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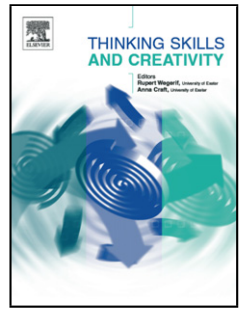

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Creative and critical thinking:

Independent or overlapping components?

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Highlights

- The abilities of thinking creatively and critically are considered to be the main cognitive competencies for our century. However, there are still doubts as to whether creativity and critical thinking are independent or complementary processes in distinct phases of creative problem solving. This paper investigated this question with Brazilian and Spanish using two different measures to assess creativity and critical thinking. The results obtained indicated there seems to be a relative differentiation and independence of creativity and critical thinking in cognitive performance, even if both constructs play small but complementary roles in different phases of creative problem solving. On conclusion, it is emphasized the importance of stimulating both creativity and critical thinking in educational contexts as they are the key ingredients for innovation in today's world.

Abstract

There are questions as to whether creative or critical thinking are relevant for problem solving. Therefore, we have analyzed the association between creative and critical thinking to determine whether their components are independent or associated with each other. A sample of 291 undergraduate students from Brazil (41.2%) and Spain (58.8%), with ages ranging from 17 to 56 years (*M* = 21.35, *SD* = 5.61), from both genders (84% women), answered two creative and critical thinking online tests. Two models were tested using the Structure of Equation Modeling, the first indicating that creativity and critical thinking converge for a general single factor, and the second indicating that they are two separate factors, even if moderately correlated. The results demonstrated that the second model has the best fit indexes, thus confirming the independence of each cognitive component in reference to critical thinking and creativity. In conclusion, the results suggest the need to enhance both skills for developing problem solving abilities.

Keywords: creativity, critical thinking, cognitive development, intelligence, problem solving.

1. Introduction

There is a debate regarding the ways in which creativity and critical thinking can promote cultural development (Westwood & Low, 2003; Zeng, Proctor, & Salvendy, 2011). In fact, the challenges faced by different countries go beyond the physical barriers, indicating that there is a need for innovations to improve the quality of life in society (Stein & Harper, 2012). Because creating new ideas, as well as analyzing and implementing them, are the main processes involved in innovation (Cropley, Kaufman, & Cropley, 2011; Reiter-Palmon, 2011), the stimulation of both creativity and critical thinking in educational contexts remains important. Indeed, results from the studies conducted by the Organization of Educational and Economic Development (OECD, 2009) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), 2015), in different countries, have emphasized that creativity, critical thinking, problem solving, and decision making can be assumed as the main 21st century competencies to be developed by the educational system.

The integration of creative and critical thinking has been emphasized in literature in recent decade (Baker, Ruddy, & Pomeroy, 2001; Glassner & Schwartz, 2007; Padget, 2013). However, studies regarding these constructs as independent remain predominant(Halpern, 2014; Kaufman, Plucker, & Baer, 2008; Runco & Garret, 2012), indicating that there are questions related to the importance of combining these two thinking processes, as well as regarding their roles in different phases of problem solving (Glassner & Schwarz, 2007; Mumford et al., 2012; Treffinger & Isaksen, 2005). There are also doubts related to the different types of cognitive processes that occur in specific stages of creative problem solving (e.g., Halpern, 2010; Osborn 1963).

According to Wallas' pioneer work (1926/2014), there are four stages in creative problem solving (preparation, incubation, illumination, and verification). Efforts to make this process more visible and deliberate were pursued by Osborn, and complemented by Parnes, with a model known as Osborn-Parnes' Creative Problem Solving Model, which was composed of five stages: fact-finding, problem clarification, idea finding, solution generation and acceptance finding (Parnes, 1967). The first two phases were renamed later as mess finding and data finding by Isaksen and Treffinger (Isaksen, Dorval, & Treffinger, 2011). Nevertheless, all these models share a common thread, that problem solving involves stages of generating ideas using creative thinking, followed by cognitive processes demanding the evaluation and implementation of ideas, which are more related to critical thinking (Grohman, Wodniecka, & Klusak, 2006). Indeed, after the illumination phase, in which new ideas appear, there is the stage of verification, during which ideas are refined and developed under a critical perspective (Lubart, 2001). Hence, further comprehension of the different dimensions involved in creative and critical thinking can facilitate the understanding of their roles in problem solving.

2- Defining creativity

Creativity can be defined in multiples ways, involving cognitive processes, personality characteristics, and environment variables, as well as the interaction of these components (Kaufman, Plucker, & Baer, 2008; MacKinnon, 1962; Rhodes, 1961; Sternberg, 2006). The misconception of identifying creativity with original and shocking ideas is moving toward an emphasis on the need to combine the concepts of novelty and usefulness in order to consider a product as creative (Beghetto, Dow, & Plucker, 2004; Runco & Garrett, 2012). These conceptions bring the issue of social relevance of a creative product to a historical moment or a specific culture (Klausen, 2010), which may require critical thinking components.

The first systematic study on creativity represented by divergent thinking is accredited to Guilford (1960) in his model of the structure of the intellect (SOI), as opposed to other cognitive processes, such as convergent thinking, cognition, memory, and evaluation (Guilford & Hoepfner, 1971). Later, creativity researchers (e.g., Jankowska & Karwowski, 2015; Kaufman & Plucker, 2011; Weisberg, 2006) questioned the idea that creative ability can be understood as a synonym of divergent thinking alone, since it involves deductive and inductive thinking, as well as the use of problem solving strategies to generate novel insights and solutions (Finke, Ward, & Smith, 1992). Although there is considerable evidence that creative ability predicts creative achievement (Feist & Barron, 2003; Runco, Millar, Acar, & Cramond, 2010; Wechsler, 2006), there is a consensus that personality traits, such as openness to experience, as well as cognitive characteristics, are predictors of creative engagement and creative production later in life (Kaufman & Baer, 2006; Kaufman et al., 2016).

Divergent thinking is currently the most used measure to assess creative thinking. Several tests have been designed to measure creativity using divergent thinking tasks, such as the creativity tests by Wallach and Kogan (1965), Urban and Jellen (1996), and the Torrance Tests of Creative Thinking (1966). The Torrance figural and verbal tests are the most popular measure of creativity (Kaufman & Baer, 2006) and have been translated to 36 languages, as well as validated in other cultures (Millar, 1995; Wechsler, 2004a, 2004b). Creativity, as measured by the Torrance tests, assesses the cognitive characteristics of fluency, flexibility, originality, and elaboration, as proposed by Guilford, as well as other qualitative aspects derived from a 30-year longitudinal study (Torrance, 1981). Due to the importance of this test for measuring creativity, several international studies have been conducted to examine its main structure. For instance, with a sample of North American children, Kim (2006) observed that there are two main factors in the responses to the figural creativity tests, and that there are more differences across grade levels than across gender. Another study using the verbal and figural Torrance tests with a Portuguese sample yielded four factors, but these were grouped according to the type of activity used to measure creativity (Primi, Nakano, Morais, Almeida, & David, 2013). The existence of four separate parameters for the figural creativity tests was also observed in a study with Brazilian children (Nakano & Primi, 2012). Similarly, a study with a Spanish sample (Almeida, Prieto, Ferrando, Oliveira, & Ferrándiz, 2008) confirmed that factors yielded from the Torrance tests seemed to vary, not according to the cognitive processes, but in the function of the format and content of tasks. The considerable amount of research dealing with creativity assessment in different cultures indicates that it is possible to define and identify creativity in valid and reliable ways (Runco, Millar, Acar, & Cramond, 2010; Wechsler, 2006).

3- Defining critical thinking

There is consensus in the literature that critical thinking is a complex process that demands high-order reasoning processes to achieve a desired outcome (Almeida & Franco, 2011; Caroll, 2005; Halpern, 2006; Sternberg, 1999). Different skills are involved in critical thinking, which concerns questioning the source of knowledge, testing the validity of the acquired information, analyzing its reliability, and drawing appropriate explanations for specific tasks or situations (Bruine, Fischhoff, & Parker, 2007; Halpern, 2014; Hong & Choi, 2015). Therefore, critical thinking can be considered as a multidimensional cognitive construct, implying inductive and deductive reasoning, as well as creative processes, interacting in distinct phases of the problem solving process (Linn, 2000; Philley, 2005).

However, critical thinking cannot be defined by referring only to the cognitive processes involved; such a complex and holistic kind of thinking comprises a certain disposition to use those cognitive skills, thus requiring a motivated attitude to engage in the reasoning process (Halpern, 2010; Saiz & Rivas, 2010). Indeed, intrinsic motivation is also a key issue in understanding the intensive energy that is present in creative problem solving (Amabile, 1996; Hennessey & Amabile, 2010). In this way, critical thinking is a multidimensional construct, one that comprises cognitive, dispositional, motivational, attitudinal, and metacognitive functions (Miele & Wigfield, 2014). To think critically is to achieve one's goals in the most efficient way. Yet, this efficiency requires dimensions that are not cognitive, for without them, critical thinking is not possible (Saiz & Rivas, 2011, 2012; Saiz, Rivas, & Olivares, 2015).

The association between critical thinking and academic performance has been studied thoroughly in the literature. Indeed, thinking and knowing are two associated processes, as thinking helps to establish knowledge, and a knowledge base is necessary for thinking to emerge (Halpern, 2014). Despite its academic relevance, particularly in higher education, critical thinking is a helpful resource to plan, manage, monitor, and, assess academic tasks (Phan, 2010), which goes beyond the classroom and into students' personal and social lives. According to a set of studies by Butler (e.g., Butler et al., 2012), students who performed better in a critical thinking assessment test, hence showing higher levels of critical thinking, reported fewer negative outcomes in their daily lives. From such an association, the relevance of thinking critically has gained strength. This relevance extends to the assessment field, in which a diverse assortment of instruments has been designed to measure critical thinking, such as the *Watson-*

Glaser Critical Thinking Appraisal (Watson & Glaser, 1980), the *Ennis-Weir Critical Thinking Essay Test* (Ennis & Weir, 1985), *The California Critical Thinking Skills Test: College Level* (Facione, 1990), the *Cornell Critical Thinking Tests - Level X* (Ennis & Millman, 2005a) and *Level Z* (Ennis & Millman, 2005b), the *Halpern Critical Thinking Assessment* (Halpern, 2012), or the *PENCRISAL* critical thinking test (Rivas & Saiz, 2012). Each test assesses different dimensions of critical thinking, such as verbal reasoning, argument analysis, inference, inductive reasoning, deductive reasoning, identification of assumptions, decision making, or problem solving, using different assessment formats (multiple choice versus/and open-answer items).

4- Relating creativity and critical thinking

Critical thinking can be related to creativity in conceptual, as well as empirical, ways. Lipman (2003), for example, consider that thinking is intrinsically critical and creative, seeing that there are phases in which we generate creative solutions, or use strategies, followed by stages that require evaluation and decision making on the course of actions, thus requiring critical thinking. Indeed, according to Osborn-Parnes' creative problem solving model, these thinking modes are present at different stages of this process (Parnes, 2000). On the other hand, Halpern (2006) conceptualizes critical and creative thinking as complementary, yet not identical processes, claiming that they may vary according to the strategies that are used to develop these skills through instructional programs. In addition, knowledge and mental modes can also affect the nature and success of people's creative problem solving efforts, as emphasized by Mumford et al. (2012), which are important variables to identify when attempting to understand the problem solving process.

Most professions entail problem solving situations, such as in mental health contexts, in which creativity and critical thinking are required, and often combined, as stressed by Seymour, Kinn, and, Sutherland (2003). In other areas, such as design, critical thinking is expressed through reflection, as well as flexibility skills, which are considered key in facilitating problem solving (Hong & Choi, 2015). According to Baker, Ruddy, and, Pomeroy (2001), educators are only able to enhance their students' ability to solve problems in different contexts if they understand the relationship between both types of thinking. Classroom environments that encourage students to present creative ideas should also help them be critical and evaluate their solutions, as proposed by Fairweather & Cramond 2010)

Due to the important role played by critical and creative thinking in problem solving, the purpose of this paper was to attempt to better understand their relationship, considering two different cultural contexts in Brazil and Spain. Therefore, two models of association between creativity and critical thinking measures were tested, the first testing the hypothesis that these constructs are independent, and the second testing the hypothesis that they are moderately correlated.

5-Method

Participants

The sample was composed of 291 undergraduate psychology students from Brazil (41.2%) and Spain (58.8%), with ages ranging from 17 to 56 years (M = 21.35, SD = 5.61), and the majority were female (84 %). Both age and gender rates were similar in students from the two countries. Professors in Spain and Brazil invited their undergraduate psychology students to participate at their convenience.

Instruments

Verbal creative thinking. Two verbal activities were created to assess divergent thinking abilities. These activities were based on the Torrance Verbal Creativity Test on product improvement and impossible situations, but the stimuli and administration format were changed on each of these activities, as they were administered via computer. In the first activity, a picture of a cock was shown, and the subjects were required to write as many ideas as possible to change this cock into a toy that children would be more interested in playing with. In the second activity, the situation provided was life under the sea, on the premise that life on Earth had become unbearable; here, subjects were required to write as many ideas as they could, imagining that the situation had become true. The time allocated for each activity was 10 minutes, and after this period, the activity was blocked by the computer.

These activities were scored for the following creative characteristics: Fluency (quantity of ideas), Flexibility (change of idea classification), Originality (unusualness of ideas), and Elaboration (enrichment of ideas). These characteristics were based on the dimensions proposed by Torrance in his verbal creativity test (Torrance, 1966). Only raw scores were used for these comparisons. Originality was evaluated on the criteria of 5% or less frequency of each idea, as proposed in the Torrance tests (Torrance, 1990), and it was evaluated separately for the Spanish and Brazilian samples. Verbal elaboration was scored by the number of adjectives near substantives to embellish each word, according to Wechsler's system, which has been shown to be reliable and valid for Brazilians (Wechsler, 2004a, 2004b). Fluency, Flexibility, Originality, and Elaboration were found to be significantly related to Brazilians' creative achievements using the Torrance Figural and Verbal Creativity Tests (r = .14 to r = .33, $p \leq$ 001). This indicates the validity of these creative characteristics, as well as their reliability by test-retest procedures ($r \geq .40$, $p \leq$. 05), as observed by Wechsler (2006).

PENCRISAL Critical Thinking Test. This test is composed of 35 problem-scenarios that ask for open answers to assess the following five factors: *Deductive*

Reasoning (seven items), *Inductive Reasoning* (seven items), *Practical Reasoning* (seven items), *Decision Making* (seven items), and *Problem Solving* (seven items). In the distribution of the problem scenarios for each factor, the following selection of structures was considered as being most characteristic to each of them: Deductive Reasoning assesses propositional reasoning and categorical reasoning; Inductive Reasoning assesses analogical reasoning, as well as hypothetical, and inductive generalizations; Practical Reasoning assesses argumentation abilities and identification of fallacies; Decision Making assesses the use of general decision making procedures, which entails the elaboration of precise judgments of likelihood, and the use of adequate heuristics to make solid decisions; Problem Solving assesses the implementation of specific strategies to resolve the situation at hand. These factors represent fundamental thinking abilities and, in each, we find the most relevant ways of reasoning and problem solving in our daily lives.

Because these items have an open format, the respondent must answer a given question, and also explain why she/he is answering that way. For this reason, there are standardized grading criteria, from which the grader gives a grade from 0 to 2 points according to the quality of the answer: 0 points if the answer given to solve the problem is incorrect; 1 point when the solution is correct, yet the respondent does not provide a proper argument to back it up (here, the respondent identifies and demonstrates comprehension of the fundamental concepts); 2 points when, in addition to providing the right answer, the respondent justifies or explains why it is so (here, the respondent uses more complex processes that imply true elaboration mechanisms). Hence, this test uses a quantitative grading system ranging between 0 and 70 points for the total score and between 0 and 14 points for each of the five scales. Considering the length of the test, it can be taken in different sessions in order to reduce possible fatigue effects and, for this reason, there is no time limit for its completion. Nevertheless, the average estimation time for its completion is between 60 and90 minutes (Saiz & Rivas, 2008). In terms of the psychometric proprieties of the test, the items factor analysis confirms the dimensionality suggested in test construction (53% of global items variance explained) and the internal consistency of items (Cronbach' alpha) were higher than .60 for the entire test and its five subtests. A value of .786 was obtained in test-retest correlation of the entire test, and the inter-rater agreement level was .60 (Cohen's Kappa) for the items (Rivas & Saiz, 2012).

Procedures

In both countries, data were collected at the beginning of the second semester of the undergraduate Psychology academic year. All participants were properly informed about the study goals and confidentiality procedures before providing written informed consent. Only students who performed both tests were included in the sample. After students completed the tests at home, a general explanation about both tests was offered to them in their own classrooms.

Data analysis procedures

Structural Equation Modeling (SEM) was used to test the relationships between the creativity and critical thinking constructs. Three models were tested using the Maximum Likelihood (ML) method with AMOS 21. 0 (IBM, 2012) software. The ML estimation method has desired asymptotic properties – that is, large sample properties, such as minimum variance and unbiasedness, and also, multivariate normality of the observed variables (Schumacker & Lomax, 2010). To test for model fit, the model followed guidelines suggested by Hair et al. (2009): use of multiple indexes of different types, and adjustment of the cut-off points according to the characteristics of the model.

The following indexes were considered: χ^2/df –Chi-squared/Degrees of Freedom Index; CFI – Comparative Fit Index; PNFI – Parsimonious Normed Fit Index; RMSEA – Root-Mean Square Error of Approximation; F0 – Estimated population discrepancy; and NCP – Non-Centrality Parameter.

Results

Two models were tested: (i) Model 1 (M1) – a single factor explained by nine indicator variables combining critical thinking and creativity, that is, the cognitive ability explained by Deductive Reasoning, Inductive Reasoning, Practical Reasoning, Decision Making, Problem Solving, Fluency, Elaboration, Originality, and Flexibility; (ii) Model 2 (M2) – two correlated factors, Critical Thinking and Creativity, explained by nine psychological variables. Critical Thinking is indicated by the variables Deductive Reasoning, Inductive Reasoning, Practical Reasoning, Decision Making, and Problem Solving, and Creativity is indicated by Fluency, Elaboration, Originality, and Flexibility.

In order to improve our model fit, we performed the analysis again using the ML method for the parameter estimation. To use the ML method, two assumptions were made. First, (i) the multivariate normality of data was considered; here, Cohen, Cohen, West, and Aiken (2002) suggest that the asymmetry index should be lower than 2, and the kurtosis index lower than 7. In the present paper, all the observed variables have indexes that respect such assumptions, with the highest asymmetry index being 1.417 for the observed variable Originality, and the highest kurtosis index being 3.525 for Fluency. Next, (ii) the variance-covariance matrices, both observed and estimated, should be defined as positive. Because our sample size is n = 291 (n > 250), and that the number of observed variables is $m = 9$ ($m < 12$), as established by Hair et al. (2009), we must consider the following base values: even if not significant, χ^2 values may result in a good model fit; CFI or TLI ≥ .95; RMSEA ≤ .07; and CFI ≥ .97. The model fit criteria and comparative indexes obtained by the ML method for the two models are presented in Table 1.

[Insert Table 1 here]

In order to achieve better adjustment indexes for the models, we used the Modification Index (MI) that presented values greater than a specified value. Therefore, if we repeat the analysis, treating the covariance among errors identified by MI as a free parameter, the discrepancy will fall. The results for models M1 and M2 are presented in Figures 1 and 2, respectively.

In the indexes model, presented in Figure 1, fit obtained for the initial model M1 are χ^2/df = 6.204, CFI = .744, TLI = .659, RMSEA =.134. Best fit indexes can be obtained for this model if we repeat the analysis, treating the covariance between e7 ↔ e8 (MI=22.394), e6 ↔ e9 (MI=13.222), e6 ↔ e8 (MI=76.875), and e6 ↔ e7 (MI=18.238). After these modifications were made, we obtained new indexes as follows: χ^2/df = 1.476, CFI = .980, TLI = .969, and RMSEA = .041.

The results for the modified model M1 indicated that the components that contribute the most to explaining the Cognitive Ability factor were the psychological variables of Critical Thinking, that is, Problem Solving, with a regression coefficient of .809, Practical Reasoning, with a coefficient of .778, and Decision Making, with a coefficient of .698. In turn, the psychological variables of Creativity presented correlated errors between Fluency and Originality (.515), Elaboration and Originality (.282), Fluency and Elaboration (.237), and Fluency and Flexibility (.195). The regression coefficients for each of the observed variables showed that the two strongest predictors were Problem Solving, which explained 65.4% of its variance, and Practical Reasoning, which explained 60.5% of the variance.

[Insert Figure 1 here]

For the second model, we investigated whether Creativity and Critical Thinking were related. The fit indexes of the initial M2 that were obtained are χ^2/df = 1.614, CFI =.962, TLI =.947, RMSEA= .039. Best fit indexes can be obtained for this model if we repeat the analysis using Creativity to predict Inductive Reasoning (Inductive Reasoning $\rightarrow$ Creativity; MI = 4.297), and Critical Thinking to predict Flexibility (Flexibility $\rightarrow$ Critical Thinking; MI = 11.226). After these modifications were done, we obtained new indexes: χ^2/df = 1.267, CFI = .985, TLI = .977, and RMSEA = .026.

[Insert Figure 2 here]

The results for the modified model M2 indicated that the Creativity and Critical Thinking factors were correlated (.280), and that the psychological variable Flexibility contributed to explaining both factors with a regression coefficient of .236 for Critical Thinking and .239 for Creativity. Additionally, the psychological variable Inductive Reasoning contributed to explaining both factors with a regression coefficient of .475 for Critical Thinking and .133 for Creativity. The psychological variables that contributed the most to explaining the Critical Thinking factor were Problem Solving, with a regression coefficient of .810, Practical Reasoning, with a coefficient of .778, and Decision Making, with a coefficient of .700. In relation to the Creativity factor, the most important variables were Fluency, with a regression coefficient of .922, and Originality, with a coefficient of .569. The regression coefficients for each of the observed variables showed that the two strongest predictors were Fluency, which explained 84.9% of its variance, Problem Solving, which explained 65.6%, and Practical Reasoning, which explained 60.6% of its variance.

6. Discussion

The abilities of thinking creatively and critically are considered to be the main cognitive competencies for our century (OECD, 2009). Additionally, most professions entail problem solving situations in which both processes are required (Seymour, Kim & Sutherland, 2003), thus indicating the importance to understand their roles in order to educate students on the use of these abilities to solve problems in different contexts (Baker, Ruddy, & Pomeroy, 2001; Saiz & Rivas, 2010). However, there are still doubts as to whether creativity and critical thinking are independent or complementary processes in distinct phases of creative problem solving (Glassner & Schwarz, 2007; Halpern, 2006; Lipman, 2003; Mumford et al., 2012; Treffinger & Isaksen, 2005. This paper investigated this question using samples of undergraduate psychology students from two different countries (Brazil and Spain).

Creativity was examined by four divergent thinking measures: fluency, flexibility, originality, and elaboration. These creative dimensions were first proposed by Guilford (1960) and later developed by Torrance (1966, 1990) in his creative figural and verbal tests, which have been validated in different parts of the world (Almeida et al., 2008; Kim, 2006; Primi et al., 2013; Wechsler 2004a, 2004b). Additionally, critical thinking abilities were inspected under five dimensions: deductive reasoning, inductive reasoning, practical reasoning, decision making, and problem solving (Halpern, 2006; Saiz & Rivas, 2010, 2011). These factors represent fundamental thinking abilities and, in each, we find the most relevant ways of reasoning and problem solving in our daily lives (Almeida & Franco, 2011; Saiz, Rivas, & Olivares, 2015; Sternberg, 1999).

In this paper, we analyzed whether performance on tests designed to measure creativity and critical thinking was similar or divergent. Hence, two alternative models were tested; while the first proposed a single factor representing cognitive ability in general, the second model defended the existence of two independent factors, differentiating students' performance into creative tests and critical thinking tests. The results indicated that the single factor model presented challenges in regard to model fit, particularly concerning the dimensions related to creativity. Indeed, the model fit was only improved after the errors in the measurements of the creativity dimensions were correlated.

The second model, which was designed to differentiate two latent variables associated with the creativity and critical thinking dimensions, respectively, appeared to be more adjusted to our data. The results show the relative autonomy of these two constructs (creativity and critical thinking) in assessments, which were found to be only moderately correlated. If we consider the original loadings, we can see that critical thinking dimensions are best defined via Problem Solving, Practical Reasoning, and Decision Making, failing to integrate the two reasoning measures, of Deductive and Inductive Reasoning. The data seems to show that critical thinking requires strong thinking and reasoning skills, yet not as much abstract reasoning or formal logic. Moreover, considering the latent variable that emerged in the creativity dimensions, we see higher loadings in regard to Fluency and Originality, and lower loadings for Elaboration and Flexibility.

In conclusion, there seems to be a relative differentiation and independence of creativity and critical thinking in cognitive performance, even if both constructs play small but complementary roles in different phases of creative problem solving. As observed, flexibility, which is the ability to consider the same information from different points of view (Torrance, 1990), can enhance critical thinking skills. Indeed, flexibility skills and critical thinking are considered as key ingredients for promoting problem examination and resolution in many professions (Hong & Choi, 2015). Therefore, critical thinking can be regarded as being associated to a kind of thinking that is less dogmatic and more relativistic, which indicates the need for flexible thinking.

On the other hand, the creative processes appeared to favor inductive reasoning, which is the ability to comprehend relationships. The importance of making connections through analogies and metaphors is an important characteristic of creative thinking (Wechsler, 2006) but intellectual critical functions can also contribute to this process, as observed in this study. With this in mind, creativity favors inductive reasoning, particularly in the identification of regularities and principles or making inferences about relationships, which does not occur in regard to logical reasoning, focused on searching for the best unique answer.

Because creative and critical thinking are essential abilities for problem solving there is the need that educators be concerned on how to develop them in their classrooms. These abilities have been associated to academic performance as well as success in students' personal and social lives (Butler et al., 2012; Phan, 2010; Runco et al., 2010; Wechsler, 2006). However, these processes also require an intensive energy that is not only cognitive but also attitudinal or motivational (Hennessey & Amabile, 2010; Miele & Wigfield, 2014; Saiz & Rivas, 2010) in order to achieve one's goal in the most efficient way. Thus, educators face the challenge to involve students to raise questions and to try to solve problems using creative as well as critical thinking skills, defined as different even complementary forms of thinking. The stimulation of both abilities can prepare students to achieve innovations in their future careers, as they are today recognized by the United Nations Educational, Scientific and Cultural Organization –UNESCO (2016) as important transversal competencies to be developed in secondary and higher education.

The limitations of this study serve to suggest some developments in this area of research. In order to conduct a cross-cultural analysis concerning the association between creativity and critical thinking, it is necessary to use equivalent samples from different countries. Moreover, this line of study would benefit if personality measures were included, considering that both creative and critical thinking involve motivation and attitudinal dispositions. Furthermore, the use of external measures, such as creative products as criteria could complement the limitations of using a divergent thinking measure based on Torrance'creativity tests. In addition, large samples from different regions of Brazil and Spain as well could be assessed, thus enhancing the comprehension of creativity and critical thinking constructs and their importance for problem solving.

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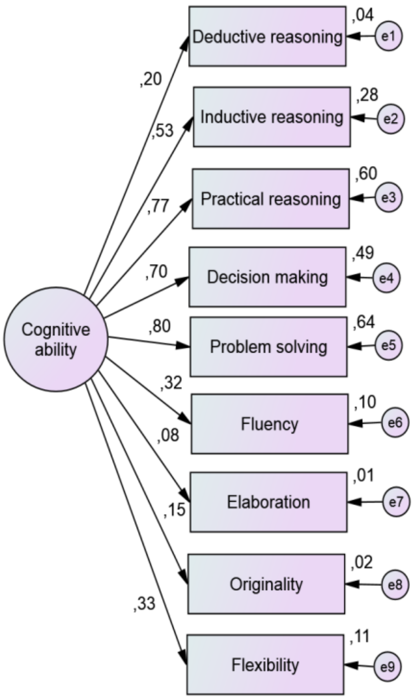
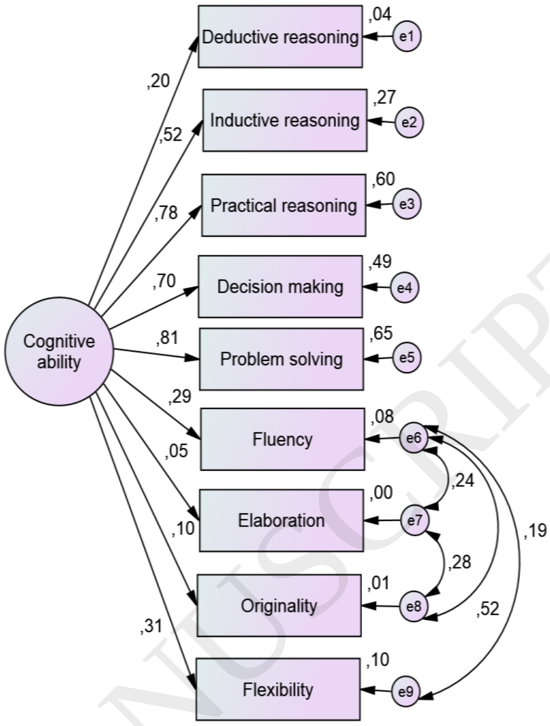


Initial model



Modified model

Figure 1. Path diagram of model M1 with parameters estimated by the Maximum Likelihood method.

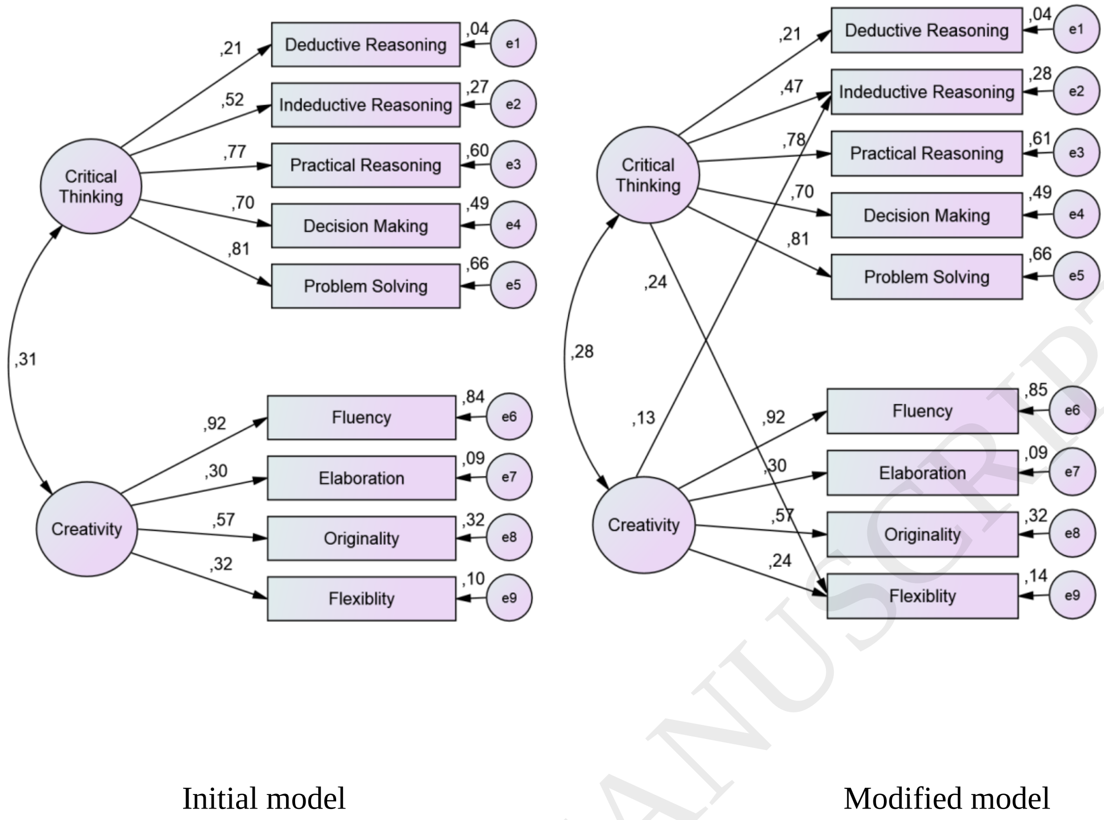


Figure 2. Path diagram of model M2 with parameters estimated by the Maximum Likelihood method.

Table 1

Model fit criteria and comparative indices obtained by the Maximum Likelihood method

Index	Statistics	Model_1 Initial	Model_1 Modified	Model_2 Initial	Model_2 Modified	Acceptable level
Absolute	χ^2/df	6.204	1.476	1.614	1.267	< 1 → Very good 1-2 → Good 2-5 → Acceptable > 5 → Inacceptable
Relative	NFI	.714	.942	.908	.933	1 → Perfect > .90 → Very good .80-.90→Acceptable < .80 → Inacceptable
	CFI	.744	.980	.962	.985	> .95 →Very good .90-.95 Acceptable <.90 →Inacceptable
	RFI	.619	.909	.872	.900	≅ 1→Good < .90 →Inacceptable
	TLI	.659	.969	.947	.977	≅ 1 → Very good The smallest is the best
Parsimony	PNFI	.536	.602	.656	.622	> .80 →Very good .60-.80 →Acceptable < .60 →Inacceptable
	PCFI	.558	.626	.695	.656	
Population Discrepancy	NCP	140.512	10.058	31.934	12.834	The smallest is the best
	F0	.485	.038	.078	.031	The smallest is the best
	RMSEA	.134	.041	.039	.026	< .05 → Very good .05-.08 → Good > .08 →Inacceptable

Note: χ^2df, chi-square/degrees of freedom; RMR, root-mean square residual; GFI, goodness of fit index; NFI, normed fit index; CFI, comparative fit index; RFI, relative fit index; TLI, Tucker-Lewis index; PCFI, parsimonious comparative fit index (PCFI); PGFI, parsimonious goodness of fit index; PNFI, parsimonious normed fit index; NCP, non-centrality parameter; F_0 = NCP/n; RMSEA, root-mean square error of approximation (RMSEA).