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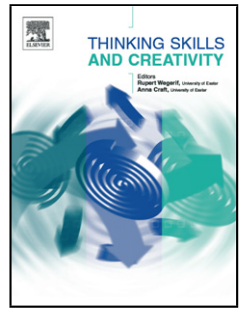

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The contribution of Executive Functions to Creativity in Children: What is the role of Crystallized and Fluid Intelligence?

Running head: Creativity, Executive Functions and Intelligence

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Highlights

- We provide data about the relationships among intelligence, executive functions and creativity.
- First study in proposing a SEM model in order to explain the components that predict creative in Spanish-speaking children.
- Only cognitive flexibility predicts creativity in children and, in the presence of this executive function, intelligence would not have direct effects on creative potential.
- This study has implications for the understanding of the higher-order cognitive mechanisms that explain individual differences in creativity.

Abstract

Recent studies have revealed that intelligence and executive functions (EFs) play an important role in creative thinking. However, most research has focused on adult populations, without providing enough clarity as regards the way this complex relationship is manifested in children. The present study broadens and deepens the scope of previous research concerning children, analyzing the relationship between creativity, intelligence and EF, and examining the bond between the three constructs through an Structural Equation Modeling (SEM) approach. A total of 209 8- to 13-year-olds of both sexes (boys n = 86, girls n = 123) were administered measures of creativity, crystallized and fluid intelligence and EFs (i.e., working memory, inhibition and shifting). Correlational analyses revealed associations between all cognitive variables under study. After controlling for the child's level of intelligence, only shifting and inhibition continued to make a significant contribution to creativity. Moreover, SEM results indicated that the effect of Gc on creativity was mediated by shifting. These findings suggest that EFs differently support creativity in children and that shifting is a more powerful predictor of creativity than fluid and crystallized intelligence.

Key words: Creativity; Executive Functions; Intellectual Abilities; Childhood; SEM

1. Introduction

The study of creativity in relation to intellectual skills and Executive Functions (EFs) has received a great deal of attention in recent years. Empirical evidence shows that fluid intelligence (Silvia, 2008a; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002), crystallized intelligence (see e.g., Cho, Nijenhuis, Vianen, Kim, & Lee, 2010; Sligh, Conners, & Roskos-Ewoldsen, 2005), and EFs (see e.g., Gilhooly, Fioratou, Anthony, & Wynn, 2007; Nusbaum & Silvia, 2011) play an important role in creativity. This fact has led to the emergence of new lines of research to examine how these higher-order cognitive skills can contribute to creative thinking. However, research has generally focused on adult samples, without providing clarity about how this complex relationship is expressed in children.

1.1. Intelligence and Creativity

Intelligence has been conceptualized from diverse theoretical perspectives, being the two-factorial theory of Cattell and Horn (Cattell, 1971, Horn & Noll, 1997) the most widely accepted within the scientific community (Ramírez-Benítez, Torres-Diaz, & Amor- Diaz, 2016). From this paradigm, intellectual performance is explained by two types of intelligences: fluid intelligence (Gf) and crystallized intelligence (Gc). Gf is defined by the intentional use of various mental operations to solve new problems. It includes concepts and inferences development, classification, hypotheses generation, identification of relationships, understanding of implications, and transformation of information (McGrew, 2009). Therefore it enhances the ability to manage inference and identify complex ideational strategies (Gilhooly et al., 2007). In contrast, Gc refers to the richness, amplitude and depth of the knowledge acquired (Cattell, 1971). According to Ackerman (1996), Gf and Gc are two general abilities (intelligence as process vs. intelligence as knowledge) involved in cognitive functioning.

Intelligence and creativity are largely responsible for individuals' behaviors and achievements (Cho et al., 2010). The study of these two constructs has been matter of debate from its beginning to the present day (for further review see Batey & Furnham, 2006; Batey, Chamorro-Premuzic, & Furnham, 2009; Furnham, Batey, Anand, & Manfield, 2008). Guilford's works (1967, 1970) have had a relevant impact on the study of the relationship between intelligence and creativity. Basically, the author's model of intellect structure integrates these two constructs, as it proposed that intelligence can be understood in terms of a three-dimensional box that represents the intersection of three faces: (a) mental operations, (b) mental contents and (c) mental products. Within mental operations, Guilford (1967) placed convergent thinking (processes that lead to correct answers) and divergent thinking (processes that broaden thinking and lead to several responses). Since then, convergent processes are seen as prototypical markers of intelligence, and divergent processes are regarded as markers of creativity (Silvia, 2015).

Research yielded by Guilford's work resulted in different perspectives for the study of how creativity and intelligence are related, i.e.: (1) creativity is a subset of intelligence, (2) intelligence is a subset of creativity, (3) creativity and intelligence are seen as two constructs that overlap, (4) intelligence and creativity are the same thing, and (5) both constructs work independently of one another (Sternberg & O 'Hara, 1999). Although there is evidence to support each of these perspectives (Kaufman & Plucker, 2011), in general, empirical evidence has reported poor correlations between creativity and intelligence (Batey & Furnham, 2006; Kaufman, 2009; Kaufman & Plucker, 2011; Kim, 2008; Kim, Cramond, & Van Tassel-Baska, 2010).

Research examining the role of fluid intelligence on creativity has found that it predicts fluency (Batey, Furnham, & Safiullina, 2010), originality (Benedek, Franz, Heene, & Neubauer, 2012), creative responses (Nusbaum & Silvia, 2011; Silvia, 2008b; Silvia & Beaty, 2012) and the learning and use of a complex strategy in a divergent thinking task (Silvia, 2015). However, less is known about how Gc is related to creativity; it would seem that in adolescents, Gc would be more related to some specific creativity indicators, such as Abstractness of titles, Elaboration and Resistance to premature closure of the TTCT Figural (Cho et al., 2010). Another study also showed positive correlations between creativity and intelligence as assessed by the Verbal TTCT and K-BIT respectively, being of .20 with Gf and of .30 with Gc (Krumm, Arán Filippetti, & Bustos, 2014). In addition, the study reported correlations of .37 with Gf as measured by the Raven and creativity evaluated through TTCT Figural in children aged 8 to 14 years (Krumm et al., 2014). However, it has also been found that Gc, as a latent variable, does not predict the creative quality of metaphors (Beaty & Silvia, 2013).

1.2. Intelligence and Executive Functions

EFs are considered higher-order cognitive processes that enable the control of cognitive, behavioral and emotional activity. It is a multidimensional construct that comprises the subprocesses of inhibition, working memory (WM), and shifting (Miyake et al., 2000) or cognitive flexibility (Diamond, 2016). These processes become crucial for the child's autonomy in its daily performance (Rosenberg, 2014), and promote social-emotional competences (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006) and academic performance at school age (Arán Filippetti & Richaud, 2015; Arán Filippetti & Richaud, 2017; Thorell, Veleiro, Siu, & Hiwa Mohammadi, 2013).

Intelligence is among those cognitive processes associated with EFs. Studies in this line have shown that the different types of intelligence (Gc and Gf) are selectively related to executive skills. For instance, in an adult sample, a study revealed that Gf became a positive predictor of planning (Zook, Davalos, DeLosh, & Davis, 2004). Also, in young adults, it has been found positive correlations between Gf and shifting as assessed through the Wisconsin Card Sorting Test (WCST), the Category Test and the Trail Making Test (Decker, Hill, & Dean, 2007). Other studies have found high positive correlations between working memory and intelligence (Ackerman, Beier, & Boyle, 2005, Colom, Abad, Quiroga, Shih, & Flores-Mendoza, 2008, Shelton, Elliot, Hill, Calania, & Gouvier, 2009). For instance, in a recent study, Benedek, Jauk, Sommer, Arendasy, and Neubauer (2014) analyzed the contribution of inhibition, shifting and updating to Gf, finding that updating was the only EF that predicts it. Friedman et al. (2006) also found that only working memory predicted Gf and Gc by examining the three-EF factor model. Finally, a study conducted with adolescents revealed that both Gf and Gc are related to EFs being working memory the component that showed the strongest association with intellectual skills (Arán Filippetti, Krumm, & Raimondi, 2015). Regarding the relationship between intelligence and EFs in children, findings are less clear. It has been found that EFs, as a unitary construct, predicts Gf and Gc in children aged 7 to 9 years (Brydges, Reid, Fox, & Anderson, 2012). Also, Duan, Wei, Wang and Shi (2010) found that working memory and to a lesser extent inhibition were predictors of Gf in children aged 11 and 12 years. However, Welsh, Pennington and Groisser (1991) found no relationship between EFs and intelligence in children aged 6 to 12 years. Other studies have also demonstrated limited (Ardila, Pineda, & Rosselli, 2000) or low correlations between Gf, Gc and EFs (i.e., working memory, inhibition, cognitive flexibility) (Arán Filippetti et al., 2015).

1.3. Creativity and Executive Functions

Creativity defined as the highest expression of new ideas, flexibility, perspectives and the ability to combine unrelated concepts in different ways and to avoid common paths (Benedek et al., 2014; Benedek, Könen et al., 2012; Chi, 1997) suggests that creative thinking clearly requires EFs. These skills are associated with the prefrontal cortex (PFC) activity (Benedek, Könen et al., 2012; Dietrich, 2004) and reciprocal connections with other cortical areas and subcortical structures (Fuster, 1997; Heyder, Suchan, & Daum, 2004). Consistently, latest advances in neuroscience have shown that the frontal lobe, as well as posterior regions of the brain (Heilman, Nadeau, & Beversdorf, 2003) and subcortical structures (Dietrich, 2004) are involved in the creative process.

Some studies that have analyzed the relationship between creativity and the different EFs components in adult populations have shown that there is an association between both constructs. For instance, as regards cognitive flexibility, it has been found that creative people fluently generate ideas and associations (Benedek, Könen et al., 2012) and that phonological verbal fluency predicts "new" uses tasks but not in family-related ones (Gilhooly et al., 2007).

Literature also provides evidence that inhibition positively correlates with divergent thinking (Golden, 1975), specifically with fluency, flexibility and other indicators of creativity based on self-reports, behavior and creative achievement (Benedek, Franz et al., 2012; Zabelina, Robinson, Council, & Bresin, 2012). However, other studies have found no relationship between the constructs (Burch, Hemsley, Pavelis, & Corr, 2006; Green & Williams, 1999). For example, it seems that creative people are characterized by a lack of cognitive and behavioral inhibition (Martindale, 1999) and a reduction in latent inhibition (Carson, Peterson, & Higgins, 2003). In addition, as already mentioned, creative people are more fluent, and this ability has been associated with impulsiveness (Burch et al., 2006; Schuldenberg, 2000). Other studies appear to indicate that creative people can focus or remove attention from the task according to its demands; i.e., they provide slow responses in tasks that require the inhibition of interfering information, but they answer faster in tasks without interference (Dorfman, Martindale, Gassimova, & Vartanian 2008; Kwiatkowski, Vartanian, & Martindale, 1999; Vartanian, Martindale, & Kwiatkowski, 2007). In conclusion, although there is evidence that offers support for the relationship between creativity and cognitive inhibition, this manifestation proves to be quite conflicting (Benedek, Franz et al., 2012).

Regarding the relationship between working memory and creativity, empirical evidence is scarcer. According to Lee and Therriault (2013), working memory plays an important role in creativity; people with high working memory ability are more likely to succeed in overcoming the interference caused by automatic and non-original responses, and in using strategies to generate new approaches and responses in creative thinking tasks. In addition, it seems that working memory influences creative tasks that require cognitive flexibility (Dietrich, 2004; Rastogi & Sharma, 2010), as it has been found positive correlations between working memory and creativity valued specifically from the perspective of divergent thinking (De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012; Oberauer, Süß, Wilhelm, & Wittmann, 2008; Süß et al., 2002).

1.4. Creativity, Intelligence and Executive Functions

Recent studies have begun to shed light about how both intelligence and FE contribute to creativity. In general, the hypothesis underlying these works is that certain executive processes mediate the relationship between intellectual abilities and divergent thinking. Among these studies, is the one conducted by Nusbaum and Silvia (2011) who found that the effect of Gf on creativity is mediated by switching ability. Lee and Therriault (2013) also found that intelligence indirectly predicts creativity through associative fluency (or shifting). However, other studies conducted in adult populations that analyzed the contribution of the three executive components -i.e., updating, shifting, and inhibition- and Gf to creativity found that updating was the executive component that represents the mechanism underlying the relationship between intelligence and creativity (Benedek, Jauk, Sommer et al., 2014). Hence, there is no conclusive evidence regarding the way intellectual abilities and EFs influence creativity when being considered together. It could be, that inconsistency of results may be due to the statistical techniques performed or the tasks used to test each construct (e.g., whether only one intellectual or EF skill is under assessment).

2. The present study

While there is evidence that indicates that intelligence and creativity are related both in children and adults and that in adults certain executive skills mediate this relationship, to our knowledge, there are no studies carried out with children including the three mentioned constructs. The study of these constructs in childhood becomes important, as their relationships and configurations could be different from those proposed in adults. Considering that both creativity and higher-order cognitive functions are in development (Krumm, Arán Filippetti, Lemos, Aranguren & Vargas Rubilar, 2013, Taylor, Barker, Heavey, & McHale, 2013), their approach in school education could have important implications for the school curriculum. For this reason, the main objectives of this work were (a) to study the relationship between intelligence, EFs and creativity in chidren, (b) to examine what intellectual ability (Gc or Gf) and what specific executive component predicts creativity and (c) to test a latent model that includes the relationships between the predictor variables and the criterion one (i.e., creativity). Given the previous theoretical and empirical evidence, we postulated the following hypotheses: (1) There is a selective association between EFs and creativity in children, being shifting the main predictor and (2) the relationship between intelligence and creativity may be attributed to individual differences in EFs. To this end, different measures will be used to assess intellectual abilities, executive skills and creativity and the relationship between these constructs will be analyzed within a latent variable framework.

3. Method

3.1. *Participants*

The sample consisted of 209 Spanish-speaking school children aged 8 to 13 years from Argentina. Participants met the following inclusion criteria: (a) children with no known history of clinical, neurological or psychiatric treatment; (b) who attend school regularly; (c) without grade repetition. Table 1 shows the sociodemographic characteristics of the total sample.

3.2. *Procedure*

An interview was requested to school principals in order to fully detail the procedures and nature of the research. Next, the parents or legal guardians were sent a note explaining the nature of the work and the way assessment would be conducted. It was also explained that children's participation in the work was voluntary and anonymous. The assessment was carried out collectively and individually, according to the nature of the tests and it included several meetings with the children. The instructions of each test that assess creativity were followed, specifying the importance of providing original, different and creative responses. Parents or legal guardians provided their written consent before starting with the assessment. This research was ethically endorsed by Universidad Adventista del Plata (Administrative resolution 06.06/2015) and the Interdisciplinary Center of Experimental Psychology research unit of the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina.

3.3. *Measures*

3.3.1. *Creativity tests*

3.3.1.1. *The Figural Torrance Tests of Creative Thinking (TTCT), Form A (Torrance, Ball, & Safter, 1992)*

This test consists of three 10-minute activities. Each task includes a particular phrase to elicit the construction of drawings or the completion of figures. The first activity stimulates the creation of a drawing or scene based on a particular form. The second activity consists of creating interesting and original drawings, using 10 incomplete figures. Finally, the third activity consists of three pages with parallel lines that must be used in the drawings. Together, the activities assess Fluency, Originality, Elaboration, Abstractness of title, and Resistance to premature closure (Torrance et al., 1992). The test scoring is either skill-based or comprehensively based on dimensions and creative strength, which is what we used in this study. A study of Argentine children and adolescents showed that the TTCT test has an internal consistency of .70 (Krumm & Lemos, 2011). With respect to construct validity, confirmatory factor analysis identified two correlated factors, Innovation and Adaptation. Innovation is composed of the Fluency and Originality skills, and Adaptation is composed of Elaboration, Resistance to premature closure and Abstractness of title (Krumm, Filippetti, Lemos, Koval, & Balabanian, 2016).

3.3.1.2. CREA. Creative Intelligence (Corbalán Berná et al., 2003)

The test is based on three stimulus sheets (A, B, and C, according to the age of the subjects) from which participants have to formulate as many questions as possible within a time limit (4 minutes). The test is for individual or collective application and can be used from the age of six. The present research used CREA C for children and adults, and followed the recommendations contained in the manual. The application in 8- and 9-year-old children was done individually and collectively with the older ones. The study of reliability between forms A and B from the strict parallel model showed an estimated reliability of .87. In terms of validity, CREA authors report the results of the concurrent validity study between CREA C and the dimensions of the Guilford Battery, which revealed significant correlations (less than .01) of .58 for Fluency, .77 for Flexibility, .68 for Originality and. 57 for Divergent Thinking (Corbalán Berná et al., 2003). Subsequent studies of convergent validity between CREA C and the TTCT figure test, Form A, showed significant correlations less than .01 with the creativity index (Krumm, Arán Filippetti, & Lemos, in press). The direct scores of each sheet of the CREA have been typified for samples of both genders from Spain and Argentina from 6 years onwards (Corbalán Berná et al., 2003).

3.3.2. K-BIT, Kaufman brief intelligence test (Kaufman & Kaufman, 2000).

The test provides a measure of crystallized (Gc) and fluid (Gf) intelligence. It consists of two sub tests: (1) vocabulary (verbal/crystallized/knowledge), which includes part A to test expressive vocabulary and part B to value definitions and (2) matrices (manipulative/fluid/mental processing). The internal consistency analyzed using the two-half method is .98 for the subtest Vocabulary and .97 for the subtest Matrices. The test-retest reliability coefficient is .94 for the subtest vocabulary and .86 for the subtest Matrices (Kaufman & Kaufman, 2000). K-BIT and WISC-R full scale IQ correlations of .80 have been found. K-BIT vocabulary subtest also showed correlations of .78 with the WISC-R, while the subtest of matrices correlated in .50 with the WISC-R (Kaufman & Kaufman, 2000).WISC-III also shows high correlations between verbal IQ, performance IQ and Full scale IQ and K-BIT Composite IQ (from r =.87 to r = .89) (Canivez, 1995). See Canivez, Neitzel, and Martin (2005) for further information.

3.3.3. Working Memory, WISC-IV (Wechsler, 2010)

It enables to obtain a WM composite index. It consists of two main subtests: Digits (D) that provides a measure of immediate oral retention when evaluated with Digit Forward (DF), and maintenance and manipulation of information when using Digit Backwards (DB). In Letters and numbers (LN) the examiner reads a series of numbers and disorganized letters and participants should recall that series, ordering numbers from lowest to highest and letters in alphabetical order. The WISC IV has been standardized in Argentina. The average internal consistency using the two-half method is .85 for LN subtest, .82 for DF and .74 for DB. The test-retest reliability coefficient is .77 for LN, .76 for DF and .68 for DB (Wechsler, 2010).

3.3.4. Stroop Color-Word Test (Golden, 1999).

It provides a measure of interference control and the ability to inhibit an automatic verbal response. It is composed of three sheets. The first sheet requires participants to read aloud and as fast as possible, random colors (red, green, blue) printed in black ink. In the second sheet that includes groups of four XXXX printed randomly in the same colors, participants have to mention the color of the concerned ink. The last sheet includes the names of the colors in sheet 1 but colored in red, green or blue without matching name with color. At this point, the subject has to name the color in which the color name is printed and ignore their verbal content. The direct score achieve in the word-color sheet was used as a measure of inhibition and interference ability. The test-retest reliability is .86 for the word page, .82 for the color page and .73 for the color-word page (Golden, 1975).

3.3.5. Shifting tasks

3.3.5.1. Wisconsin Card Sorting Test (WCST) (Heaton, Chelune, Talley, Kay, & Curtiss, 1997)

It enables to obtain a measure of EF, particularly of cognitive flexibility and categorization ability. Stability coefficients range between .39 and .72 (Heaton et al., 1997).

3.3.5.2. Semantic Verbal Fluency (SVF) (fruits and animals) and Phonologic Verbal Fluency (PVF) (letters F, A, y S).

Participants are elicit to utter all the words they remember and that belong to a particular category (SVF) or that begin with a specific letter (PVF) in the course of 60 seconds. VF tasks have been standardized for Spanish-speaking children (Arán Filippetti & Allegri, 2011) and they are widely used to measure EF in children and adolescents from different countries (Arán-Filippetti, 2013; Friesen, Luo, Luk, & Bialystok, 2015; John & Rajashekhar, 2014).

3.3.5.3. Five-Point Test (FPT) (Regard, Strauss, & Knapp, 1982)

It enables to obtain a measure of non-verbal or visual fluency, which is defined as the subject's ability to produce novelty tasks. The task demands mental flexibility. The activity consists of a sheet of paper with 40 dot matrixes arranged in eight rows and five columns. Matrices are identical to the five-point arrangement in the dice. Subjects are asked to produce as many different figures or designs as possible in three minutes by connecting the dots within each rectangle. They are also informed that only straight lines should be used, that all lines should connect points, that the figures should not be repeated and that only simple lines should be used. The subject can make simple or complex designs using some or all points (Strauss, Sherman, & Spreen, 1998). The test-retest stability coefficient for the number of single designs is .77 (Tucha, Aschenbrenner, Koerts, & Lange, 2012).

3.4. Data Analysis

For each cognitive task used, descriptive statistics (mean and standard deviation) were used. To analyze the association between the constructs, bivariate correlations were made. All analyzes were performed using the SPSS version 22.0 statistical package for Windows. To test different theoretical models analyzing predictors of creativity (intelligence and EF), Structural Equation Modeling (SEM) was performed by means of the program AMOS Graphics 7.0 (Arbuckle, 2006). The goodness of fit level of the models was assessed using the χ^2 statistic, the Incremental Fit Index (IFI), Akaike's Information Criterion (AIC), the Comparative Fit Index (CFI) and the Goodness of Fit Index (GFI). Besides, in order to test the level of error in the models, the Root Mean Square Error of Approximation (RMSEA) was used. To test the multivariate normal distribution, Mardia's coefficient was used (Mardia, 1970).

4. Results

4.1. Descriptive statistics and relationship among Creativity, Executive Functions and Intelligence

The results showed positive and significant correlations between creativity as measured by the TTCT and working memory ($p < .01$), shifting as measure with the FVF, FVF, and FPT ($p < .01$), inhibition ($p < .01$), fluid intelligence ($p < .01$), crystallized intelligence ($p < .01$), and general intelligence ($p < .01$). It was also found a positive and significant correlation at $p < .05$ with shifting as measure with the WCST. As regards the relationship between creativity as measured by the CREA C results showed a positive and significant correlation all at $p < .01$, with working memory, shifting (spontaneous and reactive flexibility), inhibition, fluid and crystallized intelligence and general intelligence (see Table 2).

4.2. Hierarchical regression analysis

To explore the unique percentage of variance explained by each EF skill on creative while controlling for the intelligence effect, hierarchical regression analysis was performed.

The first hierarchical regression model included the following blocks: (1) Gc and Gf, (2) EFs that were associated with TTCT. The total model explained 25% of the variance of the TTCT. Specifically, Gc and Gf accounted for 11% of the variance, while inhibition and shifting (as measure by the FPT) accounted for 14% of the variance above and beyond the variance explained by intelligence (see Table 3). The second model included the following blocks: (1) Gc and Gf, (2) EF skills that were associated with the CREA. The total model explained 42% of the variance of CREA. Specifically, Gc accounted for 14% of the variance, while the EF of inhibition and shifting (as measure by VF and FPT) accounted for 29% of the variance above and beyond the variance explained by Gc (see Table 4).

4.3. Structural equation models

In order to analyze the joint contribution of intelligence and EFs to creativity, two models were tested. In model 1 (Mardia's coefficient = 5.02; critical ratio = 3.23) the contribution of Gc, shifting and inhibition to creativity was analyzed. The SEM results indicate that only shifting was a significant predictor (β = .68). This suggests that, in the presence of this executive component, Gc and inhibition do not predict creativity (β = .11). In model 2 (Mardia's coefficient = 2.55; critical ratio = 1.88), we analyze whether Gc could have indirect effects on creativity through shifting. The results indicate that, although Gc predicts shifting (β = .42) only this EFs has direct effects on creativity (β = .77). Thus shifting mediates the relationship between Gf and creativity. As shown in Table 5 both models presented an excellent fit.

5. Discussion

The main aim of the present study was to examine the relationship between intelligence, EFs and creativity in children, by testing the hypothesis that executive skills mediate the relationship between intelligence and creativity through a Latent variable approach.

When analyzing the relationship between creativity and intelligence, correlations coefficients from *r* =.22 to *r* = .36 were observed, being stronger the relationship between Gc and creativity as measured by the CREA (*r* = .36). This could be due to the fact that CREA aims at making questions pertinent to the image, so it includes in its assessment a verbal fluency component. Thus, given that each question posed in CREA supposes the intention to acknowledge relationships between previous and new knowledge (Elisondo & Donolo, 2018), it was expected that it would be more strongly associated with the K-BIT vocabulary task or Gc. Previous studies have also found associations of .29 with Gf and creativity in adults (Batey et al., 2010), and correlations of .37 between Gf and the TTCT-Figures in children and of .30 between Gc and the TTCT-Verbal in adolescents (Krumm et al., 2014).

Regarding the relationship between EF and creativity, it was found that all executive components under analysis demonstrate a positive correlation with creativity as measured by both the CREA and the TTCT. Results are in line with those of previous studies conducted with adults, where EF such as flexibility, inhibition (De Dreu et al., 2012; Lee & Therriault, 2013) and working memory (Benedek, Franz et al., 2012; Benedek, Jauk, Sommer et al., 2014) related to creativity. Interestingly, the correlation indexes were higher between creativity as measured by the CREA and shifting (SVF, PVF and FPT). This could be due to the fact that CREA assesses creativity through verbal fluency by means of questions. This is not the case of the TTCT Figural, which as well as being a drawing task, its final score considers originality, resistance to premature closure, elaboration and abstractness of titles.

Although a significant association was found among all the analyzed variables, results of hierarchical regressions indicate that only inhibition and shifting predicted creativity when controlling for intelligence. In both regressions, Gc explained a minor percentage of the variance in creativity (for TTCT = 11% and for CREA = 14%) than that of EFs. Our findings suggest that among the EFs under analysis, shifting would be the main predictor of creativity and intellectual abilities would also play an important role, although on a more limited scale. Interestingly, while both types of intelligence (Gc and Gf) predicted TTCT achievement, when including EFs in the analysis only Gc continued to account for significant variance in creativity. These data suggest that EFs would mediate the relationship between Gf and creativity, and emphasizes Gc's prevailing role in creativity for it enables relationships between prior and new knowledge in order to elaborate new ideas. Surprisingly, although working memory was associated with creativity, it was not a significant predictor of any of the tasks used. These findings are different from those reported by Benedek, Jauk, Sommer, et al. (2014), who did find that working memory predicts creativity. However, the authors worked with a sample of a different age range (i.e., adults) than the present study and the creativity task used (i.e., unusual use test) imposes greater demand on working memory, as it requires keeping in mind the task main objective and additional sub-objectives. Thus, it is possible that discrepancies between studies would be partly explained by the characteristics of the tasks used. In this regard, it has been suggested that WM could positively and negatively influence creativity (Wiley & Jarosz, 2012) and that their contribution to creativity would depend on the task to be performed (Fugate, Zentall & Gentry, 2014). Besides, memory can limit the production of ideas becoming a source of interference by biasing the search processes towards the outstanding of conceptual knowledge (Beaty, Christensen, Benedek, Silvia, & Schacter, 2017).

Considering these findings and those of previous studies, the relationship between Gc, inhibition, shifting and creativity was examined by testing two hybrid models. This analysis yielded interesting results. In the first model, shifting was the only significant predictor of creativity suggesting that, in the presence of this EF component, Gc and inhibition would not have direct effects on creativity, being the residual correlation in both cases non-significant (*r* = .11). Although results indicate that inhibition predicts creativity, for it would enable to suppress dominant but irrelevant responses (see e.g., Edl, Benedek, Papousek, Weiss, & Fink, 2014), it was noticed that when including this EF in the SEM model together with shifting ability, it did not become a significant predictor. Apparently, the association between inhibition and creativity would be explained by the variance shared with shifting. Results from model 2 indicate that although Gc predicts shifting, only this EF predicts creativity. Therefore, the effects of Gc on creativity would be explained through shifting ability. These findings suggest that shifting would represent the central executive mechanism that underlies the relationship between intelligence (crystallized) and creativity. These results are similar to those found by Lee and Therriault (2013) when working with a sample of university students, who demonstrated that intelligence directly explains divergent thinking (creativity) through associative fluency (a shifting measure that use VF tasks similar to the ones used in the present study). Several studies have also found a positive relationship between cognitive flexibility (shifting) and creativity (De Dreu, Baas, & Nijstad, 2008; De Dreu et al., 2012, Mehta & Zhu, 2015, Miron-Spektor & Beenen, 2015; Miron-Spektor, Gino, & Argote, 2011). Interestingly, the two measures of creativity use in the present research (i.e., TTCT and CREA) require of fluency for idea production regarding drawings and questions in a given time. In TTCT, fluency is one of the five indicators evaluated through the number of drawings made from a stimulus. In CREA, the number of questions asked is the final score, being coherent and expected to be spontaneous flexibility (shifting) which explains creativity. Consistently, Kim and Zhong (2017) found that subjects are more creative when they perform tasks with flat information structures (without higher order categories) in comparison to those tasks with a hierarchical information structure (organized in terms of higher order categories).

According to the authors, this greater creativity, in a state of flat information structures, would be due to a high level of spontaneous cognitive flexibility (shifting).

Limitations, future directions and implications

While this study contributes to the understanding of those cognitive processes that underlie creativity in children, it is necessary to acknowledge some limitations. First, although different tasks were used in order to assess working memory and shifting, only a single task verbal in nature was used to measure inhibition. Therefore, it would be interesting to use other tasks to evaluate this component in children and examine whether the nature of the task (verbal vs. motor) could partly explain its influence on creativity. Furthermore, it would be important to address creativity from more inclusive approaches that consider the context and situation of the study, as well as the assessment of the products and the creative processes involved. Finally, considering that studies in children are limited, the results should be regarded with caution, so it would be significant to replicate the study in another cultural context. In this sense, Kim and Zhong (2017) found that social and cultural factors could also influence the relationship between the structure of information and creativity, suggesting that people who belong to a more open culture would be more creative than those belonging to a strict culture.

This study has important implications for promoting the development of creativity in the educational field. In this regard, Silvia (2015) mentions that although crystallized knowledge is important for creativity, it has been overlooked how people access, control and manage that knowledge. Therefore, creativity is not only a matter of how much children may know, but their ability to use that knowledge through shifting or other EFs. This will require to perform regular assessments of the constructs studied for the identification of children with selective deficit and strengths, in order to build programs, curricular adaptations and professional trajectories according to their needs and abilities.

In summary, this research provides support for the contribution of intelligence to creativity through shifting (spontaneous cognitive flexibility). This may promote future research in order to discover whether there exist other higher-order cognitive processes that acknowledge individual differences in creativity. In this regard, Kim and Zhong (2017) argue that the relationship between the structure of information and creativity can be moderated by individual differences in cognitive resources. Future studies would benefit from the assessment of cognitive persistence and motivation, so as to study whether shifting continues to explain creativity when considering it together with these variables. The analysis of diverse cognitive processes and the use of advanced statistical methods and tools of cognitive science enable to continue delving into the role of individual differences in children's creativity.

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Figure captions

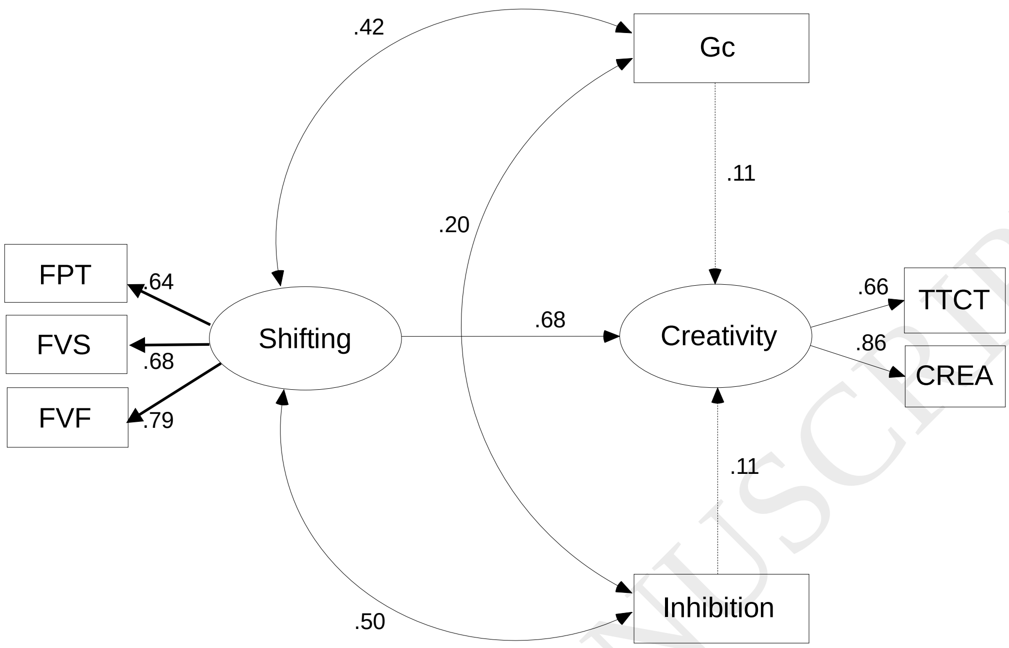

Figure 1. Model 1: Direct effects of Gc, Shifting and Inhibition on Creativity.
Note: Solid lines indicated significant effects and dashed lines indicate non-significant estimates.

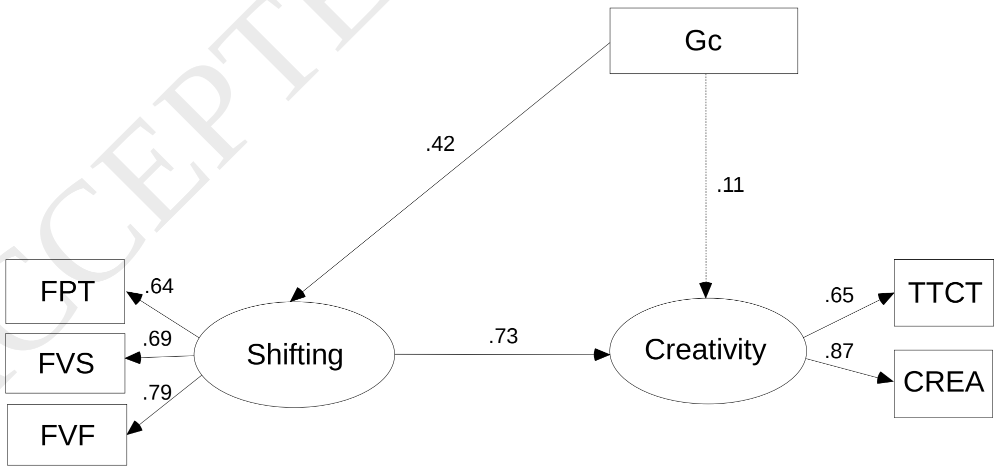

Figure 2. Model 2: Indirect effects of Gc on Creativity with Shifting mediating Gc effects.
Note: Solid lines indicated significant effects and dashed lines indicate non-significant estimates

Table 1. Sociodemographic characteristics of the sample

	Children
N	209
Age (*M* ± *DE*)	9.96 (1.23)
School year	4th grade Primary level –1st. Year- high school level
Gender	123 girls / 86 boys

Table 2. Descriptive statistics and correlations.

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11
1 TTCT	19.38	5.55	-										
2 CREAC	8.03	4.03	.56**	-									
3 WM	30.34	5.16	.32**	.44**	-								
4 SVF	24.88	6.28	.33**	.44**	.40**	-							
5 PVF	19.15	7.99	.36**	.52**	.41**	.57**	-						
6 FPT	21.76	8.77	.37**	.50**	.46**	.42**	.48**	-					
7 Stroop	27.82	7.64	.34**	.40**	.36**	.30**	.40**	.37**	-				
8 CC-WCST	3.47	1.70	.16*	.20**	.31**	.11	.15*	.06	.25**	-			
9 Gf	96.44	11.80	.24**	.22**	.24**	.19**	.26**	.30**	.22**	.35**	-		
10 Gc	93.30	12.78	.30**	.36**	.21**	.31**	.36**	.19**	.20**	.17*	.36**	-	
11 GI	91.77	11.67	.32**	.36**	.27**	.32**	.39**	.30**	.26**	.33**	.81**	.82**	-

Notes: TTCT = Final creativity score in the TTCT Figural, Form A. WM = Working memory index of the WISC IV. SVF = Semantic verbal fluency. PVF = Phonological verbal fluency. FPT = Five Point Test. Stroop = word-color Stroop; CC-WCST = Number of complete categories of the WSCT; Gf = Fluid intelligence; Gc = Crystallized intelligence; GI = General intelligence. *N* = 209.

* $p < .05$, ** $p < .01$.

Table 3. Summary of Hierarchical Regression Predicting TTCT Figural

Dependent	**Predictor**	**R^2**	**ΔR^2**	***β***	***p***
TTCT	**Block 1**				
	Gc	.11	.11	.24	.001
	Gf			.15	.036
	Block 2				
	Gc	.25	.14	.15	.038
	Gf			.04	*ns*
	WM			.07	*ns*
	Stroop			.15	.037
	FV			.14	*ns*
	FPT			.17	.028
	CC-WCST			.03	*ns*

Notes: TTCT = Final creativity score in the TTCT figural test, Form A. Gc = Crystallized intelligence; Gf = Fluid intelligence; WM = Working memory index of the WISC IV. FV = Verbal fluency. FPT = Five Point Test. Stroop = word-color Stroop; CC-WCST = Number of complete categories of the WSCT. *N* = 209.

Table 4. Summary of Hierarchical Regression Predicting CREA C

Dependent	**Predictor**	**R^2**	**ΔR^2**	***β***	***p***
CREA C	**Block 1**				
	Gc	.14	.14	.32	.000
	Gf			.11	*ns*
	Block 2				
	Gc	.42	.29	.17	.005
	Gf			-.06	*ns*
	WM			.12	*ns*
	Stroop			.13	.039
	FV			.25	.000
	FPT			.25	.000
	CC-WCST			.07	*ns*

Notes: CREA = Final creativity score in CREA C; Gc = Crystallized intelligence; Gf = Fluid intelligence; WM = Working memory index of the WISC IV. VF = Verbal fluency. FPT = Five Point Test. Stroop = word-color Stroop; CC-WCST = Number of complete categories of the WSCT. *N* = 209.

Table 5. *Goodness of Fit Index for Models*

Models	χ^2	*gl*	*p*	CFI	NFI	GFI	RMSEA
Model 1	12.01	10	.285	.99	.97	.98	.031
Model 2	9.89	7	.195	.99	.97	.98	.045

Note: CFI and GFI values above 0.90 and RMSEA values below .08 are indicators of a good fit