromedial prefrontal cortex (VMPFC), to help regulate decision-making in situations of complexity and uncertainty". Therefore, in situations of complexity and uncertainty, the marker signals allow the brain to recognise the situation and respond quickly (Dunn, et al., 2006).

As mentioned earlier, there is an intimate connection between emotion and cognition in practical decision making. Damasio, et al. (1990) used somatic marker hypothesis to explain how emotions are biologically indispensable to decisions. He suggested that when choosing between options that differ in relative risk, a somatic marker (for example, a "gut feeling") feeds back to the brain and influences cognitive appraisal (Damasio, et al., 1990).

Thus emotions often unwittingly form the basis of many of our decisions and the conventional belief that cognitive processes alone run our decision making processes has been disregarded. It is in fact an interplay between emotions and cognition that helps us during decision making processes.

Lock-in (decision-making)

Lock-in can be seen as the escalating commitment of decision-makers to an ineffective course of action. It concerns institutional lock-in as compared to technical lock-in of which the QWERTY keyboard is a famous example. The decision-making process is characterised by various informal and formal decision-making moments and decision-makers can become committed to the project before the formal decision to build was taken. The formation of commitment is not necessarily bad, but when commitment turns into lock-in, it has by definition a negative influence on the project performance. Lock-in can occur at the decision-making level or at the project level. There are possibilities to avoid lock-in when decision-makers can be made aware of this phenomenon. However, lock-in can also be used intentionally, in which case, it is much more difficult to prevent and hence manage cost overruns.

Decision-making process

The decision-making process of large infrastructure projects is marked by the formal decision to build the project. However, there are several possible moments in the decision-making process before the formal decision is taken at which decision-makers are committed to the project.

The extent of which decision-makers are committed to the project is of importance here. Early commitment, commitment to the project before the formal decision to build has been taken, is in itself not necessarily negative. It could be advantageous to the decision-making process as it could enforce a decision. This eventually could limit delay and contribute to the projects' performance.

Early commitment can result in negative outcomes once the commitment turns into escalating commitment and lock-in. As lock-in is based on escalating commitment, it has, by definition, a negative influence on project performance. Lock-in has the potential to explain the large cost overruns in large scale transportation infrastructure projects.

Formation

Lock-in with respect to decision-making (on large infrastructure projects) is created when sub-optimal policies are used as a consequence of e.g. path dependency, even though a better alternative is present. The term refers to the escalating commitment of decision-makers to an ineffective course of action (institutional lock-in as compared to technical lock-in). Escalating commitment itself refers to the style of psychological coping associated with the inability to withdraw from obligations. The process of escalating commitment is also known as "entrapment" , the "sunk-cost effect" , the "knee-deep in the big muddy" effect , and the "too-much-invested-to-quit" effect.

Occurrence

Lock-in can occur both at the decision-making level (before the decision to build) and at the project level (after the decision to build) and can influence the extent of overruns in two ways:

The first involves the "methodology" of calculating cost overruns according to the "formal decision to build". Due to lock-in, however, the "real decision to build" is made much earlier in the decision-making process and the costs estimated at that stage are often much lower than those that are estimated at a later stage in the decision-making process, thus increasing cost overruns.

The second way that lock-in can affect cost overruns is through "practice". Although decisions about the project (design and implementation) need to be made, lock-in can lead to inefficient decisions that involve higher costs. Sunk costs in terms of both time and money, the need for justification , escalating commitment , and inflexibility and the closure of alternatives are indicators of lock-in.

Prevention

There are different types of lock-in; conscious/unconscious and intentional/unintentional lock-in. Some of these types of lock-in can be avoided. Decision-makers can be made conscious about their behaviour, for example by confronting them with the lack of sufficient alternatives. When these decision-makers are willing to change their behaviour and consider other alternatives, they are less likely to become committed to one project alternative and hence, the chance for lock-in can be partly avoided.

However, other types of lock-in are more difficult to control, especially intentional lock-in. Intentional lock-in is the result of specific behaviour of parties that act deliberately in the interest of their project.

Cost overruns may thus be partly unnecessary or avoidable if such deliberate creation of lock-in had not taken place, and be partly unavoidable due to the incapacity of decision-makers to make optimal decisions.

Majority rule

Majority rule is a decision rule that selects alternatives which have a majority, that is, more than half the votes. It is the binary decision rule used most often in influential decision-making bodies, including the legislatures of democratic nations. Some scholars have recommended against the use of majority rule, at least under certain circumstances, due to an ostensible trade-off between the benefits of majority rule and other values important to a democratic society. Most famously, it has been argued that majority rule might lead to a "tyranny of the majority", and the use of supermajoritarian rules and constitutional limits on government power have been recommended to mitigate these effects. Recently some voting theorists have argued that majority rule is the rule that best protects minorities.

Distinction

Though plurality (first-past-the post) is often mistaken for majority rule, they are not the same. Plurality makes the options with the most votes the winner, regardless of whether the fifty percent threshold is passed. This is equivalent to majority rule when there are only two alternatives. However, when there are more than two alternatives, it is possible for plurality to choose an alternative that has fewer than fifty percent of the votes cast in its favor.

Use

Being a binary decision rule, majority rule has little use in public elections, with many referendums being an exception. However, it is frequently used in legislatures and other bodies in which alternatives can be considered and amended in a process of deliberation until the final version of a proposal is adopted or rejected by majority rule. It is the default rule prescribed in books like Robert's Rules of Order. The rules of order of most groups additionally prescribe the use of a supermajoritarian rule under certain circumstances, a two-thirds rule, for example, to reopen debate on a measure that has already been decided. One exception is Rusty's Rules of Order, which serves as the standing orders of the Industrial Workers of the World, which is a simplification of Robert's Rules that prescribes the use of majority rule only.

Properties

May's Theorem

According to May, majority rule is the only reasonable decision rule that is "fair", that is, that does not privilege voters by letting some votes count for more or privilege an alternative by requiring fewer votes for its passing. Stated more formally, majority rule is the only binary decision rule that has the following properties:

Fairness: This can be further separated into two properties:

Anonymity: The decision rule treats each voter identically. When using majority rule, it makes no difference who casts a vote; indeed the voter's identity need not even be known.

Neutrality: The decision rule treats each alternative equally. This is unlike supermajoritarian rules, which can allow an alternative that has received fewer votes to win.

Decisiveness: The decision rule selects a unique winner.

Monotonicity: The decision rule would always, if a voter were to change a preference, select the alternative that the voter preferred, if that alternative would have won before the change in preference. Similarly, the decision rule would never, if a voter were to change a preference, select a candidate the voter did not prefer, if that alternative would not have won before the change in preference.

Strictly speaking, it has been shown that majority rule meets these criteria only if the number of voters is odd or infinite. If the number of voters is even, there is the chance that there will be a tie, and so the criterion of neutrality is not met. Many deliberative bodies reduce one participant's voting capacity—namely, they allow the chair to vote only to break ties. This substitutes a loss of total anonymity for the loss of neutrality.

Other Properties

In group decision-making it is possible for a voting paradox to form. That is, it is possible that there are alternatives a, b, and c such that a majority prefers a to b, another majority prefers b to c, and yet another majority prefers c to a. Because majority rule requires an alternative to have only majority support to pass, a majority under majority rule is especially vulnerable to having its decision overturned. (The minimum number of alternatives that can form such a cycle (voting paradox) is 3 if the number of voters is different from 4, because the Nakamura number of the majority rule is 3. For supermajority rules the minimum number is often greater, because the Nakamura number is often greater.)

As Rae argued and Taylor proved in 1969, majority rule is the rule that maximizes the likelihood that the issues a voter votes for will pass and that the issues a voter votes against will fail.

Limitations

Arguments for limitations

Minority rights

Because a majority can win a vote under majority rule, it has been commonly argued that majority rule can lead to a "tyranny of the majority". Supermajoritarian rules, such as the three-fifths supermajority rule required to end a filibuster in the United States Senate, have been proposed as preventative measures of this problem. Other experts argue that this solution is questionable. Supermajority rules do not guarantee that it is a minority that will be protected by the supermajority rule; they only establish that one of two alternatives is the status quo, and privilege it against being overturned by a mere majority. To use the example of the US Senate, if a majority votes against cloture, then the filibuster will continue, even though a minority supports it. Anthony McGann argues that when there are multiple minorities and one is protected (or privileged) by the supermajority rule, there is no guarantee that the protected minority won't be one that is already privileged, and if nothing else it will be the one that has the privilege of being aligned with the status quo.

Another way to safeguard against tyranny of the majority, it is argued, is to guarantee certain rights. Inalienable rights, including who can vote, which cannot be transgressed by a majority, can be decided beforehand as a separate act, by charter or constitution. Thereafter, any decision that unfairly targets a minority's right could be said to be majoritarian, but would not be a legitimate example of a majority decision because it would violate the requirement for equal rights. In response, advocates of unfettered majority rule argue that because the procedure that privileges constitutional rights is generally some sort of supermajoritarian rule, this solution inherits whatever problems this rule would have. They also add the following: First, constitutional rights, being words on paper, cannot by themselves offer protection. Second, under some circumstances, the rights of one person cannot be guaranteed without making an imposition on someone else; as Anthony McGann wrote, "one man's right to property in the antebellum South was another man's slavery." Finally, as Amartya Sen stated when presenting the liberal paradox, a proliferation of rights may make everyone worse off.

Other arguments for limitations

Some argue that majority rule can lead to poor deliberation practice or even to "an aggressive culture and conflict". Along these lines, some[who?] have asserted that majority rule fails to measure the intensity of preferences. For example, the authors of An Anarchist Critique of Democracy argue that "two voters who are casually interested in doing something" can defeat one voter who has "dire opposition" to the proposal of the two.

Voting theorists have often claimed that cycling leads to debilitating instability. Buchanan and Tullock argue that unanimity is the only decision rule that guarantees economic efficiency.

Supermajority rules are often used in binary decisions where a positive decision is weightier than a negative one. Under the standard definition of special majority voting, a positive decision is made if and only if a substantial portion of the votes support that decision—for example, two thirds or three fourths. For example, US jury decisions require the support of at least 10 of 12 jurors, or even unanimous support. This supermajoritarian concept follows directly from the presumption of innocence on which the US legal system is based. Rousseau advocated the use of supermajority voting on important decisions when he said, "The more the deliberations are important and serious, the more the opinion that carries should approach unanimity."

Arguments against Limitations

Minority Rights

McGann argues that majority rule helps to protect minority rights, at least in settings in which deliberation occurs. The argument is that cycling ensures that parties that lose to a majority have an interest to remain part of the group's process, because the decision can easily be overturned by another majority. Furthermore, if a minority wishes to overturn a decision, it needs to form a coalition with only enough of the group members to ensure that more than half approves of the new proposal. (Under supermajority rules, a minority might need a coalition consisting of something greater than a majority to overturn a decision.)

To support the view that majority rule protects minority rights better than supermajority rules McGann points to the cloture rule in the US Senate, which was used to prevent the extension of civil liberties to racial minorities. Ben Saunders, while agreeing that majority rule may offer better protection than supermajority rules, argues that majority rule may nonetheless be of little help to the most despised minorities in a group.

Other Arguments against limitations

Some argue[who?] that deliberative democracy flourishes under majority rule. They argue that under majority rule, participants always have to convince more than half the group at the very least, while under supermajoritarian rules participants might only need to persuade a minority. Furthermore, proponents argue that cycling gives participants an interest to compromise, rather than strive to pass resolutions that only have the bare minimum required to "win".

Another argument for majority rule is that within this atmosphere of compromise, there will be times when a minority faction will want to support the proposal of another faction in exchange for support of a proposal it believes to be vital. Because it would be in the best interest of such a faction to report the true intensity of its preference, so the argument goes, majority rule differentiates weak and strong preferences. McGann argues that situations such as these give minorities incentive to participate, because there are few permanent losers under majority rule, and so majority rule leads to systemic stability. He points to governments that use majority rule which largely goes unchecked—the governments of the Netherlands, Austria, and Sweden, for example—as empirical evidence of majority rule's stability.

Mental accounting

A concept first named by Richard Thaler (1980), mental accounting attempts to describe the process whereby people code, categorize and evaluate economic outcomes.

One detailed application of mental accounting, the behavioral life cycle hypothesis (Shefrin & Thaler, 1988), posits that people mentally frame assets as belonging to either current income, current wealth or future income and this has implications for their behavior as the accounts are largely non-fungible and marginal propensity to consume out of each account is different.

Mental accounting, utility, value and transaction

In mental accounting theory, framing means that the way a person subjectively frames a transaction in their mind will determine the utility they receive or expect. This concept is similarly used in prospect theory, and many mental accounting theorists adopt that theory as the value function in their analysis.

Another very important concept used to understand mental accounting is that of modified utility function. There are 2 values attached to any transaction - acquisition value and transaction value. Acquisition value is the money that one is ready to part with for physically acquiring some good. Transaction value is the value one attaches to having a good deal. If the price that one is paying is equal to the mental reference price for the good, the transaction value is zero. If the price is lower than the reference price, the transaction utility is positive.

Mental accounting cost

More generally, a mental accounting cost or mental transaction cost, a kind of transaction cost, is the cost of making a useful decision, especially of a consumer making a useful decision to buy, and may set a lower bound on useful price granularity in a market.

Fallacies and biases

Mental accounting is subject to many logical fallacies and cognitive biases.

Mindset

In decision theory and general systems theory, a mindset is a set of assumptions, methods or notations held by one or more people or groups of people which is so established that it creates a powerful incentive within these people or groups to continue to adopt or accept prior behaviors, choices, or tools. This phenomenon of cognitive bias is also sometimes described as mental inertia, "groupthink", or a "paradigm", and it is often difficult to counteract its effects upon analysis and decision making processes.

On the positive side a mindset can also be seen as incident of a person's Weltanschauung or philosophy of life. For example there has been quite some interest in the typical mindset of an entrepreneur.

Mindsets in politics

A well-known example is the "Cold War mindset" prevalent in both the U.S. and USSR, which included absolute trust in two-player game theory, in the integrity of command chain, in control of nuclear materials, and in the mutual assured destruction of both in the case of war. Although most consider that this mindset usefully served to prevent an attack by either country, the assumptions underlying deterrence theory have made assessments of the efficacy of the Cold War mindset a matter of some controversy.

Most theorists consider that the key responsibility of an embedded power group is to challenge the assumptions which comprise the group's own mindset. According to these commentators, power groups which fail to review or revise their mindsets with sufficient regularity cannot hold power indefinitely, as a single mindset is unlikely to possess the flexibility and adaptability needed to address all future events. For example, the variations in mindset between Democratic Party and Republican Party Presidents in the U.S. may have made that country more able to challenge assumptions than the Kremlin with its more static bureaucracy.

Modern military theory attempts to challenge entrenched mindsets in dealing with asymmetric warfare, terrorism and the proliferation of weapons of mass destruction. In combination, these threats represent "a revolution in military affairs" and require very rapid adaptation to new threats and circumstances. In this context, the cost of not implementing adaptive mindsets cannot be afforded.

Collective mindsets

Naturally, the question regarding the embodiment of a collective mindset comes to mind. Erikson's (1974) analysis of group-identities and what he calls a life-plan seems relevant here. He recounts the example of American Indians, who were meant to undergo a reeducation process meant to imbue a modern "life-plan" which aimed for a house and a richness expressed by filled bank account. Erikson writes that the Indians' collective historic identity as buffalo hunters was oriented around such fundamentally different reasons/goals that even communication about the divergent "life plans" was itself difficult.

There is a double relation between the institution embodying for example an entrepreneurial mindset and its entrepreneurial performance. Firstly, an institution with an entrepreneurial philosophy will set entrepreneurial goals and strategies as a whole, but maybe even more importantly, it will foster an entrepreneurial milieu, allowing each entity to pursue emergent opportunities. In short, philosophical stance codified in the mind hence as mindset lead to a climate which in turn causes values which lead to practice.

Collective mindsets in this sense are described in such works as Hutchin's "Cognition in the wild" (1995), who analyzes a whole team of naval navigators as the cognitive unit or as computational system, or Senges' Knowledge entrepreneurship in universities (2007). There are also parallels to the emerging field of "collective intelligence" (e.g. (Zara, 2004)) and exploiting the "Wisdom of the crowds" (Surowiecki, 2005) of stakeholders. Zara notes that since collective reflection is more explicit, discursive and conversational it therefore needs a good gestell—especially when it comes to information and communication technology.

Decentralized decision making

Decentralized decision making is any process where the decision making authority is distributed throughout a larger group. It also connotes a higher authority given to lower level functionaries, executives, and workers. This can be in any organization of any size, from a governmental authority to a corporation. However, the context in which the term is used is generally that of larger organizations. This distribution of power, in effect, has far-reaching implications for the fields of management, organizational behavior, and government.

The decisions arising from a process of decentralized decision making are the functional result of group intelligence and crowd wisdom. Decentralized decision making also contributes to the core knowledge of group intelligence and crowd wisdom, often in a subconscious way a la Carl Jung's collective unconscious.

Decision theory is a method of deductive reasoning based on formal probability and deductive reasoning models. It is also studied in a specialized field of mathematics wherein models are used to help make decisions in all human activities including the sciences and engineering. (See also Game theory, Uncertainty, Expectation maximization principle.)

History

Decentralization and centralization have been consistent themes throughout history pertaining to governmental authority and political theory. From the rise and fall of the Roman Empire, there have been periods of centralization and decentralization in societies worldwide. Almost any political movement, from the rise of city states in Roman times, to the later rise and downfall of feudal empires during the middle ages, to the rise of fascism in Germany prior to World War II, to the late 20th century formation of the European Economic Union, the history of Europe has been one of cycles of centralization and decentralization.

MIT Professor Thomas W. Malone explains that "decentralization has three general benefits:

(1) encourages motivation and creativity;

(2) allows many minds to work simultaneously on the same problem; and

(3) accommodates flexibility and individualization."

Decentralized decision making, Malone says, tends to create less ridigity and flatter hierarchies in organizations. When upper management delegates decision making responsibilities, there also exist wider spans of control among managers, creating a more lateral flow of information. Thus there will be more bottom up directional information flow, allowing for more innovation and efficiency closer to the means of production. This increased flow information thereby allows for innovation in what is called Total Quality Management.

Online deliberation

Online deliberation is a term associated with an emerging body of practice, research, and software dedicated to fostering serious, purposive discussion over the Internet. It overlaps with, but is not identical to, e-democracy.

Online deliberation is very interdisciplinary, and includes practices such as online consultation, e-participation, online deliberative polling, online facilitation, online research communities, interactive e-learning, civic dialogue in Internet forums and online chat, and group decision making that utilizes collaborative software and other forms of computer-mediated communication. Work in all these endeavors is tied together by the challenge of using electronic media in a way that deepens thinking and improves mutual understanding.

Open international conferences on online deliberation have been held at Carnegie Mellon University in 2003, Stanford University in 2005, and the University of California, Berkeley in 2008. The most recent conference was held at the University of Leeds, June 30-July 2, 2010. Attendees of the 2005 conference voted to create an international society for online deliberation, but no formal organization has yet been established. Other events of interest have been sponsored by the Online Deliberative Democracy Consortium.

Participative decision making

Participative Decision-Making (PDM) is the extent to which employers allow or encourage employees to share or participate in organizational decision-making (Probst, 2005). According to Cotton et al. (1988), the format of PDM could be formal or informal. In addition, the degree of participation could range from zero to 100% in different PM stages (Cotton et al., 1988; Black & Gregersen, 1997; Brenda, 2001).

PDM is one of many ways in which an organization can make decisions. The leader must think of the best possible style that will allow the organization to achieve the best results. According to psychologist Abraham Maslow, workers need to feel a sense of belonging to an organization (see Maslow's Hierarchy of Needs).

Introduction

"Participative management (PM) is known by many names including shared leadership, employee empowerment, employee involvement, participative decision-making, dispersed leadership, open-book management, or industrial democracy" (Steinheider, B., Bayerl, P.S. & Wuestewald, T.,2006).

"The basic concept involves any power-sharing arrangement in which workplace influence is shared among individuals who are otherwise hierarchical unequals. Such power-sharing arrangements may entail various employee involvement schemes resulting in co-determination of working conditions, problem solving, and decision-making" (Locke & Schweiger, 1979).

The primary aim of PDM is for the organization to benefit from the "perceived motivational effects of increased employee involvement" (Latham, as cited in Brenda, 2001, p. 28).

Advantages

PDM is most effective where a large number of stakeholders are involved and all from different walks of life, coming together to make a decision which benefits everyone. Some such examples are decisions for the environment, health care, anti-animal cruelty and other similar situations. In this case, everyone can be involved, from experts, NGOs, government agencies, to volunteers and members of public.

Organizations benefit from the perceived motivational influences of employees in PDM. When employees participate in the decision making process, they improve understanding and perceptions among colleagues and superiors, and enhance personnel value in the organization (Probst, 2005).

Participatory decision making by the Top Management Team (TMT) "ensures the completeness of decision making and increases team members' commitment to final decisions" (Ling et al., as cited in Carmelli, Sheaffer, & Halevi, 2009, p. 697).

In a participative decision making process each team member has an opportunity to share their perspectives, voice their ideas and tap their skills to improve team effectiveness. As each member can relate to the team decisions, there is a better chance of their achieving the results. There is a positive relationship between decision effectiveness and organizational performance. The better the effectiveness, the better the performance.

The implementation of PDM techniques has been shown to have a wide array of organizational benefits. Researchers have found that PDM may positively impact the following (Steinheider, Bayerl, & Wuestewald, 2006):

- Job satisfaction
- Organizational commitment

- Perceived organizational support
- Organizational citizenship behavior
- Labor-management relations
- Job performance and organizational performance
- Task productivity (Locker & Schweiger, as cited in Lowin, 1968)
- Organizational profits (Cotton et al., 1988)
- Employee absenteeism (Probst, 2005)

When everyone in an organization participates in the decision-making process, organizational communication is much more effective and everyone produces more efficient results (Walker, 2007).

By sharing decision-making with other employees, participants eventually achieve organization objectives that influence them (Brenda, 2001). In this process, PDM can be used as a tool that enhance relationships in the organization, explore incentives of employees and increase the rate of information circulation across the organization (Anderson & McDaniel, as cited in Brenda, 2001).

Outcomes of PDM

The outcomes are various in PDM. In the aspect of employees, PDM refers to job satisfaction and performance, which are usually recognized as commitment and productivity (Allen & Meyer, as cited in Brenda, 2001). In the aspect of employers, PDM is evolved into decision quality and efficiency that influenced by multiple and differential mixed layers in terms of information access, level of participation, processes and dimensions in PDM.

Research primarily focuses on the work satisfaction and performance of employees in PDM (Cotton et al., 1988; Gregersen & Black, 1997; Lowin, 1968; Brenda, 2001). Different measurement systems were applied to identify the two items and the relevant properties. If they are measured with different processes in PDM, the relationship is as described below (Black & Gregersen, 1997):

- Identifying problems: Do not have strong relationship with performance. Because even with full participation, participants may not explore their skills and knowledge in identifying problems, which is likely to weaken the desires and motivation then influence performance.
- Providing solutions: Positive and "potentially strong" relations with performance (Black & Gregersen, 1997, p. 865). It is not only attributed to the skills and knowledge could be explored but also the innovative ways employees can provide and generate.
- Selecting solutions: Positive to performance but not likely to enhance satisfaction. If the solutions generated are not acknowledged by the employees who are absent at the previous stage, the satisfaction could lessen.
- Planning implementation: Positive and strong relationship with both performance and satisfaction. Participants are given the possibility to affect on the achievement

of a designed plan. As the "value attainment" is attached, the extent of performance and work satisfaction increase (Black & Gregersen, 1997, p. 863).
- Evaluating results: Weaker relationship with performance, but positive relationship with satisfaction due to the future benefit.

Disadvantages

One of the primary risks in any participative decision making or power-sharing process is that the desire on the part of the management for more inclusive participation is not genuine . In the words of Arnstein (1969. p. 216), "There is a critical difference between going through the empty ritual of participation and having the real power needed to affect the outcome of the process. This difference is brilliantly capsulized in a poster [available for viewing in her article]... [which] highlights the fundamental point that participation without redistribution of power is an empty and frustrating process for the powerless. It allows the powerholders to claim that all sides were considered, but makes it possible for only some of those sides to benefit."

When participative decision-making takes place in a team setting, it can cause many disadvantages. These can be anything from social pressures to conform to group domination, where one person takes control of the group and urges everyone to follow their standpoints. With ideas coming from many people, time can be an issue. The meeting might end and good ideas go unheard. Possible negative outcomes of PDM are high costs, inefficiency, indecisiveness and incompetence (Debruin, 2007).

With participation comes dilemmas. van der Helm (2007), an independent futurist based at the Hague, The Netherlands, outlines ten major disadvantages in form of dilemma. According to him there are ten such dilemmas and the only way to deal with them is to use foresight.

Ten Dilemmas:

- Participation as the answer and as the problem
- The involvement of the actors
- The level of ambition of the initiators, the context and the participants.
- Representation and legitimization - Participation works best in a situation where it is not needed, i.e. in an environment in which all interests are taken into consideration
- Knowledge, power and strategic behavior
- Formalism or freedom
- Entering the debate: between timing and perseverance
- Going beyond information: communication and mediation
- Results and non-results
- Appreciating and apprehending success and failure

Types

Decisions are made differently within organizations having diverse environments. A PDM style includes any type of decision transfer from a superior to their subordinates (Sager, 1999). PDM may take many forms and can run the gamut from informal suggestion systems to direct high involvement at the policy and administrative level. Most researchers agree that participative decision making is not a unitary concept. Somech (as cited in Steinheider, Bayerl, & Wuestewald, 2006) delineates five aspects of PDM: decision domain, degree of participation, structure, target of participation, and rationale for the process.

Steinheider, Bayerl, & Wuestewald (2006) cited Huang as separating PDM into informal and formal types. Ledford (as cited in Steinheider, Bayerl, & Wuestewald, 2006) distinguishes between three types of PDM: Suggestion Involvement, Job Involvement, and High Involvement. High involvement PDM entails power and information sharing, as well as advanced human resource development practices.

PDM can be broken down into four sub-types: Collective PDM, Democratic PDM, Autocratic PDM, and Consensus PDM. (Please see Page Discussion section)

Collective

In a collective participative decision making style, the members of the organization have some say in the decision process. This is the most common type used by organizations and is proven to be very effective. Although employees are asked for their opinions, the leader alone makes the final decision, has all control of how the decision will pan out, and takes full responsibility for all of the consequences (Connor, 2003).

Democratic

In a democratic participative decision making style, the leader gives up complete ownership of the decision and lets employees vote. The majority vote wins. This causes a fast and effective decision to be made. Although the team might reach a fast decision, no one takes responsibility for the decision and if something goes wrong, an employee can simply state that they did not vote for it.

Autocratic

In an autocratic participative decision making style, similar to the collective style, the leader takes control of and responsibility for the final decision. The difference is that in an autocratic style, members of the organizations are not included and the final outcome is the responsibility of the leader. This is the best style to use in an emergency when an immediate decision is needed.

Consensus

In a consensus participative decision making style, the leader gives up complete control and responsibility of the decision and leaves it to the members of the organization. Everyone must agree and come to the same decision. This might take a while, but the decisions are among the best since it involves the ideas and skills of many other people. Team work is important in this style and brings members closer together while trust and communication increase.

Delegated PDM based on Expertise

Decision makers cannot be experts in all fields. In such situations, the decision maker delegates full or partial responsibility of decision making for a particular area of concern, to the expert on the team for best management outcomes. The participative leader retains the responsibility of final compilation of the draft responses from all . Such delegation is work specific and singular. It depends on the decision maker to compile the expert reports for the final response. Advantages of this type of decision making process makes the group members feel engaged in the process, more motivated and creative. Expertise brings focused and result oriented solutions for BATNA (Best alternative to a negotiated agreement) as and when necessary. Best management outcomes are obtained by utilizing this strategy. An authoritative decision maker would have a higher rate of success than the Democratic decision maker. This strategy would be a disaster, when applied incorrectly or inappropriately is a major disadvantage.

Concepts and Methods

Dimensions of PDM

After Lewin's early research on PDM in 1947, scholars started to explore different dimensions of PDM (Lowin, 1968). In 1988, it was indicated that six dimensions of PDM had been recognized and analyzed (Cotton et al., 1988). Those six dimensions are as follows:

- Participation in Work Decisions: Characterized as formal, long-term and direct participation. The content in this dimension focuses on work, e.g. task distribution, organizational methods of the task.
- Consultative Participation: Same to the previous one except it has lower level of influence in decision-making.
- Short-term Participation: Employees' participation is temporary, ranges from sessions of several hours to campaigns of several days. It is recognized as formal and direct.
- Informal Participation: Could happen in interpersonal relationships between employers and employees. Usually no fixed rules and specific contents are decided in advance.
- Employee Ownership: Formal and indirect participation. Although subordinates have the chance to participate in decision making, usually the typical employees cannot.
- Representative Participation: Measured as formal and indirect. In organizations, the degree of the influence is medium as representatives playing a role that mediate between typical employees and superior.

Based on previous literature, Gregersen & Black (1997) also defined six different dimensions of PDM—rationale, structure, form, decision issues, degree of involvement and decision process—which can be seen in the table below:

- Rationale Democratic: employees have rights to participate in DM. Pragmatic: high work efficiency, productivity, profits, etc.
- Structure Formal: the format has been decided previously. Informal: no fixed format, content, few rules.
- Form Direct: immediately evolve in DM, present personal opinions. Indirect: representatives are assigned to participate in DM.
- Decision Issues Includes 4 aspects: work and task design, work conditions, strategies and capital distribution (derived from cotton, 1988).
- Degree of Involvement Different level of involvement generates differential outcomes.
- Decision Process Contains five processes: identify problems, solution-generating, select specific solution, planning and implementation the solution and evaluate the result.

Additionally, employee outcomes can also be evaluated according to six criteria (Brenda, 2001):

- Rationale: No distinct relationship with performance. However, high level of self-efficacy contributes to higher performance (Mitchell, Gist, & Silver, 1995).
- Structure: Informal PDM encourage job satisfaction, likewise higher level of commitment and motivation (Cotton et al., 1988).
- Form: Direct PDM is more effective than indirect PDM. The greater influence enhances work satisfaction. Whereas the power range of indirect PDM could vary from partial to decisive.
- Decision issues: The major issue relevant to decision contents is the skills and knowledge owning by employees (Latham, Locke, & Winters, 1994). Relevant knowledge brings higher decision quality and efficiency; participants achieve "value attainment" (Black & Gregersen, 1997, p. 863), thereby raising performance and satisfaction.
- Degree of involvement: Higher degree of involvement leads to greater control and then encourages employees' performance and satisfaction.
- Decision process: Planning task implementation is key to improving performance (Latham, Winters, & Locke, 1994).

Using Foresight

Some Important Constraints (van der Helm, 2007):

- Foresight is a personal skill and so repetition should involve the same individuals (not institutions), which is not compatible with the people (rapidly) moving within and between organizations.

- Foresight is often still a voluntary or peripheral job (i.e. few people make foresight their core business), which demands great efforts of organizations and individuals. This may be done once, but not at a regular basis.
- Foresight is often made at particular moments in time, which may help to converge the general attitude of the network. According to Ziegler (as cited in van der Helm, 2007), long-term vision is developed at critical historical moments (the year 2000, the ecological crisis, the re-organization of a business, etc.). Obviously, these are not very likely to be formalized.
- The results of a foresight are very often only indirectly visible in the follow up in policy and management (Tijink, as cited in van der Helm, 2007). Especially in a large exercises it is very unlikely that individuals will find justice done to their ideas unless a serious consensus is reached.
- Furthermore, because of the representation dilemma, it is unlikely that binding conclusions will be drawn from any similar activity. Hence, participants will not find any direct feedback and may lack the motivation to invest a second time.

Vigilant Interaction Theory

According to Papa et al. (2008), the vigilant interaction theory states that the quality of the group as a decision-making team is dependent upon the group's attentiveness during interaction. Critical thinking is important for all group members in order to come up with the best possible solution to the decision.

Four questions that should be asked:

- Analyze the problem - What needs to be fixed?
- Think of objectives - What are we trying to accomplish with this decision?
- Discuss choices - What possible choices can be used?
- Evaluate - After coming up with choices, what are all of the positive and negative aspects of each?

Role of Information

To make a good decision, there needs to be a good amount of information to base the outcome on. Information can include anything from charts and surveys to past sales reports and prior research. When making a decision primarily based on the information you are given from your organization, one can come to a conclusion in four different ways.

1. Decisive - Little amount of information and one course of action. Decisions are made fast, direct, and firmly.

2. Flexible - Little information available, but time is not an issue and they come up with many different courses of action.

3. Hierarchic - Much information available, but one course of action is made.

4. Integrative - Much information is available, and many decisions are made out of it.

Role of Technology

A new kind of participative decision making is communication through the computer, sometimes referred to as "Decision Making through Computer-Mediated Technology". Although a relatively new approach, this way can involve endless possibilities in order to reach a major organizational decision. There is a significant increase in more active and equal member participation. Individuals can talk to many other individuals at any time, regardless of geographic location and time zone. An organization can come together on a virtual site developed to make it easier to share ideas, share presentations and even have a chat room where anyone can add their input. Through a chat room, members of the organizations are able to see what everyone says and no one is blocked from offering their ideas. This method also allows for a convenient archival of past decision making activities (Berry, 2002).

Some disadvantages of computer-mediated meetings are that sometimes feedback can be slow or there can be many conversations under way at the same time, causing confusion. Flaming (Internet) is another computer-mediated problem which occurs when a person uses inappropriate behavior or language while interacting with another person online. Additionally, members also feel less personal and related to their team members (Berry, 2002).

Applications of PDM

While PDM could conceivably be used in nearly any arena requiring decision making, the specific examples below help to demonstrate that PDM is being used, where it is being used, and how that is occurring.

Environment

Although participation in environmental decision making processes can be granted or attained in many ways, and at many levels, one pivotal international instance establishing the rights of individuals to participate came via the Rio Declaration in 1992. In Principle 10, that declaration sets out that "[e]nvironmental decisions are best handled with the participation of all concerned citizens …" who have "... appropriate access to information concerning the environment held by public authorities …" who are then rightly afforded "… opportunity to participate in decision-making processes" (United Nations Department of Economic and Social Affairs, 1992).

In Northern Germany, while regulations have been changed to favor more participative forms of decision making, planning approval decisions for wind farms are still mostly centralized. However, in the implementation of the Water Framework Directive for River Basin Management, stakeholder advisory groups were formed, which provide input to working groups, to whom authority to decide issues by consensus has been delegated by the Federal Ministry of Agriculture, Environment, and Rural Areas (Bruns & Gee, 2009).

China has long had a reputation for centralized control of most aspects of daily life. However, since the introduction and success of market reforms, other areas including those linked to the environment have experienced increased openness toward participatory decision making. In the case of pricing, management, and provision of water services, the Chinese authorities have experimented with public hearings as a way of acclimatizing citizens to the changes in approach and opportunities for their participation, such that "…hundreds of formal public hearings on water tariffs have been organized within 30 provinces, excluding Tibet" (Zhong & Mol, 2008, p. 907).

Holley (2010) discusses a review of the extent to which the aims of New Environmental Governance (NEG) in Australia, including provisions for increased public participation, are being realized. After examining programs at the national and state levels, it was concluded that "…in all but the most rare cases, there were substantial difficulties in fully satisfying the participatory aspirations of the three NEG programs." (Holley, 2010, p. 386).

While progress is being made in many areas to increase participation in environmental decision making, as evidenced in Holley's example above, much work remains to be done.

Path dependence

Path dependence explains how the set of decisions one faces for any given circumstance is limited by the decisions one has made in the past, even though past circumstances may no longer be relevant.

In economics and the social sciences path dependence can refer to either outcomes at a single moment in time or to long run equilibria of a process. In common usage, the phrase implies either:

(A) that "history matters" - a broad concept, or
(B) that predictable amplifications of small differences are a disproportionate cause of later circumstances. And, in the "strong" form, that this historical hang-over is inefficient.

The first usage, (A): "history matters" is trivially true in the explanatory context; everything has causes. And, in these fields, the direct influence of earlier states isn't notable (compare "path dependent" options in finance, where the influence of history can be non standard).

It is the narrow concept, (B), that has the most explanatory force and which is covered in this article.
Contents

Illustration

Consider as an example the Videotape format war; Two mechanisms independent of product quality could explain how VHS achieved dominance over Betamax from a negligible early adoption lead:

A network effect: videocassette rental stores observed more VHS rentals and stocked up on VHS tapes, leading renters to buy VHS players & rent more VHS tapes, until there was complete vendor lock-in.

A VCR manufacturer bandwagon effect of switching to VHS-production because they expected it to win the standards battle.

An alternative analysis is that VHS was better adapted to market demands (e.g. having a longer recording time). In this interpretation, path dependence had little to do with VHS's success, which would have occurred even if Betamax had established an early lead.

Positive feedback mechanisms like bandwagon and network effects are at the origin of path-dependence. They lead to a reinforcing pattern, in which industries 'tip' towards one or another product design. Uncoordinated standardisation can be observed in many other situations.

Economics

Path dependency theory was originally developed by economists to explain technology adoption processes and industry evolution. The theoretical ideas have had a strong influence on evolutionary economics (e.g., Nelson & Winter 1982).

There are many models and empirical cases where economic processes do not progress steadily toward some pre-determined and unique equilibrium, so that the nature of any equilibrium achieved depends partly on the process of getting there. The outcome of a path dependent process will often not converge towards a unique equilibrium but instead reach one of several equilibria (sometimes known as absorbing states).

This dynamic vision of economic evolution is very different from the neo-classical economics tradition, which in its simplest form assumed that only a single outcome could possibly be reached, regardless of initial conditions or transitory events. With path dependence, both the starting point and 'accidental' events (noise) can have significant effects on the ultimate outcome. In each of the following examples it is possible to identify some random events that disrupted the ongoing course, with irreversible consequences:

In economic development, it is said (initially by Paul David in 1985) that a standard which is first-to-market can become entrenched (like the QWERTY layout in typewriters still used in computer keyboards). He called this "path dependence", and said that inferior standards can persist simply because of the legacy they have built up. That QWERTY vs. Dvorak is an example of this phenomenon has been re-asserted, questioned, and continues to be argued. Economic debate continues on the significance of path dependence in determining how standards form.

Economists from Adam Smith to Paul Krugman have noted that similar businesses tend to congregate geographically ("agglomerate"); opening near similar companies attracts workers with skills in that business, which draws in more businesses seeking experienced employees. There may have been no reason to prefer one place to another before the industry developed, but as it concentrates geographically participants elsewhere are at a disadvantage, and will tend to move into the hub, further increasing its relative efficiency. This network effect follows a statistical power law in the idealized case, though negative feedback can occur (through rising local costs).

Buyers often cluster around sellers, and related businesses frequently form Business clusters, so a concentration of producers (initially formed by accident & agglomeration) can trigger the emergence of many dependent businesses in the same region.

In the 1980s, the U.S. dollar exchange rate appreciated, lowering the world price of tradable goods below the cost of production in many (previously successful) U.S. manufacturers. Some of the factories which closed as a result could later have been operated at a (cash-flow) profit, after dollar depreciation, but re-opening was too expensive. This is an example of hysteresis, switching barriers, and irreversibility.

If the economy follows adaptive expectations, future inflation is partly determined by past experience with inflation, since experience determines expected inflation and this is a major determinant of realized inflation.

A transitory high rate of unemployment during a recession can lead to a permanently higher unemployment rate because of the skills loss (or skill obsolescence) by the unemployed along with a deterioration of work attitudes. In other words, cyclical unemployment may generate structural unemployment. This structural hysteresis model of the labour market differs from the prediction of a "natural" unemployment rate or NAIRU, around which 'cyclical' unemployment is said to move without influencing the "natural" rate itself.

Liebowitz and Margolis distinguish types of path dependence; some do not imply inefficiencies and do not challenge the policy implications of neoclassical economics. Only "third degree" path dependence - where switching gains are high but transition is impractical - involves such a challenge. They argue that such situations should be rare for theoretical reasons and that no real-world cases of private locked-in inefficiencies exist. Vergne and Durand qualify this critique by specifying the conditions under which path dependence theory can be tested empirically.

Technically, a path-dependence stochastic process has an asymptotic distribution that "evolves as a consequence (function of) the process's own history". This is also known as a "non-ergodic stochastic process".

In The Theory of the Growth of the Firm (1959), Edith Penrose analyzed how the growth of a firm both organically and through acquisition is strongly influenced by the experience of its managers and the history of the firm's development.

History

Recent methodological work in comparative politics and sociology has adapted the concept of path dependence into analyses of political and social phenomena. Path dependence has primarily been used in comparative-historical analyses of the development and persistence of institutions, whether they be social, political, or cultural. There are arguably two types of path-dependent processes:

One is the "critical juncture" framework, most notably utilized by Ruth and David Collier in political science. In the critical juncture, antecedent conditions allow contingent choices that set a specific trajectory of institutional development and consolidation that is difficult to reverse. As in economics, the generic drivers are: lock-in, positive feedback, increasing returns (the more a choice is made the bigger its benefits), and self-reinforcement (which creates forces sustaining the decision).

The other path-dependent process deals with "reactive sequences" where a primary event sets off a temporally-linked and causally-tight deterministic chain of events that is nearly uninterruptible. These reactive sequences have been used to link the death of Martin Luther King, Jr. with welfare expansion and the industrial revolution in England with the development of the steam engine.

The critical juncture framework has been used to explain the development and persistence of welfare states, labor incorporation in Latin America, and the variations in economic development between countries, among other things. Scholars such as Kathleen Thelen caution that the historical determinism in path-dependent frameworks is subject to constant disruption from institutional evolution.

Social sciences

An influential attempt to rigorously formalize path dependence within political science is that of Paul Pierson, partly drawing on ideas from economics. Herman Schwartz has questioned those efforts, arguing that forces analogous to those identified in the economic literature are not pervasive in the political realm, where the strategic exercise of power give rise to, and transform institutions.

The path-dependence of emergent strategy has been observed in behavioral experiments with individuals and groups.

Other examples

A general type of path dependence is a typological vestige.

In typography, for example, some customs persist, although the reason for their existence no longer applies; for example the placement of the period inside a quotation in U.S. spelling.

Evolution is considered by some to be path-dependent: random mutations occurring in the past have had long-term effects on current life forms, some of which may no longer be adaptive to current conditions. For instance, there is a controversy about whether the panda's thumb is a leftover trait or not.

In the computer and software markets, legacy systems indicate path dependence: customers' needs in the present market often include the ability to read data or run programs from past generations of products. Thus, for instance, a customer may need not merely the best available word processor but rather the best available word processor that can read Microsoft Word files. Such limitations in compatibility contribute to lock-in, and more subtly, to design compromises for independently developed products if they attempt to be compatible. Also see embrace, extend and extinguish.

Public choice theory

In economics, public choice theory is the use of modern economic tools to study problems that traditionally are in the province of political science. From the perspective of political science, it may be seen as the subset of positive political theory which deals with subjects in which material interests are assumed to predominate.

In particular, it studies the behavior of politicians and government officials as mostly self-interested agents and their interactions in the social system either as such or under alternative constitutional rules. These can be represented a number of ways, including standard constrained utility maximization, game theory, or decision theory. Public choice analysis has roots in positive analysis ("what is") but is often used for normative purposes ("what ought to be"), to identify a problem or suggest how a system could be improved by changes in constitutional rules. Another related field is social choice theory.

Origins and formation

The modern literature in Public Choice began with Duncan Black, who in 1948 identified the underlying concepts of what would become median voter theory. He also wrote The Theory of Committees and Elections in 1958. Gordon Tullock refers to him as the "father of public choice theory".

James M. Buchanan and Gordon Tullock coauthored The Calculus of Consent: Logical Foundations of Constitutional Democracy (1962), considered one of the landmark works that founded the discipline of public choice theory. In particular (1962, p. v), the book is about the political organization of a free society. But its method, conceptual apparatus, and analytics "are derived, essentially, from the discipline that has as its subject the economic organization of such a society." The book focuses on positive-economic analysis as to the development of constitutional democracy but in an ethical context of consent. The consent takes the form of a compensation principle like Pareto efficiency for making a policy change and unanimity at least no opposition as a point of departure for social choice.

Kenneth Arrow's Social Choice and Individual Values (1951) influenced formulation of the theory. Among other important works are Anthony Downs's An Economic Theory of Democracy (1957) and Mancur Olson's The Logic of Collective Action (1965).

Public choice theory is commonly associated with George Mason University, where Tullock and Buchanan are currently faculty members. Their early work took place at the University of Virginia and Virginia Polytechnic Institute and State University, hence identification of a Virginia school of political economy.

Development of public choice theory accelerated with the formation of the Public Choice Society in the United States in 1965. The loci of the Society became its journal Public Choice and its annual meetings. The journal and meetings mainly attracted economists and political scientists. The economists brought their choice-based, model-building skill. The political scientists brought their broad knowledge of different political systems and detailed knowledge of institutions and political interaction. Scholars in related fields, such as philosophy, public administration, and sociology, also contributed.

In 1970 the median voter theory was accepted without question in public choice, but by 1980 it had been assaulted on so many fronts that it was almost abandoned. Works by Romer and Rosenthal (1979) and McKelvey (1976) showed that, when political issues are considered multidimensional rather than single dimensional, an agenda setter could start at any point in the issue space and, by strategically selecting issues, end up at any other point in the issue space, so that there is no unique and stable majority rule outcome.

During the same decade, the probabilistic voting theory started to replace the median voter theory, since it clearly showed how it was able to find Nash Equilibria also in multidimensional space. The theory was later completely formalized by Peter Coughlin.

Special interests

Public choice theory is often used to explain how political decision-making results in outcomes that conflict with the preferences of the general public. For example, many advocacy group and pork barrel projects are not the desire of the overall democracy. However, it makes sense for politicians to support these projects. It may make them feel powerful and important. It can also benefit them financially by opening the door to future wealth as lobbyists. The project may be of interest to the politician's local constituency, increasing district votes or campaign contributions. The politician pays little or no cost to gain these benefits, as he is spending public money. Special-interest lobbyists are also behaving rationally. They can gain government favors worth millions or billions for relatively small investments. They face a risk of losing out to their competitors if they don't seek these favors. The taxpayer is also behaving rationally. The cost of defeating any one government give-away is very high, while the benefits to the individual taxpayer are very small. Each citizen pays only a few pennies or a few dollars for any given government favor, while the costs of ending that favor would be many times higher. Everyone involved has rational incentives to do exactly what they're doing, even though the desire of the general constituency is opposite. (It is notable that the political system considered here is very much that of the United States, with "pork" a main aim of individual legislators; in countries such as Britain with strong party systems the issues would differ somewhat.) Costs are diffused, while benefits are concentrated. The voices of vocal minorities with much to gain are heard over those of indifferent majorities with little to lose.

Decision making processes and the state

One way to organize the subject matter studied by Public Choice theorists is to begin with the foundations of the state itself. According to this procedure, the most fundamental subject is the origin of government. Although some work has been done on anarchy, autocracy, revolution, and even war, the bulk of the study in this area has concerned the fundamental problem of collectively choosing constitutional rules. This work assumes a group of individuals who aim to form a government. Then it focuses on the problem of hiring the agents required to carry out government functions agreed upon by the members.

The main questions are: (1) how to hire competent and trustworthy individuals to whom day-to-day decision-making can be delegated and (2) how to set up an effective system of oversight and sanctions for such individuals. To answer these questions it is necessary to assess the effects of creating different loci of power and decision-making within a government; to examine voting and the various means of selecting candidates and choosing winners in elections; to assess various behavioral rules that might be established to influence the behavior of elected and appointed government officials; and to evaluate alternative constitutional and legal rights that could be reserved for citizens, especially rights relating to citizen oversight and the avoidance of harm due to the coercive power of government agents.

These are difficult assessments to make. In practice, most work in the field of Public Choice has dealt with more limited issues. Extensive work has been done on different voting systems and, more generally, on how to transform what voters are assumed to want into a coherent "collective preference". Of some interest has been the discovery that a general collective preference function cannot be derived from even seemingly mild conditions. This is often called Arrow's impossibility theorem. The theorem, an economic generalization of the voting paradox, suggests that voters have no reason to expect that, short of dictatorship, even the best rules for making collective decisions will lead to the kind of consistency attributed to individual choice.

Much work has been done on the loose connection between decisions that we can imagine being made by a full contingent of citizens with zero collective decision-making costs and those made by legislators representing different voting constituencies. Of special concern has been logrolling and other negotiations carried out by legislators in exercising their law-making powers. Important factors in such legislative decisions are political parties and pressure groups. Accordingly, Public Choicers have studied these institutions extensively. The study of how legislatures make decisions and how various constitutional rules can constrain legislative decisions is a major sub-field in Public Choice.

Bureaucracy

Another major sub-field is the study of bureaucracy. The usual model depicts the top bureaucrats as being chosen by the chief executive and legislature, depending on whether the democratic system is presidential and parliamentary. The typical image of a bureau chief is a person on a fixed salary who is concerned with pleasing those who appointed him. The latter have the power to hire and fire him more or less at will. The bulk of the bureaucrats, however, are civil servants whose jobs and pay are protected by a civil service system against major changes by their appointed bureau chiefs. This image is often compared with that of a business owner whose profit varies with the success of production and sales, who aims to maximize profit, and who can hire and fire employees at will.

Rent-seeking

A field that is closely related to public choice is "rent-seeking". This field combines the study of a market economy with that of government. Thus, one might regard it as a "new political economy." Its basic thesis is that when both a market economy and government are present, government agents are a source of numerous special market privileges. Both the government agents and self-interested market participants seek these privileges in order to partake in the monopoly rent that they provide. When such privileges are granted, they reduce the efficiency of the economic system. In addition, the rent-seekers use resources that could otherwise be used to produce goods that are valued by consumers.

Rent-seeking is broader than Public Choice in that it applies to autocracies as well as democracies and, therefore, is not directly concerned with collective decision-making. However, the obvious pressures it exerts on legislators, executives, bureaucrats, and even judges are factors that public choice theory must account for in its analysis of collective decision-making rules and institutions. Moreover, the members of a collective who are planning a government would be wise to take prospective rent-seeking into account.

Political market failure: undemocratic governments

Public Choice Theory has been developed largely in the context of democratic political systems of the variety that exist in Europe and North America. A pioneering work—and, perhaps, the only work to-date of its kind—seeking to analyze collective decision-making based on rules and institutions that characterize the Less Developed Countries was undertaken by Muzaffar Ali Isani at Georgetown University. It focuses largely on the assumptions of a generation of development economists who have articulated the role of the state or political action as an efficient alternative to 'economic' market failures. Isani has suggested that once we introduce 'political' market imperfections as generally found in these countries, we may be confronted with the possibility that far from correcting market failures, political action may actually prove to be a source of further distortions in the economy. He then goes on to develop an essentially economic paradigm of politics appropriate to many developing countries and which is consistent with the axioms of economic theory.

Perspective

Prior to the emergence of public choice theory, many economists tended to consider the state as an agent outside the scope of economic theory, whose actions depend on different considerations than those driving economic agents. (The many other economists who did place the state and its agents within such theory include Vilfredo Pareto.)

Public choice theory attempts to look at governments from the perspective of the bureaucrats and politicians who compose them, and makes the assumption that they act based on Budget-maximizing model in a self-interested way for the purpose of maximizing their own economic benefits (e.g. their personal wealth). The theory aims to apply economic analysis (usually decision theory and game theory) to the political decision-making process in order to reveal certain systematic trends towards inefficient government policies. There are also Austrian variants of public choice theory (suggested by Mises, Hayek, Kirzner, Lopez, and Boettke) in which it is assumed that bureaucrats and politicians may be benevolent but have access to limited information. The assumption that such benevolent political agents possess limited information for making decisions often results in conclusions similar to those generated separately by means of the rational self-interest assumptions. Randall Holcombe and Richard E. Wagner have also developed the notion of "Political Entrepreneurship".

Claims

One of the basic claims that results from public choice theory is that good government policies in a democracy are an underprovided public good, because of the rational ignorance of the voters. Each voter is faced with a tiny probability that his vote will change the result of the elections, while gathering the relevant information necessary for a well-informed voting decision requires substantial time and effort. Therefore, the rational decision for each voter is to be generally ignorant of politics and perhaps even abstain from voting. Rational choice theorists claim that this explains the gross ignorance of most citizens in modern democracies as well as low voter turnout. Rational abstention does, however, create the "Paradox of voting" whereby strict costs benefit analysis implies that nobody should vote.

Special interests

While good government tends to be a pure public good for the mass of voters, there may be many advocacy groups that have strong incentives for lobbying the government to implement specific policies that would benefit them, potentially at the expense of the general public. For example, lobbying by the sugar manufacturers might result in an inefficient subsidy for the production of sugar, either direct or by protectionist measures. The costs of such inefficient policies are dispersed over all citizens, and therefore unnoticeable to each individual. On the other hand, the benefits are shared by a small special-interest group with a strong incentive to perpetuate the policy by further lobbying. Due to rational ignorance, the vast majority of voters will be unaware of the effort; in fact, although voters may be aware of special-interest lobbying efforts, this may merely select for policies which are even harder to evaluate by the general public, rather than improving their overall efficiency. Even if the public were able to evaluate policy proposals effectively, they would find it infeasible to engage in collective action in order to defend their diffuse interest. Therefore, theorists expect that numerous special interests will be able to successfully lobby for various inefficient policies. In public choice theory, such scenarios of inefficient government policies are referred to as government failure — a term akin to market failure from earlier theoretical welfare economics.

"Expressive interests" and democratic irrationality

Geoffrey Brennan and Loren Lomasky claim that democratic policy is biased to favor "expressive interests" and neglect practical and utilitarian considerations. Brennan and Lomasky differentiate between instrumental interests (any kind of practical benefit, both monetary and non-monetary) and expressive interests (forms of expression like applause). According to Brennan and Lomasky, the voting paradox can be resolved by differentiating between expressive and instrumental interests. While voters have virtually no instrumental incentive to vote, they do have an expressive interest in voting. Since voters vote for expressive reasons, politicians win by targeting the median expressive preferences. Bias in favor of expressive interests means that public policy often ignores important practical considerations. For example, there are instrumental costs to restricting international trade. Yet many people favor protectionism as an expression of nationalism, despite its economic costs.

This argument has led some public choice scholars to claim that politics is plagued by irrationality. In articles published in the Econ Journal Watch, economist Bryan Caplan contended that voter choices and government economic decisions are inherently irrational. Caplan's ideas are more fully developed in his book The Myth of the Rational Voter (Princeton University Press 2007). In opposition to the arguments put forward by economist Donald Wittman in his The Myth of Democratic Failure, Caplan claims that politics is biased in favor of irrational beliefs.

According to Caplan, democracy effectively subsidizes irrational beliefs. Anyone who derives utility from potentially irrational policies (such as protectionism) can receive private benefits while imposing the costs of such beliefs on the general public. Were people to bear the full costs of their "irrational beliefs", they would lobby for them optimally, taking into account both their instrumental consequences and their expressive appeal. Instead, democracy oversupplies policies based on irrational beliefs. Caplan defines rationality mainly in terms of mainstream price theory, pointing out that mainstream economists tend to oppose protectionism and government regulation more than the general population, and that more educated people are closer to economists on this score, even after controlling for confounding factors such as income, wealth or political affiliation. One criticism is that many economists do not share Caplan's views on the nature of public choice. However, Caplan does have some data to support his position. Economists have, in fact, often been frustrated by public opposition to economic reasoning. As Sam Peltzman puts it "Economists know what steps would improve the efficiency of HSE [health, safety, and environmental] regulation, and they have not been bashful advocates of them. These steps include substituting markets in property rights, such as emission rights, for command and control. . . . The real problem lies deeper than any lack of reform proposals or failure to press them. It is our inability to understand their lack of political appeal "George Stigler's Contribution to the Economic Analysis of Regulation" 101 J. Pol. Econ. 818, 830 (October 1993).

Rent-seeking

Another major claim is that much of political activity is a form of rent-seeking which wastes resources. Gordon Tullock, Jagdish Bhagwati, and Anne Osborn Krueger have argued that rent-seeking has caused considerable waste. In a parallel line of research Fred McChesney claims that rent extraction causes considerable waste, especially in the developing world. As the term implies, rent extraction happens when officials use threats to extort payments from private parties.

Political stance

From such results it is sometimes asserted that public choice theory has an anti-state tilt. But there is ideological diversity among public choice theorists. Mancur Olson for example was an advocate of a strong state and instead opposed political interest group lobbying. More generally, James Buchanan has suggested that public choice theory be interpreted as "politics without romance," a critical approach to a pervasive earlier notion of idealized politics set against market failure. As such it is more a correction of the earlier scientific record, almost requiring a certain pragmatism in comparing alternative politicized institutional structures.

Remedies for the public choice problem

Many proposals have been advanced for reducing what is often seen as excessive or improper influence on public choices by those who invest most to influence them. From game theory we have the insight that a winning strategy in competitive games should have a random component so that the opponent can't anticipate one's moves. This is confirmed by the historical resort to having decisions made by officials selected at random, perhaps with a complex process of intermediate qualifying steps, called sortition. That is what is done in countries using a trial jury selected at random.

Applications and wider recognition

Public choice's application to government regulation was developed by George Stigler (1971) and Sam Peltzman (1976). William Niskanen is generally considered the founder of Public Choice literature on the bureaucracy.

Several notable Public Choice scholars have been awarded the Nobel Prize in Economics, including James M. Buchanan (1986), George Stigler (1982), and Gary Becker (1992). In addition, Vernon Smith (2002) and Elinor Ostrom (2009) were former Presidents of the Public Choice Society.

Criticism

In their 1994 book Pathologies of Rational Choice Theory, political scientists Donald P. Green and Ian Shapiro argue that rational choice theory (of which public choice theory is a branch) has contributed less to the field than its popularity suggests. They write:

The discrepancy between the faith that practitioners place in rational choice theory and its failure to deliver empirically warrants closer inspection of rational choice theorizing as a scientific enterprise.

Linda McQuaig writes in All You Can Eat:

The absurdity of public-choice theory is captured by Nobel Prize-winning economist Amartya Sen in the following little scenario: "Can you direct me to the railway station?" asks the stranger. "Certainly," says the local, pointing in the opposite direction, towards the post office, "and would you post this letter for me on your way?" "Certainly," says the stranger, resolving to open it to see if it contains anything worth stealing.

It should be noted that scenarios of this type contain an implicit assumption of zero probability of the two strangers ever interacting again. With a positive probability of future interactions and the propensity of humans to use tit-for-tat type strategies (someone harms or helps you, you return the favor in kind), the optimal totally self-interested decision may be to point to the train station. Furthermore, as David D. Friedman observes, the benefit of cheating the stranger on one occasion may not be worth the mental effort of conceiving a way to do so and weighing the odds of suffering the consequences.

(Sen, in fact, has participated in the development of public choice theory, in such works as Collective Choice and Social Welfare.)

James Buchanan and Gordon Tullock outline the limitations of their methodology:

"even if the model [with its rational self-interest assumptions] proves to be useful in explaining an important element of politics, it does not imply that all individuals act in accordance with the behavioral assumption made or that any one individual acts in this way at all times… the theory of collective choice can explain only some undetermined fraction of collective action. However, so long as some part of all individual behavior… is, in fact, motivated by utility maximization, and so long as the identification of the individual with the group does not extend to the point of making all individual utility functions identical, an economic-individualist model of political activity should be of some positive worth."

(Calculus of Consent, page 29)

Public Choice theorists have been criticized for failure to explain human actions motivated by non-rational or non-economic considerations. They respond, however, that the theory explains a broad variety of actions since humanitarian or even a madman's actions are also rational. This way, the argument goes, public choice allows to account for a much broader variety of actions than any other approach, and in the example above, Sen's rational actors may or may not act in a way he identified, since public choice approach does not mean the actors necessarily take advantage of one another; it only implies that the actions are 'rational'. Action to direct someone to a train station would thus be just as rational as the action to direct the stranger away for one's own reasons. Furthermore, only 'rationalism' helps to explain human motivation, whereas any other approaches such as humanitarian considerations or the willingness to get extra profit (which is in no way the same as 'rational action') would only explain a part of the developments and fails to present a comprehensive picture. Also, Bryan Caplan argues against rationality in politics, and Brennan and Lomasky account for expressive (non-economic) motives in politics.

Schram and Caterino (2006) contains a fundamental methodological criticism of public choice theory for promoting the view that the natural science model is the only appropriate methodology in social science and that political science should follow this model, with its emphasis on quantification and mathematization. Schram and Caterino argue instead for methodological pluralism.

Rank reversals in decision making

This article describes the role rank reversals play in assessing the merits of decision making methods. The issue of rank reversals lies at the heart of many debates in decision making and multi-criteria decision making, in particular.

Unlike most other computational procedures, it is hard to tell if a particular decision making method has derived the correct answer or not. Such methods analyze a set of alternatives described in terms of some criteria. They determine which alternative is the best one, or they provide relative weights of how the alternatives perform, or just how the alternatives should be ranked when all the criteria are considered simultaneously. This is exactly where the challenge with decision making exists. Oftentimes it is hard, if not practically impossible, to determine whether a correct answer has been reached or not. With other computational methods, for instance with a job scheduling method, one can examine a set of different answers and then categorize the answers according to some metric of performance (for instance, a project's completion time). But this may not be possible to do with the answers derived by most decision making methods. After all, determining the best decision making method leads to a decision making paradox.

Thus the following question emerges: How can one evaluate decision making methods? This is a very difficult issue and may not be answered in a globally accepted manner.

A critical part in answering this fundamental question is played by what is known as rank reversals.

What is a rank reversal?

One way to test the validity of decision making methods is to construct special test problems and then study the solutions they derive. If the solutions exhibit some logic contradictions (in the form of undesirable rank reversals of the alternatives), then one may argue that something is wrong with the method that derived them.

To see the above point more clearly, suppose that three candidates are evaluated for some job opening. Let us designate these candidates as A, B, and C. Suppose that some decision making method has determined that the best candidate for that job is person A, followed by B, who is followed by C. This is the first ranking and it is indicated as follows: A > B > C (where > means better than). Next, suppose that candidate B (who is not the best one) is replaced by an even worse candidate, say person D. That is, now we have B > D, and candidate B is replaced by D while candidates A and C remain in the pool of candidates with exactly the same characteristics as before. When the new set of alternatives (i.e., candidates A, D and C) are ranked together and by assuming that the criteria have exactly the same weights as before, then should not candidate A still be the best one? It turns out that under some decision making methods the best alternative may be different now. This is known as a rank reversal and it is one of the types of rank reversals.

The first type of rank reversal in the above context was observed by Belton and Gear in 1983 as part of a study of the analytic hierarchy process (AHP). They first considered a simple decision problem comprised by 3 alternatives and 2 criteria. Next a copy of a non-optimal alternative was introduced. When the 4 alternatives (i.e., the previous 3 plus the copy) were evaluated, and under the assumption that the criteria weights are exactly the same as before, it was observed that now the indication of the best alternative can change. That is, a rank reversal may occur with the AHP. A few years later it was observed that the AHP, as well as a new variant to it that was introduced by Professor Thomas Saaty (the inventor of the AHP) in response to the previous observation by Belton and Gear, may exhibit rank reversals when a non-optimal alternative is replaced by a worse one (and not a copy of an alternative as in Belton and Gear's experiment).

The issue of rank reversals has captured the interest of many researchers and practitioners in the field of decision making. It is something that continues to be considered controversial by many and is debated a lot.

Different types of rank reversals

There are many different types of rank reversals, depending on how the alternatives in a problem are defined and evaluated. These types are described next as Type 1, Type 2, Type 3, Type 4, and Type 5.

Rank reversals of Type 1

As stated earlier, one may introduce identical or near-identical copies of non-optimal alternatives and then check to see if the indication of the best alternative changes or not.

Rank reversals of Type 2

Another way is to replace a non-optimal alternative with a worse one and then see if the indication of the best alternative changes or not.

Rank reversals of Type 3

A different way is to run some tests as follows. First consider a problem with all the alternatives together and get a ranking. Next, decompose the original problem into a set of smaller problems defined on two alternatives at a time and the same criteria (and their weights) as before. Get the rankings of these smaller problems and check to see if they are in conflict with the ranking of the alternatives of the original (larger) problem.

Rank reversals of Type 4

This is like the previous case, but now ignore the ranking of the original (larger) problem. Instead, check to see if the rankings of the smaller problems are in conflict with each other. For instance, suppose that the following 3 alternatives A, B, and C are considered. Next, suppose that some 2-alternative problems are solved and the rankings A > B, B > C, and C > A, are derived from these 2-alternative problems. Obviously, the above situation indicates a case of non-transitivity (or contradiction) as we get A > B > C > A.

Rank reversals of Type 5

All previous types of rank reversals are known to occur with the analytic hierarchy process (AHP) and its additive variants, the TOPSIS and ELECTRE methods and their variants.

The weighted product model (WPM) does not exhibit the previous types of rank reversals, due to the multiplication formula it uses. However, the WPM does cause rank reversals when it is compared with the weighted sum model (WSM) and under the condition that all the criteria of a given decision problem can be measured in exactly the same unit. The same is true with all the previous methods as well. This is the Type 5 ranking reversal.

It is quite possible to define more types of rank reversals. One only needs to determine ways to alter a test problem and see how the ranking of the alternatives of the new problem differs from the original ranking of the alternatives of the original problem. Furthermore, the difference in rankings, somehow, should indicate the presence of undesirable effects.

Are rank reversals always undesirable?

Decision making methods are used to make decisions in many aspects of human activity. This is especially true with decisions that involve large amounts of money or decisions that may have huge impact on large numbers of people. Given the well-established fact that difference methods may yield different answers when they are fed with exactly the same problem [my MCDM book], the question is how to evaluate them. Rank reversals are at the very heart of assessing the merits of such methods. At the same time, there are at the center of many heated debates in this area. Many authors use them as means to criticize decision making methods or to better explain rational behavior.

Let us consider a simple example of buying a car. Suppose that there are two cars available to the decision maker: Car A and Car B. Car A is much cheaper than Car B but its overall quality is much less when compared to that for Car B. On the other hand Car B is more expensive than Car A but it is also of better quality. A decision maker who is concerned of the high price issue, may choose Car A over the better quality and more expensive Car B. Next suppose that the car dealer presents to the decision maker a third car, say Car C, which is way more expensive than Car B but now the overall quality of Car C is marginally higher than that of Car B. Under such a scenario, it is quite possible for a decision maker to alter his/her opinion and purchase Car B instead of Car A, even if he/she has not actually seen Car C.

Such events may take place with many rational decision makers. In other words, rank reversals may actually be possible in rational decision making. The issue of having rank reversals by rational decision makers has been studied extensively by Amos Tversky. In other words, having rank reversals in certain occasions and of certain types may not be indicative to faulty decision making. However, the key question is how to be able to distinguish when rank reversals indicate that something is wrong or when they do not conflict rational decision making. This is a highly debated issue and it is unlikely that a consensus will be reached in the decision making community.

Methods that have been verified to exhibit rank reversals

The following is just a partial list of multi-criteria decision making methods which have been confirmed to exhibit various types of rank reversals:

- The Analytic hierarchy process (AHP) and some of its variants.
- The ELECTRE (Outranking) method and its variants.
- The TOPSIS method.
- The PROMETHEE (Outranking) method.
- Multi-attribute utility theory (MAUT).

Robust decision making

Robust decision making is an iterative decision analytic framework that helps identify potential robust strategies, characterize the vulnerabilities of such strategies, and evaluate the tradeoffs among them. RDM focuses on informing decisions under conditions of what is called ‘deep uncertainty,’ that is, conditions where the parties to a decision do not know or do not agree on the system model(s) relating actions to consequences or the prior probability distributions for the key input parameters to those model(s).

Robust decision methods

A wide variety of concepts, methods, and tools have been developed to address decision challenges that confront a large degree of uncertainty. Rosenhead was among the first to lay out a systematic decision framework for robust decisions. Similar themes have emerged from the literatures on scenario planning, robust control, imprecise probability, and info-gap decision theory and methods. An early review of many of these approaches is contained in the Third Assessment Report of the Intergovernmental Panel on Climate Change.

Robust decision making

Robust decision making (RDM) is a particular set of methods and tools developed over the last decade, primarily by researchers associated with the RAND Corporation, designed to support decision making and policy analysis under conditions of deep uncertainty.

While often used by researchers to evaluate alternative options, RDM is designed and is often employed as a method for decision support, with a particular focus on helping decision makers identify and design new decision options that may be more robust than those they had originally considered. Often, these more robust options represent adaptive decision strategies designed to evolve over time in response to new information. In addition, RDM can be used to facilitate group decision making in contentious situations where parties to the decision have strong disagreements about assumptions and values. RDM approaches have been applied to a wide range of different types of decision challenges. One of the first studies addressed adaptive strategies for reducing greenhouse gas emissions. Recent studies include a variety of applications to water management issues, evaluation of the impacts of proposed U.S. renewable energy requirements, a comparison of long-term energy strategies for the government of Israel, an assessment of science and technology policies the government of South Korea might pursue in response to increasing economic competition from China, and an analysis of Congress' options in reauthorization of the Terrorism Risk Insurance Act (TRIA).

How does robust decision making differ from traditional expected utility analysis?

RDM rests on three key concepts that differentiate it from the traditional subjective expected utility decision framework: multiple views of the future, a robustness criterion, and reversing the order of traditional decision analysis by conducting an iterative process based on a vulnerability-and-response-option rather than a predict-then-act decision framework.

First, RDM characterizes uncertainty with multiple views of the future. In some cases these multiple views will be represented by multiple future states of the world. RDM can also incorporate probabilistic information, but rejects the view that a single joint probability distribution represents the best description of a deeply uncertain future. Rather RDM uses ranges or, more formally, sets of plausible probability distributions to describe deep uncertainty.

Second, RDM uses robustness rather than optimality as a criterion to assess alternative policies. The traditional subjective utility framework ranks alternative decision options contingent on best estimate probability distributions. In general, there is a best (i.e., highest ranked) option. RDM analyses have employed several different definitions of robustness. These include: trading a small amount of optimum performance for less sensitivity to broken assumptions, good performance compared to the alternatives over a wide range of plausible scenarios, and keeping options open. All incorporate some type of satisficing criteria and, in contrast to expected utility approaches, all generally describe tradeoffs rather than provide a strict ranking of alternative options.

Third, RDM employs a vulnerability-and-response-option analysis framework to characterize uncertainty and to help identify and evaluate robust strategies. This structuring of the decision problem is a key feature of RDM. The traditional decision analytic approach follows what has been called a predict-then-act approach that first characterizes uncertainty about the future, and then uses this characterization to rank the desirability of alternative decision options. Importantly, this approach characterizes uncertainty without reference to the alternative options. In contrast, RDM characterizes uncertainty in the context of a particular decision. That is, the method identifies those combinations of uncertainties most important to the choice among alternative options and describes the set of beliefs about the uncertain state of the world that are consistent with choosing one option over another. This ordering provides cognitive benefits in decision support applications, allowing stakeholders to understand the key assumptions underlying alternative options before committing themselves to believing those assumptions.

Under what conditions is robust decision making most useful?

Robust decision methods seem most appropriate under three conditions: when the uncertainty is deep as opposed to well-characterized, when there is a rich set of decision options, and the decision challenge is sufficiently complex that decision makers need simulation models to trace the potential consequences of their actions over many plausible scenarios. When the uncertainty is well-characterized then traditional expected utility (predict-then-act) analyses are often most appropriate. In addition, if decision makers lack a rich set of decision options they may have little opportunity to develop a robust strategy and can do no better than a predict-then-act analysis. If the uncertainty is deep and a rich set of options is available, traditional qualitative scenario methods may prove most effective if the system is sufficiently simple or well-understood that decision makers can accurately connect potential actions to their consequences without the aid of simulation models. However, when uncertainty is deep, the system is complex, and a rich set of decision options opens the possibility of finding robust strategies, RDM approaches may prove most effective.

Analytic tools for robust decision making

RDM is not a recipe of analytic steps, but rather a set of methods that can be combined in varying ways for specific decisions to implement the concept. Two key items in this toolkit are worth mentioning here.

Exploratory modeling

Virtually all RDM analyses use an exploratory modeling approach, with computer simulations used not as a device for prediction, but rather as a means for relating a set of assumptions to their implied consequences. One draws useful information from such simulations by running them many times using an appropriate experimental design over the uncertain input parameters to the model(s), collecting the runs in a large database of cases, and analyzing this database to determine what policy-relevant statements can be supported. RDM represents a particular implementation of this concept. An RDM analysis typically creates a large database of simulation model results, and then uses this database to identify vulnerabilities of proposed strategies and the tradeoffs among potential responses. This analytic process provides several practical advantages:

The database of cases provides a concrete representation of the concept of a multiplicity of plausible futures.

Running a simulation multiple times in the forward direction can simplify the analytic challenge of representing adaptive strategies in many practical applications because it separates the running of the simulation from the analysis needed to evaluate alternative decision options using the simulation. In contrast, some optimization methods make it difficult to include many types of feedbacks in a simulation.

The exploratory modeling concept makes it possible to use a wide variety of decision approaches using diverse types simulation models within a common analytic framework (depending on what seems most appropriate for a particular decision application). Within this common framework RDM analyses have used traditional sequential decision approaches, rule-based descriptions of adaptive strategies, real options representations, complicated optimal economic growth models, spreadsheet models, agent-based models, and organization’s existing suites of simulation models such as one used by the U.S. government to forecast the future state of the social security trust fund.

The database of cases simplifies the comparison of alternative decision frameworks because one can apply these frameworks to an identical set of model results. For instance, one can place a joint probability distribution across the cases in a database, conduct an expected utility analysis, and compare the results to an RDM analysis using the same database.

Scenario discovery

RDM analyses often employ a process called “scenario discovery” to facilitate the identification of vulnerabilities of proposed strategies. The process begins by specifying some performance metric, such as the total cost of a policy or its deviation from optimality (regret), which can be used to distinguish those cases in the results database where the strategy is judged successful from those where it is judged unsuccessful. Statistical or data-mining algorithms are applied to the database to generate simple descriptions of regions in the space of uncertain input parameters to the model that best describe the cases where the strategy is unsuccessful.That is, the algorithm for describing these cases is tuned to optimize both the predictability and interpretability by decision-makers. The resulting clusters have many characteristics of scenarios and can be used to help decision makers understand the vulnerabilities of the proposed policies and potential response options. A review conducted by the European Environmental Agency of the rather sparse literature evaluating how scenarios actually perform in practice when used by organizations to inform decisions identified several key weaknesses of traditional scenario approaches. Scenario-discovery methods are designed to address these weaknesses. In addition, scenario discovery supports analysis for multiple stressors because it characterizes vulnerabilities as combinations of very different types of uncertain parameters (e.g. climate, economic, organizational capabilities, etc.).

Heuristic

Heuristic refers to experience-based techniques for problem solving, learning, and discovery. Heuristic methods are used to speed up the process of finding a good enough solution, where an exhaustive search is impractical. Examples of this method include using a "rule of thumb", an educated guess, an intuitive judgment, or common sense.

In more precise terms, heuristics are strategies using readily accessible, though loosely applicable, information to control problem solving in human beings and machines.

Example

The most fundamental heuristic is trial and error, which can be used in everything from matching bolts to bicycles to finding the values of variables in algebra problems.

Here are a few other commonly used heuristics, from George Pólya's 1945 book, How to Solve It:

- If you are having difficulty understanding a problem, try drawing a picture.
- If you can't find a solution, try assuming that you have a solution and seeing what you can derive from that ("working backward").
- If the problem is abstract, try examining a concrete example.
- Try solving a more general problem first (the "inventor's paradox": the more ambitious plan may have more chances of success).

Psychology

In psychology, heuristics are simple, efficient rules, hard-coded by evolutionary processes or learned, which have been proposed to explain how people make decisions, come to judgments, and solve problems, typically when facing complex problems or incomplete information. These rules work well under most circumstances, but in certain cases lead to systematic errors or cognitive biases.

Although much of the work of discovering heuristics in human decision-makers was done by Amos Tversky and Daniel Kahneman, the concept was originally introduced by Nobel laureate Herbert Simon. Gerd Gigerenzer focuses on how heuristics can be used to make judgments that are in principle accurate, rather than producing cognitive biases – heuristics that are "fast and frugal".

In 2002, Daniel Kahneman and Shane Frederick proposed that cognitive heuristics work by a process called attribute substitution which happens without conscious awareness. According to this theory, when somebody makes a judgment (of a target attribute) which is computationally complex, a rather easier calculated heuristic attribute is substituted. In effect, a cognitively difficult problem is dealt with by answering a rather simpler problem, without being aware of this happening. This theory explains cases where judgments fail to show regression toward the mean. Heuristics can be considered to reduce the complexity of clinical judgements in healthcare.

Theorized psychological heuristics

Well known

- Anchoring and adjustment
- Availability heuristic
- Representativeness heuristic
- Naïve diversification
- Escalation of commitment

Less well known

- Affect heuristic
- Contagion heuristic
- Effort heuristic
- Familiarity heuristic
- Fluency heuristic
- Gaze heuristic
- Peak-end rule
- Recognition heuristic
- Scarcity heuristic

- Similarity heuristic
- Simulation heuristic
- Social proof
- Take-the-best heuristic

Philosophy

In philosophy, especially in Continental European philosophy, the adjective "heuristic" (or the designation "heuristic device") is used when an entity X exists to enable understanding of, or knowledge concerning, some other entity Y. A good example is a model which, as it is never identical with what it models, is a heuristic device to enable understanding of what it models. Stories, metaphors, etc., can also be termed heuristic in that sense. A classic example is the notion of utopia as described in Plato's best-known work, The Republic. This means that the "ideal city" as depicted in The Republic is not given as something to be pursued, or to present an orientation-point for development; rather, it shows how things would have to be connected, and how one thing would lead to another (often with highly problematic results), if one would opt for certain principles and carry them through rigorously.

"Heuristic" is also often commonly used as a noun to describe a rule-of-thumb, procedure, or method. Philosophers of science have emphasized the importance of heuristics in creative thought and constructing scientific theories. (See The Logic of Scientific Discovery, and philosophers such as Imre Lakatos, Lindley Darden, and others.)

Law

In legal theory, especially in the theory of law and economics, heuristics are used in the law when case-by-case analysis would be impractical, insofar as "practicality" is defined by the interests of a governing body.

For instance, in all states in the United States the legal drinking age is 21, because it is argued that people need to be mature enough to make decisions involving the risks of alcohol consumption. However, assuming people mature at different rates, the specific age of 21 would be too late for some and too early for others. In this case, the somewhat arbitrary deadline is used because it is impossible or impractical to tell whether an individual is sufficiently mature for society to trust them with that kind of responsibility. Some proposed changes, however, have included the completion of an alcohol education course rather than the attainment of 21 years of age as the criterion for legal alcohol possession. This would put youth alcohol policy more on a case-by-case basis and less on a heuristic one, since the completion of such a course would presumably be voluntary and not uniform across the population.

The same reasoning applies to patent law. Patents are justified on the grounds that inventors need to be protected in order to have incentive to invent. It is therefore argued that, in society's best interest, inventors should be issued with a temporary government-granted monopoly on their product, so that they can recoup their investment costs and make economic profit for a limited period. In the United States the length of this temporary monopoly is 20 years from the date the application for patent was filed, though the monopoly does not actually begin until the application has matured into a patent. However, like the drinking-age problem above, the specific length of time would need to be different for every product in order to be efficient; a 20-year term is used because it is difficult to tell what the number should be for any individual patent. More recently, some, including University of North Dakota law professor Eric E. Johnson, have argued that patents in different kinds of industries – such as software patents – should be protected for different lengths of time.

Computer science

In computer science, a heuristic is a technique designed to solve a problem that ignores whether the solution can be proven to be correct, but which usually produces a good solution or solves a simpler problem that contains or intersects with the solution of the more complex problem. Most real-time, and even some on-demand, anti-virus scanners use heuristic signatures to look for specific attributes and characteristics for detecting viruses and other forms of malware.

Heuristics are intended to gain computational performance or conceptual simplicity, potentially at the cost of accuracy or precision.

In their Turing Award acceptance speech, Herbert Simon and Allen Newell discuss the Heuristic Search Hypothesis: a physical symbol system will repeatedly generate and modify known symbol structures until the created structure matches the solution structure.

That is, each successive iteration depends upon the step before it, thus the heuristic search learns what avenues to pursue and which ones to disregard by measuring how close the current iteration is to the solution. Therefore, some possibilities will never be generated as they are measured to be less likely to complete the solution.

A heuristic method can accomplish its task by using search trees. However, instead of generating all possible solution branches, a heuristic selects branches more likely to produce outcomes than other branches. It is selective at each decision point, picking branches that are more likely to produce solutions.

In human-computer interaction, heuristic evaluation is a usability-testing technique devised by expert usability consultants. In heuristic evaluation, the user interface is reviewed by experts and its compliance to usability heuristics (broadly stated characteristics of a good user interface, based on prior experience) is assessed, and any violating aspects are recorded.

Software interface design

This article is written like a personal reflection or essay and may require cleanup. Please help improve it by rewriting it in an encyclopedic style. (February 2011)

In software development, the use of a heuristic approach can facilitate a well-designed user interface, enabling users to navigate complex systems intuitively and without difficulty. The interface may guide the user when necessary using tooltips, help buttons, invitations to chat with support, etc., providing help when needed. However, in practice, the designer of the user interface may not find it easy to strike the optimum balance for assistance of the user.

Software developers and targeted end-users alike disregard heuristics at their own peril. End users often need to increase their understanding of the basic framework that a project entails (so that their expectations are realistic), and developers often need to push to learn more about their target audience (so that their learning styles can be judged). Business rules crucial to the organization are often so obvious to the end-user that they are not conveyed to the developer, who may lack domain knowledge in the particular field of endeavor the application is meant to serve.

A proper Software Requirements Specification (SRS) models the heuristics of how a user will process the information being rendered on-screen. An SRS is ideally shared with the end-user well before the actual Software Design Specification (SDS) is written and the application is developed, so users' feedback about their experience can be used to adapt the design of the application. This saves much time in the Software Development Life Cycle (SDLC). Unless heuristics are adequately considered, the project will likely suffer many implementation problems and setbacks.

Anchoring

Anchoring or focalism is a cognitive bias that describes the common human tendency to rely too heavily, or "anchor," on one trait or piece of information when making decisions.

Background

During normal decision-making, anchoring occurs when individuals overly rely on a specific piece of information to govern their thought-process. Once the anchor is set, there is a bias toward adjusting or interpreting other information to reflect the "anchored" information. Through this cognitive bias, the first information learned about a subject (or, more generally, information learned at an early age) can affect future decision-making and information analysis.

For example, as a person looks to buy a used car, he or she may focus excessively on the odometer reading and model year of the car, and use those criteria as a basis for evaluating the value of the car, rather than considering how well the engine or the transmission is maintained.

Focusing effect

The focusing effect (or focusing illusion) is a cognitive bias that occurs when people place too much importance on one aspect of an event, causing an error in accurately predicting the utility of a future outcome.

People focus on notable differences, excluding those that are less conspicuous, when making predictions about happiness or convenience. For example, when people were asked how much happier they believe Californians are compared to Midwesterners, Californians and Midwesterners both said Californians must be considerably happier, when, in fact, there was no difference between the actual happiness rating of Californians and Midwesterners. The bias lies in that most people asked focused on and overweighed the sunny weather and ostensible easy-going lifestyle of California and devalued and underrated other aspects of life and determinants of happiness, such as low crime rates and safety from natural disasters like earthquakes (both of which large parts of California lack).

A rise in income has only a small and transient effect on happiness and well-being, but people consistently overestimate this effect. Kahneman et al. proposed that this is a result of a focusing illusion, with people focusing on conventional measures of achievement rather than on everyday routine.

Anchoring and adjustment heuristic

Anchoring and adjustment is a psychological heuristic that influences the way people intuitively assess probabilities. According to this heuristic, people start with an implicitly suggested reference point (the "anchor") and make adjustments to it to reach their estimate. A person begins with a first approximation (anchor) and then makes incremental adjustments based on additional information.

The anchoring and adjustment heuristic was first theorized by Amos Tversky and Daniel Kahneman. In one of their first studies, the two showed that when asked to guess the percentage of African nations which are members of the United Nations, people who were first asked "Was it more or less than 10%?" guessed lower values (25% on average) than those who had been asked if it was more or less than 65% (45% on average). The pattern has held in other experiments for a wide variety of different subjects of estimation. Others have suggested that anchoring and adjustment affects other kinds of estimates, like perceptions of fair prices and good deals.

Some experts say that these findings suggest that in a negotiation, participants should begin from extreme initial positions.

As a second example, an audience is first asked to write the last two digits of their social security number and consider whether they would pay this number of dollars for items whose value they did not know, such as wine, chocolate and computer equipment. They were then asked to bid for these items, with the result that the audience members with higher two-digit numbers would submit bids that were between 60 percent and 120 percent higher than those with the lower social security numbers, which had become their anchor.

Availability heuristic

The availability heuristic is a phenomenon (which can result in a cognitive bias) in which people predict the frequency of an event, or a proportion within a population, based on how easily an example can be brought to mind.

This phenomenon was first reported by psychologists Amos Tversky and Daniel Kahneman, who also identified the representativeness heuristic. To see how availability differs from related terms vividness and salience, see availability, salience and vividness.

Overview

Essentially the availability heuristic operates on the notion that "if you can think of it, it must be important." Media coverage can help fuel a person's example bias with widespread and extensive coverage of unusual events, such as homicide or airline accidents, and less coverage of more routine, less sensational events, such as common diseases or car accidents. For example, when asked to rate the probability of a variety of causes of death, people tend to rate more "newsworthy" events as more likely because they can more readily recall an example from memory. For example, people rate the chance of death by homicide higher than the chance of death by stomach cancer, even though death by stomach cancer is five times higher than death by homicide. Moreover, unusual and vivid events like homicides, shark attacks, or lightning are more often reported in mass media than common and unsensational causes of death like common diseases. Another instance of biased ratings is the relative overestimation of plane crash deaths, compared to car-accident deaths.

Examples

A person argues that cigarette smoking is not unhealthy because his grandfather smoked three packs of cigarettes a day and lived to be 100. The grandfather's health could simply be an unusual case that does not speak to the health of smokers in general.

A politician says that walnut farmers need a special farm subsidy. He points to a farmer standing nearby and explains how that farmer will benefit. Others who watch and discuss later agree that the subsidy is needed based on the benefit to that farmer. The farmer, however, might be the only person who will benefit from the subsidy. Walnut farmers in general may not necessarily need this subsidy.

A person claims to a group of friends that drivers of red cars get more speeding tickets. The group agrees with the statement because a member of the group, "Jim," drives a red car and frequently gets speeding tickets. The reality could be that Jim just drives fast and would get a speeding ticket regardless of the color of car that he drove. Even if statistics show fewer speeding tickets were given to red cars than to other colors of cars, Jim is an available example which makes the statement seem more plausible.

Someone is asked to estimate the proportion of words that begin with the letter "R" or "K" versus those words that have the letter "R" or "K" in the third position. Most English-speaking people could immediately think of many words that begin with the letters "R" (roar, rusty, ribald) or "K" (kangaroo, kitchen, kale), but it would take a more concentrated effort to think of any words where "R" or "K" is the third letter (street, care, borrow, acknowledge); the immediate answer would probably be that words that begin with "R" or "K" are more common. The reality is that words that have the letter "R" or "K" in the third position are more common. In fact, there are three times as many words that have the letter "K" in the third position, as have it in the first position.

Where an anecdote ("I know a Brazilian man who...") is used to "prove" an entire proposition or to support a bias, the availability heuristic is in play. In these instances the ease of imagining an example or the vividness and emotional impact of that example becomes more credible than actual statistical probability. Because an example is easily brought to mind or mentally "available," the single example is considered as representative of the whole rather than as just a single example in a range of data.

Imagining outcomes

One important corollary finding to this heuristic is that people asked to imagine an outcome tend to immediately view it as more likely than people that were not asked to imagine the specific outcome. If group A were asked to imagine a specific outcome and then asked if it were a likely outcome, and group B were asked whether the same specific outcome were likely without being asked to imagine it first, the members of group A tend to view the outcome as more likely than the members of group B, thereby demonstrating the tendency toward using an availability heuristic as a basis for logic.{Caroll, 1978}

In one experiment that occurred before the 1976 US Presidential election, participants were asked simply to imagine Gerald Ford winning the upcoming election. Those who were asked to do this subsequently viewed Ford as being significantly more likely to win the upcoming election. A similar result was obtained from participants that had been asked to imagine Jimmy Carter winning. Analogous results were found with vivid versus pallid descriptions of outcomes in other experiments.

Representativeness heuristic

The representativeness heuristic is a psychological term wherein people judge the probability or frequency of a hypothesis by considering how much the hypothesis resembles available data as opposed to using a Bayesian calculation. While often very useful in everyday life, it can also result in neglect of relevant base rates and other cognitive biases. The representative heuristic was first proposed by Amos Tversky and Daniel Kahneman. In causal reasoning, the representativeness heuristic leads to a bias toward the belief that causes and effects will resemble one another (examples include both the belief that "emotionally relevant events ought to have emotionally relevant causes", and magical associative thinking).

Examples

Tom W.

In a study done in 1973, Kahneman and Tversky gave their subjects the following information:

"Tom W. is of high intelligence, although lacking in true creativity. He has a need for order and clarity, and for neat and tidy systems in which every detail finds its appropriate place. His writing is rather dull and mechanical, occasionally enlivened by somewhat corny puns and by flashes of imagination of the sci-fi type. He has a strong drive for competence. He seems to feel little sympathy for other people and does not enjoy interacting with others. Self-centered, he nonetheless has a deep moral sense."

The subjects were then divided into three groups who were given different decision tasks:

One group of subjects was asked how similar Tom W. was to a student in one of nine types of college graduate majors (business administration, computer science, engineering, humanities/education, law, library science, medicine, physical/life sciences, or social science/social work). Most subjects associated Tom W. with an engineering student, and thought he was least like a student of social science/social work.

A second group of subjects was asked instead to estimate the probability that Tom W. was a grad student in each of the nine majors. The probabilities were in line with the judgments from the previous group.

A third group of subjects was asked to estimate the proportion of first-year grad students there were in each of the nine majors.

The second group's probabilities were approximated by how much they thought Tom W. was representative of each of the majors, and less on the base rate probability of being that kind of student in the first place (the third group). Had the subjects approximated their answers by the base rates, their estimated probability that Tom W. was an engineer would have been much lower, as there were few engineering grad students at the time.

The Taxicab problem

In another study done by Tversky and Kahneman, subjects were given the following problem:

"A cab was involved in a hit and run accident at night. Two cab companies, the Green and the Blue, operate in the city. 85% of the cabs in the city are Green and 15% are Blue.

A witness identified the cab as Blue. The court tested the reliability of the witness under the same circumstances that existed on the night of the accident and concluded that the witness correctly identified each one of the two colors 80% of the time and failed 20% of the time.

What is the probability that the cab involved in the accident was Blue rather than Green knowing that this witness identified it as Blue?"

Most subjects gave probabilities over 50%, and some gave answers over 80%. The correct answer, found using Bayes' theorem, is lower than these estimates:

There is a 12% chance (15% times 80%) of the witness correctly identifying a blue cab.

There is a 17% chance (85% times 20%) of the witness incorrectly identifying a green cab as blue.

There is therefore a 29% chance (12% plus 17%) the witness will identify the cab as blue.

This results in a 41% chance (12% divided by 29%) that the cab identified as blue is actually blue.

Representativeness is cited in the similar effect of the gambler's fallacy, the regression fallacy and the conjunction fallacy.

Representativeness, Extensionality, and Bayes' Theorem

The Representativeness Heuristic violates one of the fundamental properties of probability: extensionality. For example, participants were provided with a description of Linda who resembles a feminist. Then participants were asked to evaluate the probability of her being a feminist, the probability of her being a bank teller, or the probability of being both a bank teller and feminist. Probability theory dictates that the probability of being both a bank teller and feminist (the conjunction of two sets) must be less than or equal to the probability of being either a feminist or a bank teller. However, participants judged the conjunction (bank teller and feminist) as being more probable than being a bank teller alone.

The use of the Representativeness Heuristic will likely lead to violations of Bayes' Theorem. Bayes' Theorem states:

$$P(H|D) = \frac{P(D \mid H)\, P(H)}{P(D)}.$$

However, judgments by Representativeness only look at the resemblance between the hypothesis and the data, thus inverse probabilities are equated:

$P(H \mid D) = P(D \mid H)$

As can be seen, the base rate $P(H)$ is ignored in this equation, leading to the base rate fallacy. This was explicitly tested by Dawes, Mirels, Gold and Donahue (1993) who had people judge both the base rate of people who had a particular personality trait and the probability that a person who had a given personality trait had another one. For example, participants were asked how many people out of 100 answered true to the question "I am a conscientious person" and also, given that a person answered true to this question, how many would answer true to a different personality question. They found that participants equated inverse probabilities (e.g., P(conscientious | neurotic) = P(neurotic | conscientious)) even when it was obvious that they were not the same (the two questions were answered immediately after each other).

Disjunction Fallacy

In addition to extensionality violation, base-rate neglect, and the conjunction fallacy, the use of Representativeness Heuristic may lead to a Disjunction Fallacy. From probability theory the disjunction of two events is at least as likely as either of the events individually. For example, the probability of being either a physics or biology major is at least as likely as being a physics major, if not more likely. However, when a personality description (data) seems to be very representative of a physics major (e.g., pocket protector) over a biology major, people judge that it is more likely for this person to be a physics major than a natural sciences major (which is a superset of physics).

Further evidence that the Representativeness Heuristic may be causal to the Disjunction Fallacy comes from Bar-Hillel and Neter (1986). They found that people judge a person who is highly representative of being a statistics major (e.g., highly intelligent, does math competitions) as being more likely to be a statistics major than a social sciences major (superset of statistics), but they do not think that he is more likely to be a Hebrew language major than a humanities major (superset of Hebrew language). Thus, only when the person seems highly representative of a category is that category judged as more probable than its superordinate category. These incorrect appraisals remained even in the face of losing real money in bets on probabilities.

Alternative Explanations

Jon Krosnick, a professor in Communication at Stanford, in his work[which?] has proposed that the effects that Kahneman and Tversky saw in their work may be partially attributed to information order effects. When the order of information was reversed - with probability figures coming later, a lot of the effects were mitigated.

Naive diversification

Naïve diversification is a choice heuristic (also known as "diversification heuristic"). Its first demonstration was made by Itamar Simonson in marketing in the context of consumption decisions by individuals. It was subsequently shown in the context of economic and financial decisions. Simonson showed that when people have to make simultaneous choice (e.g. choose now which of six snacks to consume in the next three weeks), they tend to seek more variety (e.g., pick more kinds of snacks) than when they make sequential choices (e.g., choose once a week which of six snacks to consume that week for three weeks). That is, when asked to make several choices at once, people tend to diversify more than when making the same type of decision sequentially.

Subsequent research replicated the effect using a field experiment: on Halloween night, young trick-or-treaters were required to make a simultaneous or subsequent choice between the candies they received. The results showed a strong diversification bias when choices had to be made simultaneously, but not when they were made sequentially.

Shlomo Benartzi and Richard Thaler commented on Read and Loewenstein's: "This result is striking since in either case the candies are dumped into a bag and consumed later. It is the portfolio in the bag that matters, not the portfolio selected at each house." Following on the Naïve diversification showed by children, Benartzi and Thaler turned to study whether the effect manifests itself among investors making decisions in the context of defined contribution saving plans. They found that "some investors follow the '1/n strategy': they divide their contributions evenly across the funds offered in the plan. Consistent with this Naïve notion of diversification, we find that the proportion invested in stocks depends strongly on the proportion of stock funds in the plan." This finding is particularly troubling in the context of laypersons making financial decisions, because they may be diversifying in a way that is sub-optimal.

Escalation of commitment

Escalation of commitment was first described by Barry M. Staw in his 1976 paper, "Knee deep in the big muddy: A study of escalating commitment to a chosen course of action". More recently the term sunk cost fallacy has been used to describe the phenomenon where people justify increased investment in a decision, based on the cumulative prior investment, despite new evidence suggesting that the cost, starting today, of continuing the decision outweighs the expected benefit. Such investment may include money, time, or — in the case of military strategy — human lives. The phenomenon and the sentiment underlying it are reflected in such proverbial images as Throwing good money after bad and In for a dime, in for a dollar (or In for a penny, in for a pound).

The term is also used to describe poor decision-making in business, government, information systems in general, software project management in particular, politics, and gambling. The term has been used to describe the United States commitment to military conflicts including Vietnam in the 1960s - 1970s and in Iraq in the 2000s, where dollars spent and lives lost justify continued involvement.

Alternatively, irrational escalation (sometimes referred to as irrational escalation of commitment or commitment bias) is a term frequently used in psychology, philosophy, economics, and game theory to refer to a situation in which people can make irrational decisions based upon rational decisions in the past or to justify actions already taken. Examples are frequently seen when parties engage in a bidding war; the bidders can end up paying much more than the object is worth to justify the initial expenses associated with bidding (such as research), as well as part of a competitive instinct.

Examples

The dollar auction is a thought exercise demonstrating the concept.

After a heated and aggressive bidding war, Robert Campeau ended up buying Bloomingdale's for an estimated 600 million dollars more than it was worth. The Wall Street Journal noted that "we're not dealing in price anymore but egos". Campeau was forced to declare bankruptcy soon afterwards.

Often, when two competing brands are attempting to increase market share, they end up spending money without either increasing market share in a significant manner. Though the most commonly cited examples of this are Maxwell House and Folgers in the early 1990s, this has also been seen between Coke and Pepsi, and Kodak and Polaroid. This can be seen as a commercial application of the Red Queen hypothesis.

Affect heuristic

The affect heuristic is a heuristic in which current affect influences decisions. Simply put, it is a "rule of thumb" instead of a deliberative decision. It is one of the ways in which human beings show bias in making a decision, which may cause them to take action that is contrary to logic or self-interest.

Concept

"Affect", in this context, is simply a feeling—fear, pleasure, surprise, etc. It is shorter in duration than a mood, occurring rapidly and involuntarily in response to a stimulus. Reading the words "lung cancer" usually generates an affect of dread, while reading the words "mother's love" usually generates an affect of affection and comfort. For the purposes of the psychological heuristic, affect is often judged on a simple diametric scale of "good" or "bad".

The theory of affect heuristic is that a human being's affect can influence their decision-making. The affect heuristic got recent attention when it was used to explain the unexpected negative correlation between benefit and risk perception. Melissa Finucane and others theorised in 2000 that a good feeling towards a situation (i.e., positive affect) would lead to a lower risk perception and a higher benefit perception, even when this is logically not warranted for that situation. This implies that a strong emotional response to a word or other stimulus might alter a person's judgment. He or she might make different decisions based on the same set of facts and might thus make an illogical decision. For example, in a blind taste test, a man might like Mirelli Beer better than Saddle Sweat Beer; however, if he has a strong gender identification, an advertisement touting Saddle Sweat as "a real man's brew" might cause him to prefer Saddle Sweat. Positive affect related to gender pride biases his decision sufficiently to overcome his cognitive judgment.

Another common situation involving affect heuristic is where a strong, emotional first impression can inform a decision, even if subsequent facts weigh cognitively against the decisions. Someone seeing a house from the street might decide to buy it immediately upon seeing it, based on the strength of the emotional response to its eye appeal. This can be true even if subsequent inspection shows that it is inferior to another house that is even more charming from the street, but which the potential buyer first encountered by entering through its back door into a rather shabby kitchen.

The affect heuristic is of influence in nearly every decision-making arena.

Experimental findings

Winkielman, Zajonc, and Schwarz flashed one of three images in the view of test subjects: a smiling face, a frowning face, or a neutral geometric shape. The subject was then shown a Chinese character and asked how he or she liked it. The test subjects preferred the characters they saw after the smiling face, even though the smiling face was shown only for 1/250 of a second, and the subject did not recall seeing it.

The same experiment demonstrated the persistence of initial affect. The testers showed the subjects the same characters, but preceded by a different face. The subjects significantly tended to prefer the characters based on the first association, even where the second exposure was preceded by a different affective stimulus. That is, if a subject liked an character following exposure to a smiling face, he would continue to like the character even when it was preceded by a frowning face. (The experimental outcome was statistically significant and adjusted for variables such as non-affective preference for certain characters.)

However, in spite of its intuitive appeal and a large number of indirect empirical findings supporting the affect heuristic (such as the experiment above), conclusive evidence proving the theoretical ideas posed in the affect heuristic has not been forthcoming as of yet.

Contagion heuristic

The contagion heuristic is a psychological heuristic leading people to avoid contact with people or objects viewed as "contaminated" by previous contact with someone or something viewed as bad—or, less often, to seek contact with objects that have been in contact with people or things considered good. For example, we tend to view food that has touched the ground as contaminated by the ground, and therefore unfit to eat, or we view a person who has touched a diseased person as likely to carry the disease (regardless of the actual contagiousness of the disease).

The contagion heuristic includes "magical thinking", such as viewing a sweater worn by Adolf Hitler as bearing his negative essence and capable of transmitting it to another wearer. The perception of essence-transfer extends to rituals to purify items viewed as spiritually contaminated, such as having Mother Teresa wear Hitler's sweater to counteract his essence.

Effort heuristic

In psychology, an effort heuristic is a rule of thumb in which the value of an object is assigned based on the amount of perceived effort that went into producing the object. An example of this would be the comparison of $100 earned, and $100 found. If someone finds $100 they might go spend it on a whim, but if that $100 is part of their paycheck, they are not going to waste it.

Another way that effort heuristic can be considered is the amount of effort a person will put into an action depending on the goal. If the goal is of little importance, the amount of effort a person is willing to put into it is going to be lower.

The effort heuristic can also affect the perceived quality rating and financial value of objects. Kruger et al. found that people who were told that a poem required 18 hours to write rated it as higher quality and gave it a higher appraised value than did people who were told that it took only 4 hours to write. They found a similar effect in the valuation of paintings. In a third study, the researchers asked students to rate the quality of medieval armor that was shown in pictures and accompanied by a description that included manufacturing time. For the pieces of armor that were shown in clear pictures, there was only a small difference in ratings between those pieces that had long versus short manufacturing times, but when the pictures were blurry, the students gave substantially higher quality ratings to pieces of armor when the manufacturing time was long. Other students gave lower ratings to the same pieces of armor when the description listed only a short manufacturing time. The manipulation of blurry pictures suggested that people are prone to rely on perceived effort to value objects when other criteria is not readily available.

Familiarity heuristic

In psychology, a mental heuristic is a rule of thumb in which current behavior is judged to be correct based on how similar it is to past behavior and its outcomes. Individuals assume that the circumstances underlying the past behavior still hold true for the present situation and that the past behavior thus can be correctly applied to the new situation. The familiarity heuristic was developed based on the discovery of the availability heuristic by Tversky and Kahneman. It can be applied to various situations that individuals experience in real life when these situations appear similar to previous situations, especially if the individuals are experiencing a high cognitive load. This heuristic is useful in most situations and can be applied to many fields of knowledge including medicine, psychology, sports, marketing, outdoor activities, and consumer choices.

Definition and history

The familiarity heuristic stems from the availability heuristic which was studied by Tversky and Kahneman. The availability heuristic suggests that the likelihood of events is estimated based on how many examples of such events come to mind. Thus the familiarity heuristic shows how "bias of availability is related to the ease of recall."

Tversky and Kahneman created an experiment in order to test this heuristic. They devised four lists of 39 names. Each list contained 19 female names and 20 male names. Half of the lists had famous female names, and the other half had famous male names. They showed the lists to two test groups. The first group was shown a list and asked to recall as many names as possible. The second group was shown a list and asked to determine if there were more female or more male names. The subjects who heard the list with famous female names said there were more female names than there were male names. Similarly, the subjects who heard the list with famous male names recalled more male names than female names. Thus the familiarity heuristic is defined as "judging events as more frequent or important because they are more familiar in memory."

The familiarity heuristic is based on using schemas or past actions as a scaffold for behavior in a new (yet familiar) situation. This is useful because it saves time for the subject who is trying to figure out the appropriate behavior for a situation they have experienced before. Individuals automatically assume that their previous behavior will yield the same results when a similar situation arises. This technique is typically useful. However, certain behaviors can be inappropriate when the situation is different from the time before.

Important research

Recent studies have used functional magnetic resonance imaging (fMRI) to demonstrate that people use different areas of the brain when reasoning about familiar and unfamiliar situations. This holds true over different kinds of reasoning problems. Familiar situations are processed in a system involving the frontal and temporal lobes whereas unfamiliar situations are processed in the frontal and parietal lobes. These two similar but dissociated processes provide a biological explanation for the differences between heuristic reasoning and formal logic.

Monin (2004) showed that familiarity of human faces is based on attractiveness. In this study Monin showed his subjects pictures of faces. The subjects were asked to rate how familiar the face was or was not using visual cues. The visual cues were choosing a picture of a butterfly (attractive) when the subject thought the face was familiar, and choosing a picture of a rat (unattractive) when the subject did not find the face familiar. The result of this study was that the subjects were more familiar when the face was attractive regardless of prior exposure to the picture (or person) itself. This has been referred to as the warm glow effect. The warm glow effect states that positive stimuli seem more familiar because of the positive emotions they evoke in us.

Examples

Avalanche victims

To see whether or not familiarity would hinder subjects, McCammon (2004) looked at subjects that had been trapped in an avalanche (211 subjects) and those that had not (56 subjects). In most cases familiarity aided the subjects when navigating the terrain. Subjects that were familiar with the terrain took more risks. The risks typically helped the subjects, but there were a couple of situations where the risks hindered the subjects.

Hindsight bias

The hindsight bias states that people perceive certain events to be more predictable after the fact than they seemed before they had occurred. People believe that a disaster could have been avoided when they are actually misattributing familiar knowledge to a time before it was available.

Applications

The familiarity heuristic increases the likelihood that customers will repeatedly buy products of the same brand. This concept is known as brand familiarity in consumer behavior. Due to the familiarity heuristic, the customers have the rule of thumb that their past behavior of buying this specific brand's product was most likely correct and should be repeated. A study examining the choice of various models of microwave ovens based on the subjects' familiarity with them showed that high familiarity with the features of microwave ovens allowed for a faster and more confident choice.

This effect can also have important implications for medical decision making. Lay people tend to make health decisions that are based on familiarity and availability as opposed to factual knowledge about diseases. This means that they are more likely to take actions and pursue treatment options that have worked in the past, whether they are effective in the current situation or not. This also extends to treatments the patient has not used before but is familiar with. For example, a lay person may request a name-brand medication because they have heard of it before, even though a generic drug may be essentially the same but less expensive. Medical professionals are much more likely to use scientific facts to prescribe treatments.

Current criticisms

There is some criticism of the concept of familiarity heuristic. It mainly focuses on the point that past behavior does influence present behavior but that this is based on a different cognitive model than the familiarity heuristic. One study examining multiple possible mechanisms of how previous behavior influences present behavior found little support for the familiarity heuristic. The study showed that the influence of past behavior on a present one decreased when subjects were distracted. However, in order for a heuristic to be valid, its effect should be more prevalent when individuals are distracted and their cognitive capacity is highly strained. This result indicates that it is unlikely that a familiarity heuristic was applied during the experiment.

Another limit of familiarity heuristic according to a study by Quellette and Wood is that it might not always be applicable. This study showed that the familiarity heuristic might only occur in situations where the target behavior is habitual and occurs in a stable context within the situation. Thus, the familiarity heuristic could be limited to habits and behaviors in routine situations.

Peak-end rule

According to the peak-end rule, we judge our past experiences almost entirely on how they were at their peak (pleasant or unpleasant) and how they ended. Other information is not lost, but it is not used. This includes net pleasantness or unpleasantness and how long the experience lasted.

In one experiment, one group of people were subjected to loud, painful noises. In a second group, subjects were exposed to the same loud, painful noises as the first group, after which were appended somewhat less painful noises. This second group rated the experience of listening to the noises as much less unpleasant than the first group, despite having been subjected to more discomfort than the first group, as they experienced the same initial duration, and then an extended duration of reduced unpleasantness.

This heuristic was first suggested by Daniel Kahneman and others. He argues that because people seem to perceive not the sum of an experience but its average, it may be an instance of the representativeness heuristic.

Recognition heuristic

The recognition heuristic has been used as a model in the psychology of judgment and decision making and as a heuristic in artificial intelligence. It states:

" If one of two objects is recognized and the other is not, then infer that the recognized object has the higher value with respect to the criterion. "

Daniel Goldstein and Gerd Gigerenzer quizzed students in Germany and the United States on the populations of both German and American cities. Each group scored slightly higher on the foreign cities despite only recognizing a fraction of them. The experimenters theorized that the students would be able to attain such high accuracy on foreign cities if they relied on the heuristic and particular conditions, concerning cue validity for example, were met. They posited the heuristic as a domain specific strategy for inference.

In later research, Daniel M. Oppenheimer presented participants pairs of cities made from actual cities and fictional cities. Although the recognition heuristic predicts that participants would judge the actual (recognizable) cities to be larger, participants judged the fictional (unrecognizable) cities to be larger, showing that more than recognition can play a role in such inferences.

Research by Newell & Fernandez and Richter & Späth tests the non-compensatory prediction of the recognition heuristic and states that "recognition information is not used in an all-or-none fashion but is integrated with other types of knowledge in judgment and decision making."

Scarcity heuristic

In human psychology, the scarcity heuristic is a mental heuristic in which the mind values something based on how easily it may lose it, especially to competitors.

For example, take a group of boys playing marbles. Each player has at least one of every color marble except blue. Only one boy has a blue marble. By the scarcity heuristic, that boy and his playmates will value the blue marble more because there is only one, regardless of whether the blue marble is "better" (more aesthetically attractive, or better in the marbles game, for instance).

Similarity heuristic

The similarity heuristic is a lesser-known psychological heuristic pertaining to how people make judgments based on similarity. More specifically, the similarity heuristic is used to account for how people make judgments based on the similarity between current situations and other situations or prototypes of those situations.

At its most basic level, the similarity heuristic is an adaptive strategy. The goal of the similarity heuristic is maximizing productivity through favorable experience while not repeating unfavorable experiences. Decisions based on how favorable or unfavorable the present seems are based on how similar the past was to the current situation.

For example, a person may use the similarity heuristic when deciding on a book purchase. If a novel has a plot similar to that of novels read and enjoyed or the author has a writing style similar to that of favored authors, the purchasing decision will be positively influenced. A book with similar characteristics to previously pleasurable books is likely to also be enjoyed, causing the person to decide to obtain it.

Background

The similarity heuristic directly emphasizes learning from past experience. For example, the similarity heuristic has been observed indirectly in experiments such as phonological similarity tests. These tests observe how well a person can distinguish similar sounds from dissimilar ones based on a comparison to previously heard sounds. While not involving a decision making process characteristic to heuristics in general, these studies show a reliance on past experience and comparison to the current experience. In addition, the similarity heuristic has become a valuable tool in the field of economics and consumerism.

Real-world examples

The similarity heuristic is very easy to observe in the world of business, both from a marketing standpoint and from the position of the consumer. People tend to let past experience shape their world view; thus, if something presents itself as similar to a good experience had in the past, it is likely that the individual will partake in the current experience. The reverse holds true for situations that have proven unfavorable. A very basic example of this concept is a person deciding to get a meal at a particular restaurant because it reminds them of a similar establishment.

Marketing

Companies often use the similarity heuristic as a marketing strategy. For example, companies will often advertise their services as something similar to a successful competitor, but better — such a concept is evident in the motion picture industry. Trailers for upcoming films will promote the latest movie as being made by a particular director, citing said director's past film credentials. In effect, a similarity heuristic is created in an audience's mind; creating a similarity between the coming attraction and past successes will likely make people decide to see the upcoming film.

Automotive parts companies and their distributors and dealers leverage similarity heuristics when they interchange the term, "OEM" (original equipment manufacturer), and "OE" (original equipment). For example, the OE design specifications may ask for a certain durability factor, corrosion resistance, and material composition. The OEM realizes they can produce the same part less expensively and with possibly greater profit, if they do not adhere to all or most of the OE design specifications. By marketing their product as "OEM" against a well-known brand or product (e.g., Mercedes-Benz), they predict that enough customers will purchase their OEM product vs. the OE product. The converse happens when the OE factory (e.g., Mercedes-Benz) promotes their brand of a commodity product (e.g., anti-freeze/coolant, spark plugs, etc.) as superior or better quality than the commodity product.

In addition, the use of a reverse similarity heuristic can be a highly valuable marketing tool. For example, when Nintendo wished to launch its Nintendo Entertainment System (NES) in the United States, it did so in the middle of a video game depression; Atari had managed to make video games one of the least popular American pastimes. Initial showing of the NES were met poorly — clearly, a similarity heuristic was in place, and people had created biases against anything relating to interactive television gaming. Nintendo's goal, then, became the differentiation of their system from the past examples. Employing a dissimilarity heuristic, Nintendo managed to create enough of a gap from the former video game industry and market a successful product.

Problem Solving

Some professions, such as software developers, regularly utilize the similarity heuristic. For software developers, the similarity heuristic is utilized when performing debugging tasks. A software bug exhibits a set of symptoms indicating the existence of a problem. In general, similar symptoms are caused by similar types of programming errors. By comparing these symptoms with those of previously corrected software flaws, a developer is able to determine the most probable cause and take an effective course of action. Over time, a developer's past experiences will allow their use of the similarity heuristic to be highly effective, quickly choosing the debugging approach that will likely reveal the problem's source.

Problem solving in general is benefitted by the similarity heuristic. When new problems arise similar to previous problems, the similarity heuristic selects an approach that previously yielded favorable results. Even if the current problem is novel, any similarity to previous issues will help choose a proper course of action.

Simulation heuristic

The simulation heuristic is a psychological heuristic, or simplified mental strategy, according to which people determine the likelihood of an event based on how easy it is to picture the event mentally. Partially as a result, people regret more missing outcomes that had been easier to imagine, such as "near misses" instead of when accomplishment had been much further away. The simulation heuristic was first theorized by Daniel Kahneman and Amos Tversky as a specialized adaptation of the availability heuristic to explain counterfactual thinking and regret. However, it should not be thought of as the same thing as the availability heuristic. Specifically the simulation heuristic is defined as "how perceivers tend to substitute 'normal' antecedent events for exceptional ones in psychologically 'undoing' this specific outcome."

It was also believed by Kahneman and Tversky that people utilized this heuristic to understand and predict others behaviors in certain circumstances and to answer questions involving counterfactual propositions. People, they believe, do this by mentally undoing events that have occurred and then running mental simulations of the events with the corresponding input values of the altered model. For example, a study was proposed that provided a group of participants with a situation describing two men who were delayed by half an hour in a traffic jam on the way to the airport. Both men were delayed enough that they both missed flights on which they were booked, one of them by half an hour and the second by only five minutes (because his flight had been delayed for 25 minutes). The results showed that a greater number of participants thought that the second man would be more upset then the first man.

Kahneman and Tversky argued that this difference could not be attributed to disappointment, because both had expected to miss their flights. They believed instead that the true explanation was that the students utilized the simulation heuristic and so it was easier for them to imagine minor alterations that would have enabled the second man to arrive in time for his flight then it was for them to devise the same alterations for the first man.

History

This heuristic was introduced by the Israeli psychologists Daniel Kahneman (born 1934) and Amos Tversky (1937–96). They did so at a lecture in 1979 and also, published it as a book chapter in 1982.

Simulation Different from Availability

The Subjective probability judgments of an event, used in the simulation heuristic do not follow the availability heuristic, in that these judgments are not the cause of relevant examples in memory but are instead based on the ease with which self generated fictitious examples can be mentally simulated or imagined.

Application

The theory that underlies the simulation heuristic assumes that one's judgments are bias towards information that is easily imagined or simulated mentally. It is because of this that we see biases having to do with the overestimation of how causally plausible an event could be or the enhanced regret experienced when it is easy to mentally undo an unfortunate event, such as an accident. Significant research on simulation heuristic's application in counterfactual reasoning has been performed by Dale T Miller and Bryan Taylor.

- For example, they found that if an affectively negative experience, such as a fatal car accident was brought about by an extraordinary event, such as someone usually goes by train to work but instead drove; the simulation heuristic will cause an emotional reaction of regret. This emotional reaction is because the exceptional event is easy to mentally undo and replace with a more common one that would not have caused the accident.

- Kahneman and Tversky did a study in which two individuals were given lottery tickets and then were given the opportunity to sell those same tickets back either two weeks before the drawing or an hour before the drawing. They proposed this question to some participants whose responses showed that they believed that the man who had sold his ticket an hour before the drawing would experience the greatest anticipatory regret when that ticket won.

Kahneman and Tversky explained these findings through the understanding of the norm theory, by stating that "people's anticipatory regret, along with reluctance to sell the ticket, should increase with their ease of imagining themselves still owning the winning ticket". Therefore, the man who recently sold his ticket will experience more regret because the "counterfactual world", in which he is the winner, is perceived as closer for him than the man who sold his ticket two weeks ago. This example shows the bias in this type of thinking because both men had the same probability of winning if they had not sold their tickets and the time differences in which they did will not increase or decrease these chances.

- Similar results were found with plane crash survivors. These individuals experienced a greater amount of anticipatory regret when they engaged in the highly mutable action of switching flights last minute. It was reasoned that this was due to a person "anticipating counterfactual thoughts that a negative event was evoked, because it tends to make the event more vivid, and so tends to make it more subjectively likely".

Implication in Real World Situations

This heuristic has shown to be a salient feature of clinical anxiety and its disorders, which are marked by elevated subjective probability judgments that future negative events will happen to the individual.

A study done by David Raune and Andrew Macleod tried to tie the cognitive mechanisms that underlie this type of judgment to the simulation heuristic.

- Their findings showed that anxious patient's simulation heuristic scores were correlated with the subjective probability. Such that, the more reasons anxious patients could think of why negative events would happen, relative to the number why they would not happen, the higher their subjective probability judgment that the events would happen to them. Further it was found that anxious patients displayed increase access to the simulation compared to control patients.

They also found support for the hypothesis that the easier it was for anxious patients to form the visual image, the greater the subjective probability that the event would happen to them. Through this work they purposed that the main clinical implication of the simulation heuristic results is that, in order to lower elevated subjective probability in clinical anxiety, patients should be encouraged to think of more reasons why the negative events will not occur then why they will occur .

How it is Affected by other Heuristics

A study done by Philip Broemer was done to test the hypothesis that the subjective ease with which one can imagine a symptom will be affected by the impact of differently framed messages on attitudes toward performing health behaviors.

By drawing on the simulation heuristic, he argued that the vividness of information is reflected in the subjective ease with which people can imagine having symptoms of an illness.

- His results showed that the impact of message framing upon attitudes was moderated by the ease of imagination and clearly supported the congruency hypothesis for different kinds of health behavior. Finding that, negatively framed messages led to more positive attitudes when the recipients of these messages could easily imagine the relevant symptoms. Ease of imagination thus facilitates persuasion when messages emphasize potential health risks. A positive framing however, leads to more positive attitudes when symptom imagination was rather difficult.

Therefore, a message with a reassuring theme is more congruent with a recipient's state of mind when he or she cannot easily imagine the symptoms whereas a message with an aversive theme is more congruent with a recipient's state of mind when he or she can easily imagine having the symptoms .

Social proof

Social proof, also known as informational social influence, is a psychological phenomenon where people assume the actions of others reflect correct behavior for a given situation. This effect is prominent in ambiguous social situations where people are unable to determine the appropriate mode of behavior, and is driven by the assumption that surrounding people possess more knowledge about the situation.

The effects of social influence can be seen in the tendency of large groups to conform to choices which may be either correct or mistaken, a phenomenon sometimes referred to as herd behavior. Although social proof reflects a rational motive to take into account the information possessed by others, formal analysis shows that it can cause people to converge too quickly upon a single choice, so that decisions of even large groups of individuals may be grounded in very little information (see information cascades).

Social proof is a type of conformity. When a person is in a situation where they are unsure of the correct way to behave, they will often look to others for cues concerning the correct behavior. When "we conform because we believe that other's interpretation of an ambiguous situation is more accurate than ours and will help us choose an appropriate course of action," it is informational social influence. This is contrasted with normative social influence wherein a person conforms to be liked or accepted by others.

Social proof often leads not just to public compliance (conforming to the behavior of others publicly without necessarily believing it is correct) but private acceptance (conforming out of a genuine belief that others are correct). Social proof is more powerful when being accurate is more important and when others are perceived as especially knowledgeable.

Mechanisms

Multiple source effect

The multiple source effect occurs when people give more credence to ideas that are stated by multiple sources. This effect can be clearly seen when social proof occurs. For instance, one study observed that people who hear five positive reviews on a book as read by five different synthesized voices perceive that book more favorably than if they hear the same five reviews as read by one sythesized voice.

Uncertainty about the correct conclusion

Uncertainty is a major factor that encourages the use of social proof. One study found that when evaluating a product, consumers were more likely to incorporate the opinions of others through the use of social proof when their own experiences with the product were ambiguous, leaving uncertainty as to the correct conclusion that they should make.

Similarity to the surrounding group

Similarity also motivates the use of social proof; when a person perceives themselves as similar to the people around them, they are more likely to adopt and perceive as correct the observed behavior of these people. This has been noted in areas such as the use of laugh tracks, where participants will laugh longer and harder when they perceive the people laughing to be similar to themselves.

Research

Early research

The most famous study of social proof is Muzafer Sherif's 1935 experiment. In this experiment subjects were placed in a dark room and asked to look at a dot of light about 15 feet away. They were then asked how much, in inches, the dot of light was moving. In reality it was not moving at all, but due to the autokinetic effect it appeared to move. How much the light appears to move varies from person to person but is generally consistent over time for each individual. A few days later a second part of the experiment was conducted. Each subject was paired with two other subjects and asked to give their estimate of how much the light was moving out loud. Even though the subjects had previously given different estimates, the groups would come to a common estimate. To rule out the possibility that the subjects were simply giving the group answer to avoid looking foolish while still believing their original estimate was correct, Sherif had the subjects judge the lights again by themselves after doing so in the group. They maintained the group's judgment. Because the movement of the light is ambiguous the participants were relying on each other to define reality.

Another study looked at informational social influence in eyewitness identification. Subjects were shown a slide of the "perpetrator". They were then shown a slide of a line-up of four men, one of whom was the perpetrator they had seen, and were asked to pick him out. The task was made difficult to the point of ambiguity by presenting the slides very quickly. The task was done in a group that consisted of one actual subject and three confederates (a person acting as a subject but actually working for the experimenter). The confederates answered first and all three gave the same wrong answer. In a high-importance condition of the experiment subjects were told that they were participating in a real test of eyewitness identification ability that would be used by police departments and courts, and their scores would establish the norm for performance. In a low-importance condition subjects were told that the slide task was still being developed and that the experimenters had no idea what the norm for performance was—they were just looking for useful hints to improve the task. It was found that when subjects thought the task was of high importance they were more likely to conform, giving the confederate's wrong answer 51% of the time as opposed to 35% of the time in the low-importance condition.

Cultural effects on social proof

The strength of social proof also varies across different cultures. For instance, studies have shown that subjects in collectivist cultures conform to others' social proof more often than those in individualist cultures.

Copycat suicides

Social proof has been proposed as an explanation for Copycat suicide, where suicide rates increase following media publication about suicides. One study using agent-based modeling showed that copycat suicides are more likely when there are similarities between the person involved in the publicized suicide and the potential copycats.

Examples

In social interactions

The social value of unfamiliar people is ambiguous and requires a lot of effort to assess accurately. Given limited time and motivation, other people will often evaluate others based on how surrounding people behave towards them. For example, if a man is seen to be in the company of attractive women, or is associated with them, then his social value and attractiveness will be perceived to be greater. The implied cognition in this case would be "All those girls seem to really like him, there must be something about him that's high value".

If he is seen to be rejected by many women, his social value will be judged negatively. The implied cognition is then "I just saw him being rejected by many women, there is probably a good reason why they don't like him".

The concept of "Social Proof" and the fundamental attribution error can be easily exploited by persuading (or paying) attractive women to display (or at least fake) public interest in a man. Other people will attribute the women's behavior as due to the man's character and are unlikely to consider that they are interested in him due to the actual reasons (external gain).

Some men use photos of themselves surrounded by attractive women to enhance their perceived social value. The effectiveness of such tactics without support by other consistent behaviors associated with high social value is questionable.

Some nightclub and bar owners effectively employ social proof to increase the popularity of their venues. This is usually done by deliberately reducing the rate at which people are allowed to enter, thus artificially causing the line to be longer. Uninformed customers might perceive the long line as a signal of the place's desirability and may wait in the line merely because "if all these people are waiting, the place must be good", while in fact the venue is mediocre and nowhere near its full capacity.

In employment

Similarly, a person who has been unemployed for a long time may have a hard time finding a new job - even if they are highly skilled and qualified. Potential employers attribute wrongly the person's lack of employment to the person rather than the situation. This causes the potential employers to search more intensively for flaws or other negative characteristics that are "congruent" with or explain the person's failure and to discount the applicant's virtues.

Similarly, a person who is in high demand - for example a CEO - may continue to get many attractive job offers and can as a result extract a considerable wage premium - even if his/her objective performance has been poor. When people appear successful, potential employers and others who evaluate them tend to search more intensively for virtues or positive characteristics that are "congruent" with or explain the person's success, and to ignore or underestimate the person's faults. People who experience positive social proof may also benefit from a halo effect. Other attributes are deemed to be more positive than they actually are. Additionally, the person's attributes may be viewed with a positive framing bias. For example, a person might be viewed as arrogant if they have negative social proof, and bold if they have positive social proof.

For these reasons, social proof is important in determining a potential employer's consideration set. Social proof naturally also applies to products and is used extensively in marketing and sales. Situations that violate social proof can cause cognitive dissonance, and can cause people to have a sense of loss of control or failure of the "just world hypothesis".

In entertainment

Theaters sometimes use specially planted audience members who are instructed to give ovations at pre-arranged times. Usually, these people are the ones who clap initially, and the rest of the audience follows. Such ovations may be perceived by non-expert audience members as signals of the performance's quality.

Contrary to common annoyance of canned laughter in television shows, television studios have discovered that they can increase the perceived "funniness" of a show by merely playing canned laughter at key "funny" moments. They have found that even though viewers find canned laughter highly annoying, they perceive shows that happen to use canned laughter more funny than the shows that do not use canned laughter.

Modifiers

Possession of special knowledge

If one perceives that s/he is better advised about a situation than the surrounding group, then s/he is less likely to follow the group's behavior.

Identification with authority

If one perceives themselves as a relevant authority figure in the situation, they are less likely to follow the surrounding group's behavior. This is a combination of "Identification of the surrounding group with self" and "Possession of special knowledge". People in authority positions tend to place themselves in different categories than other people and usually they have special training or knowledge that allows them to conclude that they are better informed than the surrounding group.

"Smart money"

One might perceive particular groups of others, identified by their behavior or other characteristics, to be more reliable guides to the situation than the average person. One might think truck drivers to be more frequent, and therefore more experienced drivers than others, and therefore weigh more heavily the number of trucks than the number of cars parked when judging the quality of a restaurant. One might identify the movement of betting odds or securities prices at certain times as revealing the preferences of "smart money" -- those more likely to be in the know.

Take-the-best heuristic

According to the take-the-best heuristic, when making a judgment based on multiple criteria, the criteria are tried one at a time according to their cue validity, and a decision is made based on the first criterion which discriminates between the alternatives.

Gerd Gigerenzer and Daniel Goldstein discovered that the heuristic did surprisingly well at making accurate inferences in real-world environments, such as inferring which of two cities is larger. The heuristic has since been modified and applied to domains from medicine, artificial intelligence, and political forecasting .

Creativity

Creativity refers to the phenomenon whereby a person creates something new (a product, a solution, a work of art etc.) that has some kind of value. What counts as "new" may be in reference to the individual creator, or to the society or domain within which the novelty occurs. What counts as "valuable" is similarly defined in a variety of ways.

Scholarly interest in creativity ranges widely: Topics to which it is relevant include the relationship between creativity and general intelligence; the mental and neurological processes associated with creative activity; the relationship between personality type and creative ability; the relationship between creativity and mental health; the potential for fostering creativity through education and training, especially as augmented by technology; and the application of an individual's existing creative resources to improve the effectiveness of learning processes and of the teaching processes tailored to them.

Creativity and creative acts are therefore studied across several disciplines - psychology, cognitive science, education, philosophy (particularly philosophy of science), technology, theology, sociology, linguistics, business studies, and economics. As a result, there are a multitude of definitions and approaches.

Etymology

The lexeme in the English word creativity comes from the Latin term creō "to create, make" and its derivational suffixes also come from Latin. The word "create" appears in English as early as the 14th century, notably in Chaucer (in The Parson's Tale). However, its modern meaning as an act of human creation did not emerge until after the Enlightenment.

Definition

In a summary of scientific research into creativity Michael Mumford suggested: "“Over the course of the last decade, however, we seem to have reached a general agreement that creativity involves the production of novel, useful products” (Mumford, 2003, p. 110). Beyond this general commonality, authors have diverged dramatically in their precise definitions, with Peter Meusburger claiming that over a hundred different versions can be found in the literature.

Aspects of creativity

Theories of creativity (in particular investigating why some people are more creative than others) have focused on a variety of aspects. The most dominant are usually identified as the four "Ps" - process, product, person and place. A focus on process is shown in cognitive approaches that try to describe thought mechanisms and techniques for creative thinking. Theories invoking divergent rather than convergent thinking (such as Guilford), or those describing the staging of the creative process (such as Wallas) are primarily theories of creative process. A focus on creative product usually appears in attempts to measure creativity in people (psychometrics, see below), or in creative ideas framed as successful memes. A focus on the nature of the creative person considers more general intellectual habits, such as openness, levels of ideation, autonomy, expertise, exploratory behaviour and so on. A focus on place considers the best circumstances in which creativity flourishes, including degrees of autonomy, access to resources and the nature of gatekeepers.

Historical and personal creativity

The product of "creativity" has typically been defined in one of two ways: either as something historically new (and relatively rare), such as scientific discoveries or great works of art; or as producing something new in a personal sense - an apparent innovation for the creator, regardless of whether others have made similar innovations, or whether others value the particular act of creation. In the former sense there are writers such as Mihály Csíkszentmihályi have defined creativity in terms of rare individuals who have been judged by others to have made significant creative, often domain-changing contributions (and as such, the level of creativity of an individual can vary over historical time as perceptions change), and Simonton, who has analysed the career trajectories of the creatively eminent in order to map patterns and predictors of creative productivity. In the latter sense, writers such as Ken Robinson, and Anna Craft have focussed on creativity in a general population, particularly with respect to education.

There are a variety of labels for the two sides of this dichotomy. Margaret Boden distinguishes between h-creativity (historical) and p-creativity (personal). Craft makes a similar distinction between "high" and "little c" creativity. while Craft cites Robinson referring to "high" and "democratic" creativity. Common also is the pairing of terms "Big C" and "Little C".

Kozbelt, Beghetto and Runco, use a little-c/Big-C model to review major theories of creativity This approach was first introduced by James C. Kaufman and Beghetto into a four C model: mini-c (transformative learning), which are "personally meaningful interpretations of experiences, actions and insights"; little-c (everyday problem solving and creative expression); Pro-C, exhibited by people who are professionally or vocationally creative but not eminent, and Big-C, reserved for those who are considered truly great in their field. This was to help distinguish more clearly between the amateur unapprenticed in the particular creative domain (e.g. the visual arts, astrophysics etc.), the professional who was domain-competent, and creative genius. The four-c model was also intended to help accommodate models and theories of creativity that stressed domain-competence as an essential component, and domain transformation as the highest mark of creativity; it also, they argued, made a useful framework for analysing creative processes in individuals.

History of the term and the concept

The Muses Clio, Euterpe, and Thalia, by Eustache Le Sueur. Up to the Renaissance, creativity in Western culture was seen as a form of divine inspiration.

Traditional views in the West and East

It is generally thought that "creativity" in Western culture was originally seen as a matter of divine inspiration. In Greek culture, for instance, Muses were seen as mediating inspiration from the Gods. Romans and Greeks invoked the concept of an external creative "daemon" (Greek) or "genius" (Latin), linked to the sacred or the divine. This probably came closest to describing what the modern age views as creative talent. In the Judaeo-Christian tradition, creativity was the sole province of God; humans were not considered to have the ability to create something new except as an expression of God's work.

The traditional Western view of creativity can be contrasted with the traditional Eastern view. For Hindus, Confucianists, Taoists and Buddhists, creation was at most a kind of discovery or mimicry, and the idea of creation "from nothing" had no place in these philosophies and religions.

The Enlightenment and after

In the West, this view of creativity as divinely inspired was dominant until the time of the renaissance and even later. However, by the 18th century and the Age of Enlightenment, mention of creativity (notably in art theory), linked with the concept of imagination, became more frequent. In the writing of Thomas Hobbes, imagination became a key element of human cognition; William Duff was one of the first to identify imagination as a quality of genius, typifying the separation being made between talent (productive, but breaking no new ground) and genius.

As a direct and independent topic of study, creativity effectively received no attention until the 19th century. Runco and Albert argue that creativity as the subject of proper study began seriously to emerge in the late 19th century with the increased interest in individual differences inspired by the arrival of Darwinism. In particular they refer to the work of Francis Galton, who through his eugenicist outlook took a keen interest in the heritability of intelligence,with creativity taken as an aspect of genius.

In the late 19th and early 20th centuries, leading mathematicians and scientists such as Hermann von Helmholtz (1896) and Henri Poincaré (1908) began to reflect on and publicly discuss their creative processes, and these insights were built on in early accounts of the creative process by pioneering theorists such as Graham Wallas and Max Wertheimer.

In 1927, Alfred North Whitehead gave the Gifford Lectures at the University of Edinburgh, later published as Process and Reality. He is credited with having coined the term "creativity" to serve as the ultimate category of his metaphysical scheme: "Whitehead actually coined the term – our term, still the preferred currency of exchange among literature, science, and the arts. . . a term that quickly became so popular, so omnipresent, that its invention within living memory, and by Alfred North Whitehead of all people, quickly became occluded".

The formal psychometric measurement of creativity, from the standpoint of orthodox psychological literature, is usually considered to have begun with J. P. Guilford's 1950 address to the American Psychological Association, which helped popularize the topic and focus attention on a scientific approach to conceptualizing creativity. (It should be noted that the London School of Psychology had instigated psychometric studies of creativity as early as 1927 with the work of H. L. Hargreaves into the Faculty of Imagination, but it did not have the same impact.) Statistical analysis led to the recognition of creativity(as measured) as a separate aspect of human cognition to IQ-type intelligence, into which it had previously been subsumed. Guilford's work suggested that above a threshold level of IQ, the relationship between creativity and classically measured intelligence broke down.

Creativity in psychology and cognitive science

The study of the mental representations and processes underlying creative thought belongs to the domains of psychology and cognitive science.

A psychodynamic approach to understanding creativity was proposed by Sigmund Freud, who suggested that creativity arises as a result of frustrated desires for fame, fortune and love, with the energy that was previously tied up in frustration and emotional tension in the neurosis being sublimated into creative activity. Freud later retracted this view.

Graham Wallas

Graham Wallas, in his work Art of Thought, published in 1926, presented one of the first models of the creative process. In the Wallas stage model, creative insights and illuminations may be explained by a process consisting of 5 stages:

(i) preparation (preparatory work on a problem that focuses the individual's mind on the problem and explores the problem's dimensions),

(ii) incubation (where the problem is internalized into the unconscious mind and nothing appears externally to be happening),

(iii) intimation (the creative person gets a "feeling" that a solution is on its way),

(iv) illumination or insight (where the creative idea bursts forth from its preconscious processing into conscious awareness); and

(v) verification (where the idea is consciously verified, elaborated, and then applied

In numerous publications, Wallas' model is just treated as four stages, with "intimation" seen as a sub-stage. There has been some empirical research looking at whether, as the concept of "incubation" in Wallas' model implies, a period of interruption or rest from a problem may aid creative problem-solving. Ward lists various hypotheses that have been advanced to explain why incubation may aid creative problem-solving, and notes how some empirical evidence is consistent with the hypothesis that incubation aids creative problem-solving in that it enables "forgetting" of misleading clues. Absence of incubation may lead the problem solver to become fixated on inappropriate strategies of solving the problem. This work disputes the earlier hypothesis that creative solutions to problems arise mysteriously from the unconscious mind while the conscious mind is occupied on other tasks.

Wallas considered creativity to be a legacy of the evolutionary process, which allowed humans to quickly adapt to rapidly changing environments. Simonton provides an updated perspective on this view in his book, Origins of genius: Darwinian perspectives on creativity.

J. P. Guilford

Guilford performed important work in the field of creativity, drawing a distinction between convergent and divergent production (commonly renamed convergent and divergent thinking). Convergent thinking involves aiming for a single, correct solution to a problem, whereas divergent thinking involves creative generation of multiple answers to a set problem. Divergent thinking is sometimes used as a synonym for creativity in psychology literature. Other researchers have occasionally used the terms flexible thinking or fluid intelligence, which are roughly similar to (but not synonymous with) creativity.

Arthur Koestler

In The Act of Creation, Arthur Koestler lists three types of creative individual - the Artist, the Sage and the Jester.

Believers in this trinity hold all three elements necessary in business and can identify them all in "truly creative" companies as well. Koestler introduced the concept of bisociation—that creativity arises as a result of the intersection of two quite different frames of reference.

Geneplore model

In 1992, Finke et al. proposed the "Geneplore" model, in which creativity takes place in two phases: a generative phase, where an individual constructs mental representations called preinventive structures, and an exploratory phase where those structures are used to come up with creative ideas. Weisberg argued, by contrast, that creativity only involves ordinary cognitive processes yielding extraordinary results.

Conceptual blending

In the '90s, various approaches in cognitive science that dealt with metaphor, analogy and structure mapping have been converging, and a new integrative approach to the study of creativity in science, art and humor has emerged under the label conceptual blending.

> "Creativity is the ability to illustrate what is outside the box from within the box."
> —The Ride

Creativity and everyday imaginative thought

In everyday thought, people often spontaneously imagine alternatives to reality when they think "if only...". Their counterfactual thinking is viewed as an example of everyday creative processes. It has been proposed that the creation of counterfactual alternatives to reality depends on similar cognitive processes to rational thought.

Psychological examples from science and mathematics

Jacques Hadamard

Jacques Hadamard, in his book Psychology of Invention in the Mathematical Field, uses introspection to describe mathematical thought processes. In contrast to authors who identify language and cognition, he describes his own mathematical thinking as largely wordless, often accompanied by mental images that represent the entire solution to a problem. He surveyed 100 of the leading physicists of his day (ca. 1900), asking them how they did their work. Many of the responses mirrored his own.

Hadamard described the experiences of the mathematicians/theoretical physicists Carl Friedrich Gauss, Hermann von Helmholtz, Henri Poincaré and others as viewing entire solutions with "sudden spontaneity."

The same has been reported in literature by many others, such as Denis Brian, G. H. Hardy, Walter Heitler, B. L. van der Waerden, and Harold Ruegg.

To elaborate on one example, Einstein, after years of fruitless calculations, suddenly had the solution to the general theory of relativity revealed in a dream "like a giant die making an indelible impress, a huge map of the universe outlined itself in one clear vision."

Hadamard described the process as having steps (i) preparation, (ii) incubation, (iv) illumination, and (v) verification of the five-step Graham Wallas creative-process model, leaving out (iii) intimation, with the first three cited by Hadamard as also having been put forth by Helmholtz:

Marie-Louise von Franz

Marie-Louise von Franz, a colleague of the eminent psychiatrist Carl Jung, noted that in these unconscious scientific discoveries the "always recurring and important factor ... is the simultaneity with which the complete solution is intuitively perceived and which can be checked later by discursive reasoning." She attributes the solution presented "as an archetypal pattern or image." As cited by von Franz, according to Jung, "Archetypes ... manifest themselves only through their ability to organize images and ideas, and this is always an unconscious process which cannot be detected until afterwards."

Creativity and affect

Some theories suggest that creativity may be particularly susceptible to affective influence.

Creativity and positive affect relations

According to Alice Isen, positive affect has three primary effects on cognitive activity:

Positive affect makes additional cognitive material available for processing, increasing the number of cognitive elements available for association;

Positive affect leads to defocused attention and a more complex cognitive context, increasing the breadth of those elements that are treated as relevant to the problem;

Positive affect increases cognitive flexibility, increasing the probability that diverse cognitive elements will in fact become associated. Together, these processes lead positive affect to have a positive influence on creativity.

Barbara Fredrickson in her broaden-and-build model suggests that positive emotions such as joy and love broaden a person's available repertoire of cognitions and actions, thus enhancing creativity.

According to these researchers, positive emotions increase the number of cognitive elements available for association (attention scope) and the number of elements that are relevant to the problem (cognitive scope).

Various meta-analyses, such as Matthijs et al. (2008) of 66 studies about creativity and affect support the link between creativity and positive affect.

Creativity and negative affect relations

On the other hand, some theorists have suggested that negative affect leads to greater creativity. A cornerstone of this perspective is empirical evidence of a relationship between affective illness and creativity. In a study of 1,005 prominent 20th century individuals from over 45 different professions, the University of Kentucky's Arnold Ludwig found a slight but significant correlation between depression and level of creative achievement. In addition, several systematic studies of highly creative individuals and their relatives have uncovered a higher incidence of affective disorders (primarily bipolar disorder and depression) than that found in the general population.

Creativity and affect at work

Three patterns may exist between affect and creativity at work: positive (or negative) mood, or change in mood, predictably precedes creativity; creativity predictably precedes mood; and whether affect and creativity occur simultaneously.

It was found that not only might affect precede creativity, but creative outcomes might provoke affect as well. At its simplest level, the experience of creativity is itself a work event, and like other events in the organizational context, it could evoke emotion. Qualitative research and anecdotal accounts of creative achievement in the arts and sciences suggest that creative insight is often followed by feelings of elation. For example, Albert Einstein called his 1907 general theory of relativity "the happiest thought of my life." Empirical evidence on this matter is still very tentative.

In contrast to the possible incubation effects of affective state on subsequent creativity, the affective consequences of creativity are likely to be more direct and immediate. In general, affective events provoke immediate and relatively-fleeting emotional reactions. Thus, if creative performance at work is an affective event for the individual doing the creative work, such an effect would likely be evident only in same-day data.

Another longitudinal research found several insights regarding the relations between creativity and emotion at work. First, a positive relationship between positive affect and creativity, and no evidence of a negative relationship. The more positive a person's affect on a given day, the more creative thinking they evidenced that day and the next day—even controlling for that next day's mood. There was even some evidence of an effect two days later.

In addition, the researchers found no evidence that people were more creative when they experienced both positive and negative affect on the same day. The weight of evidence supports a purely linear form of the affect-creativity relationship, at least over the range of affect and creativity covered in our study: the more positive a person's affect, the higher their creativity in a work setting.

Finally, they found four patterns of affect and creativity affect can operate as an antecedent to creativity; as a direct consequence of creativity; as an indirect consequence of creativity; and affect can occur simultaneously with creative activity. Thus, it appears that people's feelings and creative cognitions are interwoven in several distinct ways within the complex fabric of their daily work lives.

Creativity and intelligence

There has been debate in the psychological literature about whether intelligence and creativity are part of the same process (the conjoint hypothesis) or represent distinct mental processes (the disjoint hypothesis). Evidence from attempts to look at correlations between intelligence and creativity from the 1950s onwards, by authors such as Barron, Guilford or Wallach and Kogan, regularly suggested that correlations between these concepts were low enough to justify treating them as distinct concepts.

Some researchers believe that creativity is the outcome of the same cognitive processes as intelligence, and is only judged as creativity in terms of its consequences, i.e. when the outcome of cognitive processes happens to produce something novel, a view which Perkins has termed the "nothing special" hypothesis.

An often cited model is what has come to be known as "the threshold hypothesis," proposed by Ellis Paul Torrance, which holds that a high degree of intelligence appears to be a necessary but not sufficient condition for high creativity. That is, while there is a positive correlation between creativity and intelligence, this correlation disappears for IQs above a threshold of around 120. Such a model has found acceptance by many researchers, although it has not gone unchallenged. A study in 1962 by Getzels and Jackson among high school students concluded that high IQ and high creativity tend to be mutually exclusive with a majority of the highest scoring students being either highly creative or highly intelligent, but not both. While this explains the threshold, the exact interaction between creativity and IQ remains unexplained.

An alternative perspective, Renzulli's three-rings hypothesis, sees giftedness as based on both intelligence and creativity. More on both the threshold hypothesis and Renzulli's work can be found in O'Hara and Sternberg.

Neurobiology of creativity

The neurobiology of creativity has been addressed in the article "Creative Innovation: Possible Brain Mechanisms." The authors write that "creative innovation might require coactivation and communication between regions of the brain that ordinarily are not strongly connected." Highly creative people who excel at creative innovation tend to differ from others in three ways:

- they have a high level of specialized knowledge,
- they are capable of divergent thinking mediated by the frontal lobe.
- and they are able to modulate neurotransmitters such as norepinephrine in their frontal lobe.

Thus, the frontal lobe appears to be the part of the cortex that is most important for creativity.

This article also explored the links between creativity and sleep, mood and addiction disorders, and depression.

In 2005, Alice Flaherty presented a three-factor model of the creative drive. Drawing from evidence in brain imaging, drug studies and lesion analysis, she described the creative drive as resulting from an interaction of the frontal lobes, the temporal lobes, and dopamine from the limbic system. The frontal lobes can be seen as responsible for idea generation, and the temporal lobes for idea editing and evaluation. Abnormalities in the frontal lobe (such as depression or anxiety) generally decrease creativity, while abnormalities in the temporal lobe often increase creativity. High activity in the temporal lobe typically inhibits activity in the frontal lobe, and vice versa. High dopamine levels increase general arousal and goal directed behaviors and reduce latent inhibition, and all three effects increase the drive to generate ideas.

Working memory and the cerebellum

Vandervert described how the brain's frontal lobes and the cognitive functions of the cerebellum collaborate to produce creativity and innovation. Vandervert's explanation rests on considerable evidence that all processes of working memory (responsible for processing all thought) are adaptively modeled by the cerebellum. The cerebellum (consisting of 100 billion neurons, which is more than the entirety of the rest of the brain) is also widely known to adaptively model all bodily movement. The cerebellum's adaptive models of working memory processing are then fed back to especially frontal lobe working memory control processes where creative and innovative thoughts arise. (Apparently, creative insight or the "aha" experience is then triggered in the temporal lobe.)

According to Vandervert, the details of creative adaptation begin in "forward" cerebellar models which are anticipatory/exploratory controls for movement and thought. These cerebellar processing and control architectures have been termed Hierarchical Modular Selection and Identification for Control (HMOSAIC). New, hierarchically arranged levels of the cerebellar control architecture (HMOSAIC) develop as mental mulling in working memory is extended over time. These new levels of the control architecture are fed forward to the frontal lobes. Since the cerebellum adaptively models all movement and all levels of thought and emotion, Vandervert's approach helps explain creativity and innovation in sports, art, music, the design of video games, technology, mathematics, the child prodigy, and thought in general.

REM sleep

Creativity involves the forming of associative elements into new combinations that are useful or meet some requirement. Sleep aids this process. REM rather than NREM sleep appears to be responsible. This has been suggested to be due to changes in cholinergic and noradrenergic neuromodulation that occurs during REM sleep. During this period of sleep, high levels of acetylcholine in the hippocampus suppress feedback from the hippocampus to the neocortex, and lower levels of acetylcholine and norepinephrine in the neocortex encourage the spread of associational activity within neocortical areas without control from the hippocampus. This is in contrast to waking consciousness, where higher levels of norepinephrine and acetylcholine inhibit recurrent connections in the neocortex. It is proposed that REM sleep would add creativity by allowing "neocortical structures to reorganize associative hierarchies, in which information from the hippocampus would be reinterpreted in relation to previous semantic representations or nodes."

Creativity and mental health

A study by psychologist J. Philippe Rushton found creativity to correlate with intelligence and psychoticism. Another study found creativity to be greater in schizotypal than in either normal or schizophrenic individuals. While divergent thinking was associated with bilateral activation of the prefrontal cortex, schizotypal individuals were found to have much greater activation of their right prefrontal cortex. This study hypothesizes that such individuals are better at accessing both hemispheres, allowing them to make novel associations at a faster rate. In agreement with this hypothesis, ambidexterity is also associated with schizotypal and schizophrenic individuals. Three recent studies by Mark Batey and Adrian Furnham have demonstrated the relationships between schizotypal and hypomanic personality and several different measures of creativity.

Particularly strong links have been identified between creativity and mood disorders, particularly manic-depressive disorder (a.k.a. bipolar disorder) and depressive disorder (a.k.a. unipolar disorder). In Touched with Fire: Manic-Depressive Illness and the Artistic Temperament, Kay Redfield Jamison summarizes studies of mood-disorder rates in writers, poets and artists. She also explores research that identifies mood disorders in such famous writers and artists as Ernest Hemingway (who shot himself after electroconvulsive treatment), Virginia Woolf (who drowned herself when she felt a depressive episode coming on), composer Robert Schumann (who died in a mental institution), and even the famed visual artist Michelangelo.

Measuring creativity

Creativity quotient

Several attempts have been made to develop a creativity quotient of an individual similar to the intelligence quotient (IQ), however these have been unsuccessful. Most measures of creativity are dependent on the personal judgement of the tester, so a standardized measure is difficult, if not impossible, to develop.

Psychometric approach

J. P. Guilford's group, which pioneered the modern psychometric study of creativity, constructed several tests to measure creativity in 1967:

- Plot Titles, where participants are given the plot of a story and asked to write original titles.
- Quick Responses is a word-association test scored for uncommonness.
- Figure Concepts, where participants were given simple drawings of objects and individuals and asked to find qualities or features that are common by two or more drawings; these were scored for uncommonness.
- Unusual Uses is finding unusual uses for common everyday objects such as bricks.

- Remote Associations, where participants are asked to find a word between two given words (e.g. Hand _____ Call)
- Remote Consequences, where participants are asked to generate a list of consequences of unexpected events (e.g. loss of gravity)

Building on Guilford's work, Torrance developed the Torrance Tests of Creative Thinking in 1966. They involved simple tests of divergent thinking and other problem-solving skills, which were scored on:

- Fluency – The total number of interpretable, meaningful and relevant ideas generated in response to the stimulus.
- Originality – The statistical rarity of the responses among the test subjects.
- Elaboration – The amount of detail in the responses.

The Creativity Achievement Questionnaire, a self-report test that measures creative achievement across 10 domains, was described in 2005 and shown to be reliable and valid when compared to other measures of creativity and to independent evaluation of creative output. The psychometric approach has been criticized by Robert Sternberg for falling "short of distinguishing imagination from fantasy, relevant from irrelevant material, and contextually valid from rambling associations".

Social-personality approach

Some researchers have taken a social-personality approach to the measurement of creativity. In these studies, personality traits such as independence of judgement, self-confidence, attraction to complexity, aesthetic orientation and risk-taking are used as measures of the creativity of individuals. Other researchers have related creativity to the trait, openness to experience.

As the research into the relationship between personality traits and creativity continues to grow, a more complete picture has developed. Within the framework of the Big Five model of personality some consistent traits have emerged. Openness to experience has been shown to be consistently related to a whole host of different assessments of creativity. Among the other Big Five traits, research has demonstrated subtle differences between different domains of creativity. A meta-analysis by Gregory Feist showed that artists tend to have higher levels of neuroticism and introversion, while scientists are more conscientious.

Other approaches to measurement

Genrich Altshuller in the 1950s introduced approaching creativity as an exact science with TRIZ and a Level-of-Invention measure.

The creativity of thousands of Japanese, expressed in terms of their problem-solving and problem-recognizing capabilities, has been measured in Japanese firms.

Howard Gruber insisted on a case-study approach that expresses the existential and unique quality of the creator. Creativity to Gruber was the product of purposeful work and this work could be described only as a confluence of forces in the specifics of the case.

Creativity in various contexts

An electric wire reel reused like a center table in a Rio de Janeiro decoration fair. The creativity of this designer in reusing this waste was used with good effects to the environment.

Creativity has been studied from a variety of perspectives and is important in numerous contexts. Most of these approaches are undisciplinary, and it is therefore difficult to form a coherent overall view. The following sections examine some of the areas in which creativity is seen as being important.

Creativity Profiles

Creativity comes in different forms. A number of different theorists have suggested models of the creative person. One model suggests that there are kinds to produce growth, innovation, speed, etc. These are referred to as the four "Creativity Profiles" that can help achieve such goals.

(i) Incubate (Long-term Development)
(ii) Imagine (Breakthrough Ideas)
(iii) Improve (Incremental Adjustments)
(iv) Invest (Short-term Goals)

Research by Dr Mark Batey of the Psychometrics at Work Research Group at Manchester Business School has suggested that the creative profile can be explained by four primary creativity traits with narrow facets within each

(i) "Idea Generation" (Fluency, Originality, Incubation and Illumination)
(ii) "Personality" (Curiosity and Tolerance for Ambiguity)
(iii) "Motivation" (Intrinsic, Extrinsic and Achievement)
(iv) "Confidence" (Producing, Sharing and Implementing)

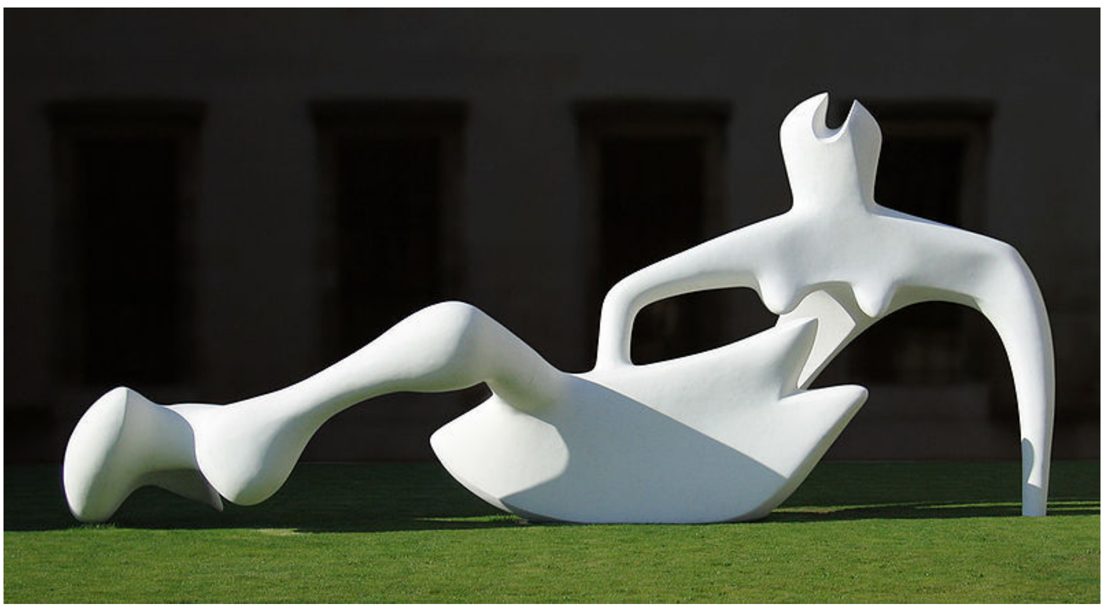
This model was developed in a sample of 1000 working adults using the statistical techniques of Exploratory Factor Analysis followed by Confirmatory Factor Analysis by Structural Equation Modelling.

An important aspect of the creativity profiling approach is to account for the tension between predicting the creative profile of an individual, as characterised by the psychometric approach, and the evidence that team creativity is founded on diversity and difference.

Creativity in diverse cultures

Francois Jullien in "Process and Creation, 1989" invites us to look at that concept from a Chinese cultural point of view. Fangqi Xu has reported creativity courses in a range of countries. Todd Lubart has studied extensively the cultural aspects of creativity and innovation.

Creativity in art and literature



Henry Moore's Reclining Figure

Most people associate creativity with the fields of art and literature. In these fields, originality is considered to be a sufficient condition for creativity, unlike other fields where both originality and appropriateness are necessary.

Within the different modes of artistic expression, one can postulate a continuum extending from "interpretation" to "innovation". Established artistic movements and genres pull practitioners to the "interpretation" end of the scale, whereas original thinkers strive towards the "innovation" pole. Note that we conventionally expect some "creative" people (dancers, actors, orchestral members, etc.) to perform (interpret) while allowing others (writers, painters, composers, etc.) more freedom to express the new and the different.

Contrast alternative theories, for example:

- artistic inspiration, which provides the transmission of visions from divine sources such as the Muses; a taste of the Divine. Compare with invention.
- artistic evolution, which stresses obeying established ("classical") rules and imitating or appropriating to produce subtly different but unshockingly understandable work. Compare with crafts.
- artistic conversation, as in Surrealism, which stresses the depth of communication when the creative product is the language.

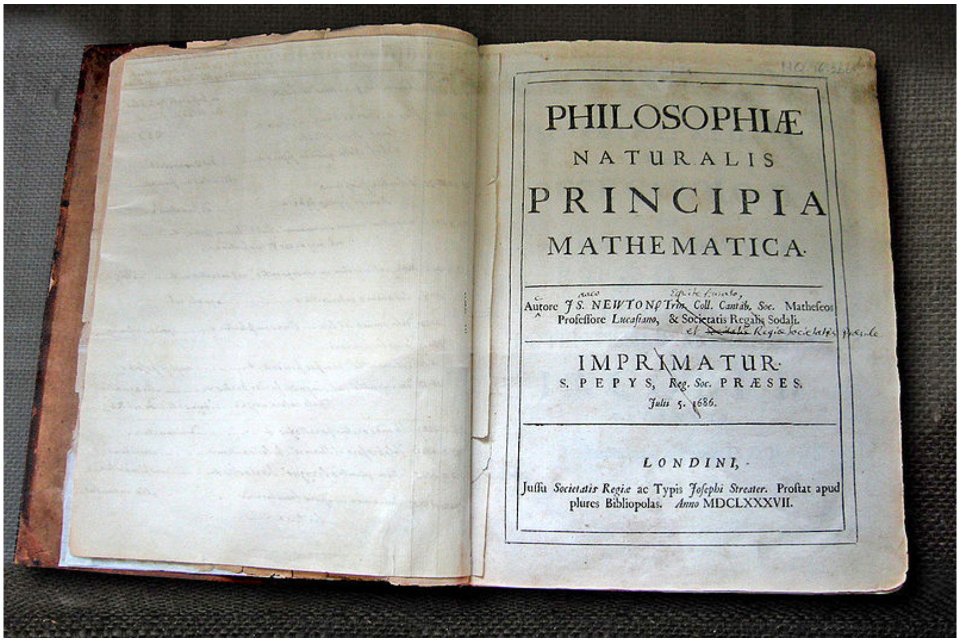
In the art practice and theory of Davor Dzalto, human creativity is taken as a basic feature of both the personal existence of human being and art production. For this thinker, creativity is a basic cultural and anthropological category, since it enables human manifestation in the world as a "real presence" in contrast to the progressive "virtualization" of the world.

Creative industries and services

Today, creativity forms the core activity of a growing section of the global economy—the so-called "creative industries"—capitalistically generating (generally non-tangible) wealth through the creation and exploitation of intellectual property or through the provision of creative services. The Creative Industries Mapping Document 2001 provides an overview of the creative industries in the UK. The creative professional workforce is becoming a more integral part of industrialized nations' economies.

Creative professions include writing, art, design, theater, television, radio, motion pictures, related crafts, as well as marketing, strategy, some aspects of scientific research and development, product development, some types of teaching and curriculum design, and more. Since many creative professionals (actors and writers, for example) are also employed in secondary professions, estimates of creative professionals are often inaccurate. By some estimates, approximately 10 million US workers are creative professionals; depending upon the depth and breadth of the definition, this estimate may be double.

Creativity in other professions



Isaac Newton's law of gravity is popularly attributed to a creative leap he experienced when observing a falling apple.

Creativity is also seen as being increasingly important in a variety of other professions. Architecture and industrial design are the fields most often associated with creativity, and more generally the fields of design and design research. These fields explicitly value creativity, and journals such as Design Studies have published many studies on creativity and creative problem solving.

Fields such as science and engineering have, by contrast, experienced a less explicit (but arguably no less important) relation to creativity. Simonton shows how some of the major scientific advances of the 20th century can be attributed to the creativity of individuals. This ability will also be seen as increasingly important for engineers in years to come.

Accounting has also been associated with creativity with the popular euphemism creative accounting. Although this term often implies unethical practices, Amabile has suggested that even this profession can benefit from the (ethical) application of creative thinking.

In a recent global survey of approximately 1600 CEO's, the leadership trait that was considered to be most crucial for success was creativity. This suggests that the world of business is beginning to accept that creativity is of value in a diversity of industries, rather than being simply the preserve of the creative industries.

Creativity in organizations

It has been the topic of various research studies to establish that organizational effectiveness depends on the creativity of the workforce to a large extent. For any given organization, measures of effectiveness vary, depending upon its mission, environmental context, nature of work, the product or service it produces, and customer demands. Thus, the first step in evaluating organizational effectiveness is to understand the organization itself - how it functions, how it is structured, and what it emphasizes.

Amabile argued that to enhance creativity in business, three components were needed:

- Expertise (technical, procedural and intellectual knowledge),
- Creative thinking skills (how flexibly and imaginatively people approach problems),
- and Motivation (especially intrinsic motivation).

There are two types of motivation:

- extrinsic motivation – external factors, for example threats of being fired or money as a reward,
- intrinsic motivation – comes from inside an individual, satisfaction, enjoyment of work etc.

Six managerial practices to encourage motivation are:

- Challenge – matching people with the right assignments;
- Freedom – giving people autonomy choosing means to achieve goals;
- Resources – such as time, money, space etc. There must be balance fit among resources and people;
- Work group features – diverse, supportive teams, where members share the excitement, willingness to help and recognize each other's talents;
- Supervisory encouragement – recognitions, cheering, praising;
- Organizational support – value emphasis, information sharing, collaboration.

Nonaka, who examined several successful Japanese companies, similarly saw creativity and knowledge creation as being important to the success of organizations. In particular, he emphasized the role that tacit knowledge has to play in the creative process.

In business, originality is not enough. The idea must also be appropriate—useful and actionable.

Economic views of creativity

Economic approaches to creativity have focussed on three aspects - the impact of creativity on economic growth, methods of modelling markets for creativity, and the maximisation of economic creativity (innovation).

In the early 20th century, Joseph Schumpeter introduced the economic theory of creative destruction, to describe the way in which old ways of doing things are endogenously destroyed and replaced by the new. Some economists (such as Paul Romer) view creativity as an important element in the recombination of elements to produce new technologies and products and, consequently, economic growth. Creativity leads to capital, and creative products are protected by intellectual property laws.

Mark A. Runco and Daniel Rubenson have tried to describe a "psychoeconomic" model of creativity. In such a model, creativity is the product of endowments and active investments in creativity; the costs and benefits of bringing creative activity to market determine the supply of creativity. Such an approach has been criticised for its view of creativity consumption as always having positive utility, and for the way it analyses the value of future innovations.

The creative class is seen by some to be an important driver of modern economies. In his 2002 book, The Rise of the Creative Class, economist Richard Florida popularized the notion that regions with "3 T's of economic development: Technology, Talent and Tolerance" also have high concentrations of creative professionals and tend to have a higher level of economic development.

Fostering creativity

Daniel Pink, in his 2005 book A Whole New Mind, repeating arguments posed throughout the 20th century, argues that we are entering a new age where creativity is becoming increasingly important. In this conceptual age, we will need to foster and encourage right-directed thinking (representing creativity and emotion) over left-directed thinking (representing logical, analytical thought). However, this simplification of 'right' versus 'left' brain thinking is not supported by the research data.

Nickerson provides a summary of the various creativity techniques that have been proposed. These include approaches that have been developed by both academia and industry:

- Establishing purpose and intention
- Building basic skills
- Encouraging acquisitions of domain-specific knowledge
- Stimulating and rewarding curiosity and exploration
- Building motivation, especially internal motivation
- Encouraging confidence and a willingness to take risks
- Focusing on mastery and self-competition
- Promoting supportable beliefs about creativity
- Providing opportunities for choice and discovery
- Developing self-management (metacognitive skills)
- Teaching techniques and strategies for facilitating creative performance
- Providing balance

Some see the conventional system of schooling as "stifling" of creativity and attempt (particularly in the pre-school/kindergarten and early school years) to provide a creativity-friendly, rich, imagination-fostering environment for young children. Researchers have seen this as important because technology is advancing our society at an unprecedented rate and creative problem solving will be needed to cope with these challenges as they arise. In addition to helping with problem solving, creativity can also helps students identify problems where others have failed to do so. See the Waldorf School as an example of an education program that promotes creative thought.

Promoting intrinsic motivation and problem solving are two areas where educators can foster creativity in students. Students are more creative when they see a task as intrinsically motivating, valued for its own sake. To promote creative thinking educators need to identify what motivates their students and structure teaching around it. Providing students with a choice of activities to complete allows them to become more intrinsically motivated and therefore creative in completing the tasks.

Teaching students to solve problems that do not have well defined answers is another way to foster their creativity. This is accomplished by allowing students to explore problems and redefine them, possibly drawing on knowledge that at first may seem unrelated to the problem in order to solve it.

Several different researchers have proposed methods of increasing the creativity of an individual. Such ideas range from the psychological-cognitive, such as Osborn-Parnes Creative Problem Solving Process, Synectics, Science-based creative thinking, Purdue Creative Thinking Program, and Edward de Bono's lateral thinking; to the highly-structured, such as TRIZ (the Theory of Inventive Problem-Solving) and its variant Algorithm of Inventive Problem Solving (developed by the Russian scientist Genrich Altshuller), and Computer-Aided Morphological analysis.

Understanding and enhancing the creative process with new technologies

A simple but accurate review on this new Human-Computer Interactions (HCI) angle for promoting creativity has been written by Todd Lubart, an invitation full of creative ideas to develop further this new field.

Groupware and other Computer Supported Collaborative Work (CSCW) platforms are now the stage of Network Creativity on the web or on other private networks. These tools have made more obvious the existence of a more connective, cooperative and collective nature of creativity rather than the prevailing individual one. Creativity Research on Global Virtual Teams is showing that the creative process is affected by the national identities, cognitive and conative profiles, anonymous interactions at times and many other factors affecting the teams members, depending on the early or later stages of the cooperative creative process. They are also showing how NGO's cross-cultural virtual team's innovation in Africa would also benefit from the pooling of best global practices online. Such tools enhancing cooperative creativity may have a great impact on society and as such should be tested while they are built following the Motto: "Build the Camera while shooting the film". Some European FP7 scientific programs like Paradiso are answering a need for advanced experimentally-driven research including large scale experimentation test-beds to discover the technical, societal and economic implications of such groupware and collaborative tools to the Internet.

On the other hand, creativity research may one day be pooled with a computable metalanguage like IEML from the University of Ottawa Collective Intelligence Chair, Pierre Levy. It might be a good tool to provide an interdisciplinary definition and a rather unified theory of creativity. The creative processes being highly fuzzy, the programming of cooperative tools for creativity and innovation should be adaptive and flexible. Empirical Modelling seems to be a good choice for Humanities Computing.

If all the activity of the universe could be traced with appropriate captors, it is likely that one could see the creative nature of the universe to which humans are active contributors. After the web of documents, the Web of Things might shed some light on such a universal creative phenomenon which should not be restricted to humans. In order to trace and enhance cooperative and collective creativity, Metis Reflexive Global Virtual Team has worked for the last few years on the development of a Trace Composer at the intersection of personal experience and social knowledge.

Metis Reflexive Team has also identified a paradigm for the study of creativity to bridge European theory of "useless" and non-instrumentalized creativity, North American more pragmatic creativity and Chinese culture stressing more creativity as a holistic process of continuity rather than radical change and originality. This paradigm is mostly based on the work of the German philosopher Hans Joas, one that emphasizes the creative character of human action. This model allows also for a more comprehensive theory of action. Joas elaborates some implications of his model for theories of social movements and social change. The connection between concepts like creation, innovation, production and expression is facilitated by the creativity of action as a metaphore but also as a scientific concept.

The Creativity and Cognition conference series, sponsored by the ACM and running since 1993, has been an important venue for publishing research on the intersection between technology and creativity. The conference now runs biennially, next taking place in 2011.

Social attitudes to creativity

Although the benefits of creativity to society as a whole have been noted, social attitudes about this topic remain divided. The wealth of literature regarding the development of creativity and the profusion of creativity techniques indicate wide acceptance, at least among academics, that creativity is desirable.

There is, however, a dark side to creativity, in that it represents a "quest for a radical autonomy apart from the constraints of social responsibility". In other words, by encouraging creativity we are encouraging a departure from society's existing norms and values. Expectation of conformity runs contrary to the spirit of creativity. Sir Ken Robinson argues that the current education system is "educating people out of their creativity".

Nevertheless, employers are increasingly valuing creative skills. A report by the Business Council of Australia, for example, has called for a higher level of creativity in graduates. The ability to "think outside the box" is highly sought after. However, the above-mentioned paradox may well imply that firms pay lip service to thinking outside the box while maintaining traditional, hierarchical organization structures in which individual creativity is not rewarded.

Conceptual blending

Conceptual Blending (aka Conceptual Integration) is a general theory of cognition. According to this theory, elements and vital relations from diverse scenarios are "blended" in a subconscious process known as Conceptual Blending, which is assumed to be ubiquitous to everyday thought and language. Insights obtained from these blends constitute the products of creative thinking, though conceptual blending theory is not itself a theory of creativity, inasmuch as it does not illuminate the issue of where the inputs to a blend actually come from. Blending theory does provide a rich terminology for describing the creative products of others, but has little to say on the inspiration that serves as the starting point for each blend.

The theory of Conceptual Blending was developed by Gilles Fauconnier and Mark Turner. The development of this theory began in 1993 and a representative early formulation is found in their online article Conceptual Integration and Formal Expression. Mark Turner and Gilles Fauconnier cite Arthur Koestler´s 1964 book The Act of Creation as an early forerunner of conceptual blending: Koestler had identified a common pattern in creative achievements in the arts, sciences and humor that he had termed "bisociation of matrices" - a notion he described with many striking examples, but did not formalize in algorithmic terms. Conceptual Blending theory is also not formalized at the level of algorithmic detail , but its various optimality principles provide some guidance for those building computational models.

A newer version of blending theory, with somewhat different terminology, was presented in their book The Way We Think (ISBN 0-465-08786-8). Their theory is partially based on basic ideas advanced by George Lakoff in his 1987 book Women, Fire and Dangerous Things and in Lakoff's coauthored 1980 book with Mark Johnson Metaphors We Live By. It is also related to Cognitive architecture theories like Soar and ACT-R, and to frame-based theories of Marvin Minsky, Jaime Carbonell among others.

Counterfactual thinking

Counterfactual thinking is a term of psychology that describes the tendency people have to imagine alternatives to reality. Humans are predisposed to think about how things could have turned out differently if only..., and also to imagine what if?.

Overview

A person may imagine how an outcome could have turned out differently, and they can reflect on how the antecedents that led to the event might have been different. For example, a person may reflect upon how a car accident could have turned out, and they can reflect on how some of the antecedents might have been different e.g., if only I hadn't been speeding... or the same even if I had been going slower.... People can imagine alternatives that are better or worse than reality, e.g., if only I hadn't been speeding, my car wouldn't have been wrecked or if I hadn't been wearing a seatbelt I would have been killed (Roese & Olson, 1995). People can contemplate the consequences of the alternative outcome. Their counterfactual thoughts can affect their emotions, such as regret, guilt, relief, or satisfaction; their social ascriptions such as blame and responsibility, and their causal judgments (Markman, Klein, & Suhr, 2009).

Counterfactual thinking is marked during the period immediately after a negotiation has ended. In this context, the participants are more likely to dwell on alternative outcomes which were plausibly missed rather than thinking about the unwanted consequences which were effectively avoided.

History

Daniel Kahneman and Amos Tversky (1982) pioneered the study of counterfactual thought, showing that people tend to think 'if only' more often about exceptional events than about normal events. Many related tendencies have since been examined, e.g., whether the event is an action or inaction, whether it is controllable, its place in the temporal order of events, or its causal relation to other events (Mandel, Hilton, & Catellani, 2005).

Theories of Counterfactual Thinking

Daniel Kahneman and Dale Miller (1986) proposed that the cognitive processes that give rise to counterfactual thoughts include memory retrieval processes by which exceptional events recruit their normal counterparts. Ruth M.J. Byrne (2005) proposed that the mental representations and cognitive processes that underlie the imagination of alternatives to reality are similar to those that underlie rational thought, including reasoning from counterfactual conditionals.

In Popular Culture

In the fourth series of the CBS comedy series The Big Bang Theory, Sheldon Cooper and Amy Farrah Fowler develop a game called 'Counterfactuals' which is based on changing one accepted state of the universe and postulating the answer to a question based on such a change. For example: "In a world where Rhinoceroses are domesticated pets, who wins the Second World War?"

Incubation (psychology)

Incubation is one of the 4 proposed stages of creativity: preparation, incubation, illumination, and verification. Incubation is defined as a process of unconscious recombination of thought elements that were stimulated through conscious work at one point in time, resulting in novel ideas at some later point in time.

The experience of leaving a problem for a period of time, then finding the difficulty evaporates on returning to the problem, or even more striking, that the solution "comes out of the blue", when thinking about something else, is widespread. Many guides to effective thinking and problem solving advise the reader to set problems aside for a time.

Paradigm for Investigating Incubation

The most widely adopted paradigm for investigating incubation involves comparing problems on which participants take a break during solving with problems on which participants work for a continuous period. The total time spent on each problem is equated across the conditions and the incubation period is usually filled with unrelated activity to prevent further conscious work on the problem. Superior performance on problems for which work is split over two sessions is taken as evidence for the incubation effect, which is thus operationally defined as any benefit of a break during problem solving.

Incubation effect and Emotions & Creativity

When discussing the relation between incubation effect – emotions and creativity, researchers found that positive mood enhances creativity at work. That means that we would expect a given day's creativity to follow reliably from the previous day's mood, above and beyond any carry-over of that previous day's mood. Theory and research on incubation, long recognized as a part of the creative process, suggest such cross-day effects. Thus, if positive mood on a particular day increases the number and scope of available thoughts, those additional thoughts may incubate overnight, increasing the probability of creative thoughts the following day.

Recent advances in neuroscience provide intriguing evidence of the mechanisms underlying incubation effects, particularly those that occur during sleep. This research reveals that people's experiences while awake can be consolidated into memory and result in enhanced performance the next day without any additional practice or engagement in the task. Moreover, there is mounting evidence that sleep can facilitate the types of memory and learning processes, such as associative memory, that contribute to creative problem solving. In one relevant experiment, researchers demonstrated that problem-solving insight can be dramatically enhanced by a period of sleep following initial work on a problem.

The Cases For and Against Dreams Being Useful In Problem-Solving

In the 1970s, Stanford Sleep Lab Director William Dement gave 500 undergraduate students three "brain-teaser" problems to read over before going to sleep and to note whether they had solutions in their dreams that night; seven students had a dream containing the solution. Two decades later, 1993, Harvard psychologist Deirdre Barrett conducted research asking college students to incubate answers to real-life homework and other objective problems on which they were working, finding that in one week's time, ½ had dreamed about their topic and ¼ had a dream which provided an answer. Barrett also interviewed modern artists and scientists about their use of their dreams, documenting dramatic anecdotes including Nobel Prizes and MacArthur 'genius grants' whose ideas originated in dreams. Her research concludes that while anything—math, musical composition, business dilemmas—may get solved during dreaming, the two areas dreams are especially likely to help are 1) anything where vivid visualization contributes to the solution, whether in artistic design or invention of 3-D technological devices and 2) any problem where the solution lies in thinking outside the box—i.e. where the person is stuck because the conventional wisdom on how to approach the problem is wrong.

Not everybody agrees about the usefulness of dreams in solving problems. In an August 2004 article, "Dreams: The Case Against Problem-Solving," G. William Domhoff concluded : "When all is said and done, there is only occasional anecdotal evidence for the idea that recalled dreams have any role in solving or detecting problems. This evidence is not impressive when it is arrayed against the small percentage of dreams that are recalled and the even smaller percentage of recalled dreams that might be construed as having a solution to a problem. Dreams may on occasion be useful to waking consciousness as a basis for thinking about problems in a new way, or as a basis for discussing personal problems, as some clinical research shows (Fiss, 1991; Greenberg et al., 1992). And dreams that have a dramatic emotional impact create a strong subjective sense that they must have a useful message. However, it does not follow from clinical usefulness or a waking impression of importance that dreaming has an adaptive function (Antrobus, 1993)."

The New-Paradigm Incubation Framework is another alternative to dreams that aims to reduce complexity and improve creativity, upstream, in decision-making and policy formulation. Its architect, Alain Paul Martin, has researched the incubation cycles of new paradigms related to creativity in economics, social psychology and other social sciences, medicine, and governance.

Divergent thinking

Divergent thinking is a thought process or method used to generate creative ideas by exploring many possible solutions. It is often used in conjunction with convergent thinking, which follows a particular set of logical steps to arrive at one solution, which in some cases is a "correct" solution. Divergent thinking typically occurs in a spontaneous, free-flowing manner, such that many ideas are generated in an emergent cognitive fashion. Many possible solutions are explored in a short amount of time, and unexpected connections are drawn. After the process of divergent thinking has been completed, ideas and information are organized and structured using convergent thinking.

Psychologists have found that a high IQ alone does not guarantee creativity. Instead, personality traits that promote divergent thinking are more important. Divergent thinking is found among people with personalities which have traits such as nonconformity, curiosity, willingness to take risks, and persistence. Additionally, researchers at Vanderbilt

University found that musicians are more adept at utilizing both hemispheres and more likely to use divergent thinking in their thought processes.

Activities which promote divergent thinking include creating lists of questions, setting aside time for thinking and meditation, brainstorming, subject mapping / "bubble mapping", keeping a journal, creating artwork, and free writing. In free writing, a person will focus on one particular topic and write non-stop about it for a short period of time, in a stream of consciousness fashion.

Convergent thinking

Convergent thinking is a term coined by Joy Paul Guilford as the opposite of divergent thinking. It generally means the ability to give the "correct" answer to standard questions that do not require significant creativity, for instance in most tasks in school and on standardized multiple-choice tests for intelligence.

Ellis Paul Torrance (Research on Creativity)

Ellis Paul Torrance (October 8, 1915 - July 12, 2003) was an American psychologist from Milledgeville, Georgia.

After completing his undergraduate degree at Mercer University, he went on to complete a Master's degree at the University of Minnesota, and then a doctorate from the University of Michigan. His teaching career spanned from 1957 to 1984, first at the University of Minnesota and then later the University of Georgia, where he became professor of Educational Psychology in 1966.

In 1984, the University of Georgia established the Torrance Center for Creativity and Talent Development.

Torrance is best known for his research in creativity. His major accomplishments include 1,871 publications:88 books; 256 parts of books or cooperative volumes; 408 journal articles; 538 reports, manuals, tests, etc.; 162 articles in popular journals or magazines; 355 conference papers; and 64 forewords or prefaces. He also created the Future Problem Solving Program International, the Incubation Curriculum Model, and the Torrance Tests of Creative Thinking.

Torrance Tests of Creative Thinking (TTCT)

Building on J.P. Guilford's work, the Torrance Tests of Creative Thinking (TTCT) originally involved simple tests of divergent thinking and other problem-solving skills, which were scored on four scales:

- Fluency. The total number of interpretable, meaningful, and relevant ideas generated in response to the stimulus.
- Flexibility. The number of different categories of relevant responses.
- Originality. The statistical rarity of the responses.
- Elaboration. The amount of detail in the responses.

The third edition of the TTCT in 1984 eliminated the Flexibility scale from the figural test, but added Resistance to Premature Closure (based on Gestålt Psychology) and Abstractness of Titles as two new criterion referenced scores on the figural. Torrance called the new scoring procedure Streamlined Scoring. With the five norm-referenced measures that he now had (fluency, originality, abstractness of titles, elaboration and resistance to premature closure), he added 13 criterion referenced measures which include: emotional expressiveness, story-telling articulateness, movement or actions, expressiveness of titles, syntheses of incomplete figures, synthesis of lines, of circles, unusual visualization, extending or breaking boundaries, humor, richness of imagery, colourfulness of imagery, and fantasy.

According to Arasteh and Arasteh (1976) the most systematic assessment of creativity in elementary school children has been conducted by Torrance and his associates (1960a,1960b, 1960c, 1961,1962,1962a,1963a 1964), who have developed and administered the Minnesota Tests of Creative Thinking (MTCT) to several thousands of school children. Although they have used many of Guilfords concepts in their test construction, the Minnesota group, in contrast to Guilford, has devised tasks which can be scored for several factors, involving both verbal and non-verbal aspects and relying on senses other than vision. These tests represent a fairly sharp departure from the factor type tests developed by Guilford and his associates (Guilford, Merrifield and Cox, 1961; Merrifield, Guilford and Gershan,1963), and they also differ from the battery developed by Wallach and Kogan (1965) , which contains measures representing creative tendencies that are similar in nature (Torrance, 1968).

To date, several longitudinal studies have been conducted to follow up the elementary school-aged students who were first administered the Torrance Tests in 1958 in Minnesota. There was a 22-year follow-up, a 40-year follow-up , and a 50 year follow-up

Torrance (1962) grouped the different subtests of the Minnesota Tests of Creative Thinking (MTCT) into three categories.

- Verbal tasks using verbal stimuli
- Verbal tasks using non-verbal stimuli
- Non-verbal tasks

A brief description of the tasks used by Torrance is given below:

Unusual Uses

The unusual uses tasks using verbal stimuli are direct modifications of Guilford's Brick uses test. After preliminary tryouts, Torrance (1962) decided to substitute tin cans and books for bricks. It was believed the children would be able to handle tin cans and books more easily since both are more available to children than bricks.

Impossibilities task

It was used originally by Guilford and his associates (1951) as a measure of fluency involving complex restrictions and large potential. In a course in personality development and mental hygiene, Torrance has experimented with a number of modifications of the basic task, making the restrictions more specific. In this task the subjects are asked to list as many impossibilities as they can.

Consequences task

The consequences task was also used originally by Guilford and his associates (1951). Torrance has made several modifications in adapting it. He chose three improbable situations and the children were required to list out their consequences.

Just suppose task

It is an adaptation of the consequences type of test designed to elicit a higher degree of spontaneity and to be more effective with children. As in the consequence task, the subject is confronted with an improbable situation and asked to predict the possible outcomes from the introduction of a new or unknown variable.

Situations task

The situation task was modeled after Guilford's (1951) test designed to assess the ability to see what needs to be done. Subjects were given three common problems and asked to think of as many solutions to these problems as they can. For example, if all schools were abolished, what would you do to try to become educated?

Common problems task

This task is an adoption of Guilford's (1951) Test designed to assess the ability to see defects, needs and deficiencies and found to be one of the test of the factors termed sensitivity to problems. Subjects are instructed that they will be given common situations and that they will be asked to think of as many problems as they can that may arise in connection with these situations. For example, doing homework while going to school in the morning.

Improvement task

This test was adopted from Guilford's (1952) apparatus test which was designed to assess ability to see defects and all aspects of sensitivity to problems. In this task the subjects are given a list of common objects and are asked to suggest as many ways as they can to improve each object. They are asked not to bother about whether or not it is possible to implement the change thought of.

Mother- Hubbard problem

This task was conceived as an adoption of the situations task for oral administration in the primary grades and also useful for older groups. This test has stimulated a number of ideas concerning factors which inhibit the development of ideas.

Imaginative stories task

In this task the child is told to write the most interesting and exciting story he can think of. Topics are suggested (e.g., the dog that did not bark); or the child may use his own ideas.

Cow jumping problems

The Cow jumping problem is a companion task for the Mother- Hubbard problem and has been administered to the same groups under the same conditions and scored according to the similar procedures. The task is to think of all possible things which might have happened when the cow jumped over the moon.

Verbal tasks using nonverbal stimuli

Ask and guess task

The ask and guess task requires the individual first to ask questions about a picture – questions which cannot be answered by just looking at the picture. Next he is asked to make guesses or formulate hypotheses about the possible causes of the event depicted, and then their consequences both immediate and remote.

Product improvement task

In this task common toys are used and children are asked to think of as many improvements as they can which would make the toy 'more fun to play with'. Subjects are then asked to think of unusual uses of these toys other than 'something to play with'.

Unusual uses task

In this task, along with the product improvement task another task (unusual uses) is used. The child is asked to think of the cleverest, most interesting and most unusual uses of the given toy, other than as a plaything. These uses could be for the toy as it is, or for the toy as changed.

Non-verbal tasks

Incomplete figures task

It is an adaptation of the 'Drawing completion test' developed by Kate Franck and used by Barron (1958). On an ordinary white paper an area of fifty four square inches is divided into six squares each containing a different stimulus figure. The subjects are asked to sketch some novel objects or design by adding as many lines as they can to the six figures.

Picture construction task or shapes task

In this task the children are given shape of a triangle or a jelly bean and a sheet of white paper. The children are asked to think of a picture in which the given shape is an integral part. They should paste it wherever they want on the white sheet and add lines with pencil to make any novel picture. They have to think of a name for the picture and write it at the bottom.

Circles and squares task

It was originally designed as a nonverbal test of ideational fluency and flexibility, then modified in a such a way as to stress originality and elaboration. Two printed forms are used in the test. In one form, the subject is confronted with a page of forty two circles and asked to sketch objects or pictures which have circles as a major part. In the alternate form, squares are used instead of circles.

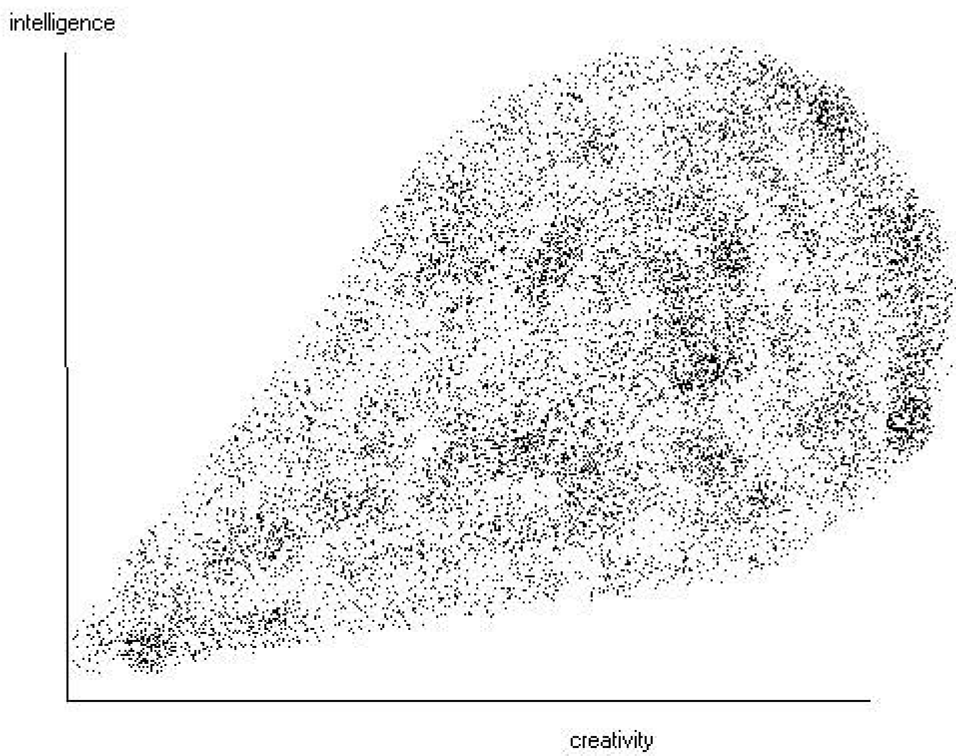
Creative design task

Hendrickson has designed it which seems to be promising, but scoring procedures are being tested but have not been perfected yet. The materials consist of circles and strips of various sizes and colours, a four page booklet, scissors and glue. Subjects are instructed to construct pictures or designs, making use of all of the coloured circles and strips with a thirty minute time limit. Subjects may use one, two, three, or four pages; alter the circles and strips or use them as they are; add other symbols with pencil or crayon.

Threshold Hypothesis

There has been debate in the psychological literature about whether intelligence and creativity are part of the same process (the conjoint hypothesis) or represent distinct mental processes (the disjoint hypothesis).

Evidence from attempts to look at correlations between intelligence and creativity from the 1950s onwards, by authors such as Barron, Guilford or Wallach and Kogan, regularly suggested that correlations between these concepts were low enough to justify treating them as distinct concepts. Some researchers believe that creativity is the outcome of the same cognitive processes as intelligence, and is only judged as creativity in terms of its consequences, i.e., when the outcome of cognitive processes happens to produce something novel, a view which Perkins has termed the "nothing special" hypothesis.



Threshold hypothesis

A very popular model is what has come to be known as "the threshold hypothesis", proposed by Torrance, which holds that, in a general sample, there will be a positive correlation between low creativity and intelligence scores, but a correlation will not be found with higher scores. Research into the threshold hypothesis, however, has produced mixed results ranging from enthusiastic support to refutation and rejection.

Creativity techniques (Fostering Creativity)

Creativity techniques are methods that encourage creative actions, whether in the arts or sciences. They focus on a variety of aspects of creativity, including techniques for idea generation and divergent thinking, methods of re-framing problems, changes in the affective environment and so on. They can be used as part of problem solving, artistic expression, or therapy. Some techniques require groups of two or more people while other techniques can be accomplished alone. These methods include word games, written exercises and different types of improvisation, or algorithms for approaching problems. Aleatory techniques exploiting randomness are also common.

Aleatory techniques

Aleatoricism is the incorporation of chance (random elements) into the process of creation, especially the creation of art or media. Aleatoricism is commonly found in music, art, and literature, particularly in poetry. In film, Andy Voda made a movie in 1979 called "Chance Chants" which he produced by a flip of a coin, or roll of a dice. In music, John Cage, an avant-garde musician, composed music by superimposing star maps on blank sheet music, by rolling dice, and by preparing open ended scores that depended on the spontaneous decisions of the performers. (1) Other ways of practicing randomness include coin tossing, picking something out of a hat, or selecting random words from a dictionary.

In short, aleatoricism is a way to introduce new thoughts or ideas into a creative process.

Improvisation

Improvisation is a creative process which can be spoken, written, or composed without prior preparation. Improvisation, also called extemporization, can lead to the discovery of new ways to act, new patterns of thought and practices, or new structures. Improvisation is used in the creation of music, theater, and other various forms. Many artists also use improvisational techniques to help their creative flow.

The following are two significant methods:

Improvisational theater is a form of theater in which actors use improvisational acting techniques to perform spontaneously. Many improvisational (“improv”) techniques are taught in standard drama classes. The basic skills of listening, clarity, confidence, and performing instinctively and spontaneously are considered important skills for actors to develop.

Free improvisation is real-time composition. Musicians of all kinds improvise (“improv”) music; such improvised music is not limited to a particular genre. Two contemporary musicians that use free improvisation are Anthony Braxton and Cecil Taylor. Through free improvisation, musicians can develop increased spontaneity and fluency.

Each type of improvisation improves the thinking and acting skills of the actor, and this is done by using no practice. A similar set of techniques is called alienation since one of its many techniques uses actors that haven't rehearsed or even read the play. Improvisation is an acting technique during which actors make up a storyline, start and end on the spot, and try their best to keep in character.

Problem solving

In problem-solving contexts, the random-word creativity technique is perhaps the simplest method. A person confronted with a problem is presented with a randomly generated word, in the hopes of a solution arising from any associations between the word and the problem. A random image, sound, or article can be used instead of a random word as a kind of creativity goad or provocation.

Improvisation

Improvisation is the practice of acting, singing, talking and reacting, of making and creating, in the moment and in response to the stimulus of one's immediate environment and inner feelings. This can result in the invention of new thought patterns, new practices, new structures or symbols, and/or new ways to act. This invention cycle occurs most effectively when the practitioner has a thorough intuitive and technical understanding of the necessary skills and concerns within the improvised domain. Improvisation can be thought of as an "on the spot" or "off the cuff" spontaneous activity.

The skills of improvisation can apply to many different abilities or forms of communication and expression across all artistic, scientific, physical, cognitive, academic, and non-academic disciplines. For example, improvisation can make a significant contribution in music, dance, cooking, presenting a speech, sales, personal or romantic relationships, sports, flower arranging, martial arts, psychotherapy, and much more. Techniques of improvisation are widely trained in the entertainment arts; for example, music, theatre and dance. To "extemporize" or "ad lib" is basically the same as improvising. Colloquial terms such as "let's play it by ear," "take it as it comes," and "make it up as we go along" are all used to describe "improvisation."

The simple act of speaking requires a good deal of improvisation because the mind is addressing its own thought and creating its unrehearsed delivery in words, sounds and gestures, forming unpredictable statements that feed back into the thought process (the performer as listener), creating an enriched process that is not unlike instantaneous composition [with a given set or repertoire of elements].

Where the improvisation is intended to solve a problem on a temporary basis, the 'proper' solution being unavailable at the time, it may be known as a stop-gap. This particularly applies to engineering improvisations.

Music

Improvisation is usually defined as composing music while singing or playing an instrument at the same time. In other words, the art of improvisation can be understood as composing music "on the fly". This requires great skill and knowledge, and is a very important aspect of music in general. Musical improvisers often understand the idiom of one or more musical styles — such as blues, rock, folk, jazz — and work within the idiom and music-theory of the certain style to express ideas with creativity and originality. Improvisation can take place as a solo performance, or interdependently in ensemble with other players. When done well, it often elicits gratifying emotional responses from the audience. Very few musicians have ever dared to offer fully improvised concerts such as the famous improvised piano recitals by classical composers/pianists like Franz Liszt. The origins of Liszt's improvisation in an earlier tradition of playing variations on a theme were mastered and epitomized by Bach, Mozart and Beethoven. However, some have managed some attempts similar to these precedents, one of the most successful of these is Keith

Jarrett, a jazz pianist and multi-instrumentalist who has performed many completely improvised concerts all over the world. In the same creative aesthetic as such named masters, including the late innovator and guitar master Derek Bailey, comes a new breed of improvising musician. Pioneers like cellist Eugene Friesen have brought improvisation to traditionally classical instruments. A few pianists have given modern recitals of improvisation in the baroque style, which may be less intimidating because of its stricter development and range of modulation and yet, on the other hand, more daunting because of its polyphony. One of the masters in the style of baroque improvisation was Glenn Gould. There have also been a few other exceptional improvised solo piano concerts in Stuttgart, Southern Germany in the 1990s. There are also full bands who play 100% live improvisation music at their concerts, making up the standards, patterns, rhythms, melodies, harmonies, lyrics, solos, etc. at the top of their heads. Examples are bands like Xlovers 'Beyond Jazz' 2003 Concerts, and the band 42winA2, Holland 2010. In the realm of silent film music, there are also a small number of musicians whose work has been recognized as exceptional by critics, scholars and audiences alike: Neil Brand, Guenter A. Buchwald, Philip Carli, Stephen Horne, Donald Sosin, John Sweeney, and Gabriel Thibaudeau, all performers at the annual conference on silent film in Pordenone, Italy, "Le Giornate del Cinema Muto." Their performances have to match the style and pacing of the films they accompany, often at first sight, and demand a knowledge of a wide range of musical styles, as well as the stamina to play for films which occasionally run over three hours in length without a pause. It is used in drama to act out characters.

Theatre

Dance

Dance improvisation as a choreographic tool: Improvisation is used as a choreographic tool in dance composition. Experimenting with the concepts of shape, space, time, and energy while moving without inhibition or cognitive thinking can create unique and innovative movement designs, spatial configuration, dynamics, and unpredictable rhythms. Improvisation without inhibition allows the choreographer to connect to their deepest creative self, which in turn clears the way for pure invention.

Contact improvisation: a form developed in 1973, that is now practiced around the world. Contact improvisation originated from the movement studies of Steve Paxton in the 1970s and developed through the continued exploration of the Judson Dance Theater. It is a dance form based on sharing weight, partnering, playing with weight and unpredictable outcomes.

Sculpture

Sculpture often relies on the enlargement of a small model or maquette to create the final work in a chosen material. Where the material is plastic such as clay, a working structure or armature often needs to be built to allow the pre-determined design to be realized. Alan Thornhill's method for working with clay abandons the maquette, seeing it as ultimately deadening to creativity. Without the restrictions of the armature, a clay matrix of elements allows that when recognisable forms start to emerge, they can be essentially disregarded by turning the work, allowing for infinite possibility and the chance for the unforeseen to emerge more powerfully at a later stage.

Moving from adding and taking away to purely reductive working, the architectural considerations of turning the work are eased considerably but continued removal of material through the rejection of forms deemed too obvious can mean one ends up with nothing. Former pupil Jon Edgar uses Thornhill's method as a creative extension to direct carving in stone and wood.

Film

The director Mike Leigh uses lengthy improvisations developed over a period of weeks to build characters and story lines for his films. He starts with some sketch ideas of how he thinks things might develop but does not reveal all his intentions with the cast who discover their fate and act out their responses as their destinies are gradually revealed, including significant aspects of their lives which will not subsequently be shown onscreen. The final filming draws on dialogue and actions that have been recorded during the improvisation period.

The youth film company ACT 2 CAM uses improvisation extensively both in the devising and preparation of films and also while shooting. Most of the company's films are unscripted, improvised by the young people in the cast and crew.

Comedy

Improvisational comedy is a theater art performed throughout the world and has had on-again, off-again status throughout history.

Some of the more famous improv theaters and training centers in the world include: i.O. (formerly ImprovOlympic) in Chicago and Los Angeles, The Second City in Chicago and Toronto, The Players Workshop in Chicago, National Comedy Theatre in San Diego, New York and Phoenix, Upright Citizens Brigade in New York City, the Groundlings, BATS Improv in San Francisco, Wing-It Productions in Seattle, Philly Improv Theater in Philadelphia, The Hideout Theatre and The ColdTowne Theater in Austin, Dudley Riggs BraveNew Workshop in Minneapolis, ComedySportz in Milwaukee, The Improv Effect in Jacksonville, Fl, The ImprovTrick and The Improv Shop in Saint Louis, Missouri, Washington Improv Theater in Washington D.C., and Theatresports in Calgary, Canada.

There are also many well known university improv teams, including The University of Pennsylvania's Without a Net, Duke University Improv, the Titanic Players, and Theatre Strike Force at the University of Florida.

Notable pioneers in the field of improvisation, comedic or otherwise, include Viola Spolin, Paul Sills, David Shepherd, Del Close, Josephine Forsberg, Stan Wells, Martin de Maat, and Keith Johnstone. Notable performers include: Richard Pryor, Paul Merton, Stephen Colbert, Steve Carell, Bill Murray, Harold Ramis, Robert Townsend, Colin Mochrie, Ryan Stiles, Ross Noble, Wayne Brady, Robin Williams, Jonathan Winters, Bill Chott, Eddie Izzard and Gil Christner.

Poetry

Traditional epic poetry included improvisation moments where the reciter flattered the audience (especially the authorities) or to substitute a forgotten passage. There are also societies that value improvised poetry as a genre, often as a debate or "poetic joust", where improvisators compete for public approval. Some of these impromptu poems are later recorded in paper or transmitted orally. Usually wit is as valued as conformity to poetical form.

Some of these forms also include humour. But Michel Ducom established himself within Bordeaux poetical improvisation movement in the 1990s but has since composed and performed with a wide range of poets working in diverse poetical areas (Bernat Manciet, Serge Pey, Méryl Marchetti…). The emergence of poetical improvisation, like previous developments in French poetry, was largely tied to the free jazz experience.

Television

Improvisation was originally rarely used on dramatic television. A major exception was the situation comedy Mork and Mindy where star Robin Williams, famed for this kind of performing, was allotted specific sections in each episode where he was allowed to perform freely.

In the 1990s, a TV show called Whose Line Is It Anyway? popularized shortform comedic improvisation. The original version was British, but it was later revived and popularized in the United States with Drew Carey as a host. More recently, television shows such as HBO's Curb Your Enthusiasm (starring Seinfeld co-creator Larry David) and Bravo series Significant Others (2004 TV series) have used improvisation to create longer-form programs with more dramatic flavor. Other long-form partially improvised programs of note are The Loop, Sons & Daughters (U.S. TV series), 10 Items or Less (TV series), Dog Bites Man, Halfway Home (TV series), Reno 911!, Free Ride (TV series), Campus Ladies, and Players (2010 TV series)

In Canada, the Global Television soap opera Train 48, based on the Australian series Going Home, uses a form of structured improvisation, in which actors improvise dialog from written plot outlines. Australia's Thank God You're Here is a game show where celebrities are put into scenes they know nothing about and have to improvise.

Engineering

Improvisation in engineering is to solve a problem with the tools and materials immediately at hand. A classic example of such improvisation was the re-engineering of carbon dioxide scrubbers with the materials on hand during the Apollo 13 space mission.

Engineering improvisations may be needed because of emergencies, embargo, obsolescence of a product and the loss of manufacturer support, or perhaps just a lack of funding appropriate for a better solution.

The popular television program MacGyver used as its gimmick a hero who could solve almost any problem with jury rigged devices from everyday materials, a Swiss Army knife and some duct tape.

Improvised weapons

Improvised weapons are often used by guerrillas, insurgents and criminals as conventional weapons may be unavailable. Such weapons vary in sophistication from simple sharpened sticks, to petrol bombs and home made napalm, to IEDs and make shift bomber aircraft.