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The relationship between analytical and creative cognitive skills from middle childhood to adolescence: Testing the threshold theory in the Kingdom of Saudi Arabia☆

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ABSTRACT

Guilford's seminal studies (Guilford, 1967) propose that an average level of intelligence is required to demonstrate a creative skill. However, according to the threshold theory, in individuals with high levels of intelligence (IQ ≥ 120) creativity is no longer related to intelligence. Studies that have explored this phenomenon have shown inconsistent results. Most of the available literature has originated from Western countries and used a correlation approach to find a threshold for the association between different measures of IQ and creativity. The goal of this study was to find a threshold using novel tasks of analytical skills (verbal, scientific and mechanical reasoning) and creativity (fluency, flexibility, originality and elaboration) by conducting segmented regression analysis in a representative sample of Saudi Arabian students. The sample of 4368 3rd to 11th grade students (53.1% girls) was divided into three grade-groups (3rd–5th, 6th–8th, and 9th–11th). A threshold was found only for 6th–8th graders at a level of analytical skills of 108.8, and at 108.4 for 9th–11th graders. The analysis of gender differences showed that the threshold was significantly higher for boys than girls in the group of 9th–11th graders (105.6 for boys, 81.46 for girls). These thresholds were generally lower than those reported in other studies. Contrary to the threshold theory, for both grade-groups the relationship between creativity and analytical skills was positive and significant only above the thresholds. Potential factors accounting for these findings may be the type of analytical skills tasks, more related with crystallized intelligence and the culture-specific educational experiences of Saudi children.

The relationship between intelligence[1] and creativity has been explored for several decades, yet interpretations of research findings have defied consensus. Is one construct dependent upon the other? Are they independent but overlapping, completely disjointed, or perhaps associated in some way that has not yet been revealed (Getzels & Jackson, 1962; Sternberg & O'Hara, 1999)? Further, when students are differentiated by level of IQ, the correlations between intelligence and creativity have been found to vary, with weak and non-significant correlations at high levels of IQ, but positive and linear correlations in the lower to average IQ range (Guilford, 1967; Yamamoto, 1964). Guilford's (1967) proposal that high creativity requires high or at least above-average intelligence led to a specification that at IQ levels above 120 (a so-called "threshold"), creativity is no longer limited by intelligence (Jauk, Benedek, Dunst, & Neubauer, 2013). That is, a moderate level of intelligence is necessary to be creative, so that a person can select and integrate relevant information, or can identify a problem and subsequently generate an original solution or several solutions for that problem (Runco, 1991). The relationship between intelligence and creativity has indeed been found in many studies to be weak above a specific threshold of analytical ability. As long as certain analytical skills are present, it seems, creativity may diverge from intelligence.

Studies that have systematically investigated this theory have produced inconsistent results. There is a group of studies that has established support for the threshold theory. For example Fuchs-Beauchamp, Karnes, and Johnson (1993) found moderate correlations between intelligence and creative potential in preschool children with IQ below 120 ($r = .49$ to $r = .09$ depending of the dimension of creativity) and a lower correlation ($r = .12$ to $r = .05$) in children with IQ above 120. Another study demonstrated the threshold effect using

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[1] In this study, we use the term intelligence interchangeably with such terms as IQ, aptitude, intelligence test scores and performance on other analytically-based assessments.

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measures of verbal and figural creative potential in a sample of adolescents and adults; correlations between intelligence and creative potential of up to $r = .40$ were observed in the average IQ sample, while correlations in the higher IQ (>120) sample were close to zero (Cho, Nijenhuis, Van Vianen, Kim, & Lee, 2010).

In contrast to these supportive results, though, other studies have registered only negligible differences between IQ–creativity correlations in different ability groups. Mednick and Andrews (1967) detected no differences in the correlations between students' scores on the Remote Associated Test (RAT) and the SAT-V and SAT-M when the sample was broken in quintiles of performance (the SAT here is a proxy for IQ). Similarly, Runco and Albert (1986) using a correlation approach and correction for range restriction found no significant correlations between intelligence (using the WISC-R or Stanford-Binet) and divergent thinking within four IQ levels (98–120, 121–130, 131–145, 146–165)—with the exception of a positive relationship between intelligence and verbal fluency ($r = .25$) and verbal flexibility ($r = .27$) within the 131–145 IQ group. When they used scores from the California Achievement Test (CAT) to divide the student sample into subgroups, the correlations between CAT scores and creativity remained insignificant for most groups but were lower than those obtained with the WISC; the largest and the only significant CAT-creativity coefficients were for the subgroups above the 4th quartile in CAT performance.

Finally, a meta-analysis by Kim (2005) ultimately rejected the threshold theory by compiling and analyzing data from 21 quantitative studies of creativity, intelligence and the correlation between them. Estimated mean correlations below and above an IQ of 120 were $r = .20$ and $r = .23$, respectively, clearly contradicting the threshold theory as the correlations across the studies above and below the threshold were both statistically significant and statistically undistinguishable from each other. In the same meta-analysis Kim (2005) examined the variations in the correlations between creativity and intelligence. These variations appeared to be due to 1) the nature of the tests used to measure analytical skills and creativity (e.g., verbal vs. non-verbal); 2) the dimensions of creativity being tested (e.g., fluency, flexibility, originality, and elaboration); and 3) the age and gender in the samples selected for the meta-analysis. Some examples of these variations are provided in the next section.

1. Type of tests used to measure analytical skills and creativity

Regarding the use of different IQ measures, three studies exemplified the variability of results. The first study, conducted by Runco and Albert (1986) showed that the correlations between analytical skills and creativity differed when the CAT and IQ scores from the Stanford Binet or WISC-R were correlated with creativity measured by the Wallach and Kogan (1965) test of creativity. They found that, using the thresholds of 145 for IQ and the 4th quartile for the CAT, IQ correlations with creativity were higher in both groups above the threshold, although the CAT-creativity correlations were lower than the IQ–creativity correlations for each of the different dimensions of creativity (e.g., fluency, flexibility, originality and elaboration) as well as for the verbal and figurative tasks.

Sligh, Conners, and Roks-Ewoldsen (2005) reported correlations between creativity measured by the Finke Creative Invention Task (FCIT: Finke, 1990) and IQ measured with the Kaufman Adolescent and Adult Intelligence Scale (KAIT; Kaufman, 1993) (assessing fluid, crystallized and composite intelligence) as well as the Raven's Advanced Progressive Matrices Set I (Raven & John, 1985). The participants were classified into two groups based on their composite KAIT scores (average and high IQ). The correlations with crystallized IQ, as indicated by KAIT scores, were significant in the average IQ group, but non-significant in the high IQ group ($r = .34$, $p < .05$ and $r = .19$, $p =$ ns respectively). However, the opposite pattern was found when using fluid IQ, as measured by the Raven's matrices: the correlations with creativity measures were non-significant in the average IQ group, but significant in the high IQ group ($r = .12$ and $r = .39$, $ps < .05$, respectively). Different results were obtained by Cho et al. (2010). Korean students were classified as average IQ or high IQ (IQ < 120) based on the WAIS test. They were then administered the Raven's Advanced Progressive Matrices (RPM) as a measure of fluid intelligence. The average IQ group showed significant and positive correlations between the figural and verbal tasks of the TTCT with WAIS ($r = .44$ and $r = .42$ respectively) but no correlations were found with RPM. The high IQ group showed no significant correlations with either the WAIS or RPM.

In the Kim (2005) meta-analysis when the type of creativity test was taken into account as a moderator, IQ–creativity correlations varied, indicating that the type of test and the dimension of creativity being assessed may influence the correlations between analytical skills and creativity, as well as the IQ level of the threshold. Specifically, different correlations between IQ and creativity were found between studies that used the Torrance Tests of Creative Thinking (TTCT; $r = .22$) and those using the Wallach–Kogan divergent thinking measures ($r = .12$). In addition, verbal and figural task correlations with IQ were different depending on whether verbal tests ($r = .16$) or figural (i.e., nonverbal) tests ($r = .23$) of creativity were used.

2. Dimensions of creativity

Kim's meta-analysis (Kim, 2005) also showed that the correlation between IQ and creativity tended to change depending on the dimension of creativity being measured. For example, low IQ–creativity correlations were found for originality ($r = .13$) and fluency ($r = .17$), whereas slightly higher correlations were observed for flexibility ($r = .23$) and figural redefinition ($r = .36$). Significant differences between the dimensions were found using chi-square comparisons. These variations in the correlation coefficients by dimension suggest the possibility of different thresholds for each dimension. In fact, Jauk et al. (2013) did establish different thresholds for different dimensions of creativity. When analytical skills were measured using the Intelligence Structure Battery (Intelligenz-Struktur-Batterie, INSBAT; Arendasy et al., 2005), and creativity with the Inventory of Creative Activities and Achievements (ICAA), the correlation between IQ and ideational fluency changed at IQ = 86.09, with the correlation below the threshold at $r = .56$ and above, $r = .09$. For originality, the threshold was detected at an IQ of 119.60; the correlation below was $r = .38$ and above $r = .14$.

3. Thresholds as a function of gender and age

In two meta-analyses, Kim (2005, 2008) did not find statistically significant differences between males and females for the correlation between IQ and creativity. However, differences in IQ–creativity correlations for different age groups were found (Kim, 2005). These correlations were lowest for students in elementary school ($r = .09$), but higher and of similar magnitude among students in middle school ($r = .21$), high school ($r = .26$), and for adults ($r = .21$). All of the correlations between and within the groups were significantly different (Kim, 2005).

However, studies that explore specifically the variation of the threshold by gender are non-existent to our knowledge. An early study of Yamamoto (1964) found no support for a threshold in elementary school students, but found a threshold in secondary school students (IQ < 120). In this study, the threshold was explored through an analysis of variance between three groups of IQ performance (below 120, between 120 and 135, above 135).

4. Methods used to explore the threshold theory

Early studies exploring the threshold theory segmented their samples into groups by IQ performance, then creativity scores between groups were compared using analyses of variance. The assumption was that creativity scores of the high IQ group would be greater than the creativity scores of the low IQ group, but the same as the middle IQ groups. Thus, if the groups of high and average IQ were similar in their creative performance, but were both different from the low IQ group, the threshold theory was accepted (Dacey & Madaus, 1971; Guilford & Christensen, 1973; Yamamoto, 1964). Other studies following the same idea used visual exploration of scatterplots of creativity scores (on the y-axis) and scores for intelligences (on the x-axis). If the scatterplot was similar to a right triangle in which the hypotenuse was oriented to the left, then one could infer a higher variability in creativity scores as IQ scores increase (Getzels & Jackson, 1962). Also, regression analyses with polynomial terms have been conducted to assess the presence of a curvilinear relationship. Regarding this analysis, linear relationships indicate the absence of a threshold. A threshold may be confirmed when the slope indicates a non-linear (U-shaped or J-shaped) relationship between IQ and creativity (Ginsburg & Whittemore, 1968). Later studies looked at IQ–creativity correlations across different groups of IQ-proficiency (e.g. quartiles, quintiles). In these studies, the presence of a threshold is proved if the IQ–creativity correlation above the threshold is non-significant and positive and significantly higher below the threshold (Child & Croucher, 1977). More recently Karwowski and Gralewski (2013) described three categories that have been used to assess the threshold theory based on the correlations between creativity and intelligence. First, when a sample is stratified by IQ, the IQ–creativity correlation should be statistically significant (i.e., different from zero) below, but not statistically significant above the IQ threshold. Second, the correlations above and below the threshold should differ statistically significantly from each other and the correlation below the threshold should be different from zero. This category was classified as the most conservative. Third, the correlation below the threshold should be statistically different from zero and higher than the correlation above the threshold.

Employing a different approach but referencing Karwowski and Gralewski's criteria, Jauk et al. (2013) examined the relationship between creativity and intelligence using segmented regressions, also called piecewise regression. This is a technique that allows the inclusion or detection of breakpoints in a linear regression to improve the variance explained by the model, but also to detect the point in which the association between the variables changes significantly. In these models, the independent variable is partitioned into intervals and separate linear models are computed for each segment. The breakpoint represents the point at which the relationship between the variables changes (Muggeo, 2003). In the framework of the threshold hypothesis, the breakpoints are located at points where the relationship between creativity and intelligence changes; a positive and significant linear relationship is expected below the breakpoint and an insignificant relationship between the variables above the breakpoint. This method was used in the present study to identify thresholds.

5. Cultural correlates of analytical and creative skills

In sum, the literature shows contradictory results regarding the threshold theory. As outlined above, important factors in the variation of the IQ–creativity correlations across different levels of analytical ability appear to be the type of task used to assess these areas of skill, whether it focuses upon verbal or non-verbal domains, and what dimensions of creativity are examined. Other influential factors that have received less attention in the threshold theory literature are the educational practices and socialization experiences (i.e., environmental influences) that shape the development of analytical and creative skills (Bornstein, 2012; Bronfenbrenner & Morris, 2006; Sternberg & Grigorenko, 2001). In particular, formal education in school settings (e.g., instructional practices and curricular differentiation) is an important source of variation in the development of children's cognitive skills (Christian, Bachnan, & Morrison, 2001; Eccles & Roesner, 2012; Nisbett, 2009). How analytical and creative skills are nurtured in the environment depends, among other things, on the cultural milieu in which children grow up (Jensen, 2012; Rogoff, 2007). Although the literature has attested to strong links between education and cognitive skills, and between education and culture, fewer studies have examined the relationship between creativity and analytical skills in contexts that are different from Anglo-American and European educational and cultural contexts. Specifically, in the school context in the Kingdom of Saudi Arabia (KSA), the gender segregated school system and the cultural rules of interaction and expectation might foster different academic and non-academic skills in boys and girls (Hein, Tan, Aljughaiman, & Grigorenko, 2014; Hein, Tan, Aljughaiman & Grigorenko, 2015a).

In the present study, we have an opportunity to focus on a middle-eastern culture, the KSA, in which educational experiences are somewhat distinct from Western modes of schooling in at least two important ways. First, the KSA's educational system is completely segregated by gender (both students and teachers); the higher education sector remains almost completely segregated by gender (Marsh et al., 2014). Second, the teaching methodologies employed have been described as more centered on memorization, factual knowledge and the reproduction skills required in formal studies of the Quran (The World Bank, 2008; UNESCO, 2011).

Over the past decade, increasing attention has been paid to both general education and gifted education in KSA (Aljughaiman & Ayoub, 2012; Muammar, 2011; Subhi-Yamin, 2009) More specifically, Saudi Arabia has started to promote gifted education with an emphasis on nurturing students' thinking skills and creativity, shifting from a predominantly frontal style of teaching to one that promotes more active and exploratory learning and creative thinking (Subhi-Yamin, 2009; The World Bank, 2008; United Nations Development Programme & Regional Bureau for Arab States, 2005). As part of this shift, the King Abdulaziz and His Companions Foundation for Giftedness and Creativity (Mawhiba) was established in 1999 to nurture giftedness and creativity in the KSA. The vision of the organization is to foster a creative society of gifted and talented young leaders who are innovative, highly educated and well-trained to support the sustained growth and prosperity of the Kingdom (Subhi-Yamin, 2009). The National Center for Assessment in Higher Education (Qiyas) has worked closely with Mawhiba to realize this mission, supporting the development of adequate assessment and procedures to identify gifted children and foster their skills (Aljughaiman & Grigorenko, 2013).

Giftedness in this context has been understood as a multidimensional construct (Brody, 2003; Mandelman, Tan, Aljughaiman, & Grigorenko, 2010; Renzulli, 2005; Sternberg, Castejón, Prieto, Hautamäki, & Grigorenko, 2001) that is not solely represented by high academic achievement. The conceptual distinctions proposed by the Theory of Successful Intelligence (Sternberg, 1999) highlight the importance of the integration and evaluation of different domains and skills. Individuals may manifest a mixture of creative, analytical, and practical skills to different degrees. Following this approach, the Qiyas Center, in collaboration with the Mawhiba project, has developed an assessment that addresses creative, analytical, and practical skills using several tasks to obtain a more complete picture of children and their skills (Mawhiba, 2015). Thresholds in the association between creativity and analytical skills might indicate for which groups the evaluation of creativity skills—when uncorrelated with IQ—represents new information.

6. The present study

The present study has two aims. First, we examined the mean differences between analytical and creative skills across three grade-groups (spanning grades 3 to 11) and between boys and girls. The second aim was to explore whether the relationship between creativity and analytical skills varies across groups that exhibit different levels of analytical skills. Consistent with the threshold theory described above, we expected the correlation coefficients for students below each of the thresholds to be significantly different from zero. Moreover, we expected that the correlations for students above the threshold would be either close to zero or at least significantly smaller than the coefficient for the students below the threshold.

7. Method

7.1. Participants

The analytical and creative skills of a randomly selected sample of 4368 (53.1% females) 3rd- to 11th-grade students (age range 7 to 19 years, $M_{\text{Age}} = 13.46$ years, $SD_{\text{Age}} = 2.67$ years) from 17 regions in KSA were assessed in 2011 as part of a larger project aimed at identifying gifted students. The cohort was divided into three groups according to grade level, and a specific, age-appropriate version of the Multiple Cognitive Abilities Assessment (MCAA) was administered to each group. Grade-Group 1 comprised 1258 3rd- to 5th-grade students (51.8% females, $M_{\text{Age}} = 12.54$ years, $SD_{\text{Age}} = 2.57$ years). Grade-Group 2 comprised 1482 6th- to 8th-grade students (54.8% females, $M_{\text{Age}} = 13.41$ years, $SD_{\text{Age}} = 2.56$ years). Grade-Group 3 comprised 1628 9th- to 11th grade students (52.8% females, $M_{\text{Age}} = 14.48$ years, $SD_{\text{Age}} = 2.54$ years).

7.2. Measures

The measures presented here were developed and administered by Mawhiba as tools for identifying gifted children in the KSA.

7.2.1. Analytical skills

Analytical skills were assessed using the Multiple Cognitive Abilities Assessment (MCAA). The MCAA has four subtests to assess four analytic skills: (1) Mental Flexibility (MF); (2) Verbal Reasoning and Reading Comprehension (VR); (3) Scientific and Mechanical Reasoning (MR); and (4) Mathematical and Spatial Reasoning (MSR). The MF subtest measures flexible mapping and inferencing (average Cronbach's α across grades was = .79). VR encompasses associative reasoning, syllogisms, and complex analogies (average Cronbach's α across grades was .80); and the MR subtest assesses scientific reasoning and mechanical reasoning (average Cronbach's α across grades was .70). Note: For the MR subtest, two anchor items (see below) across versions A and B were removed, and one anchor item across versions B and C was removed. The MSR subtest was not included in the analysis due to low internal consistency (average Cronbach's α across grades was .58).

Three parallel age-appropriate versions of the MCAA were developed to assess these skills within each Grade-Group. Each subtest of Grade-Group 1's test (version A) had 12 to 13 items; each subtest of Grade-Groups 2's test (version B) comprised 16 to 20 items; and each subtest of Grade-Group 3's test (version C) contained 16 to 25 items. Each subtest of versions A and B shared five identical anchor items across these versions (A–B items); similarly, versions B and C shared five identical anchor items across these versions (B–C items), except for the MR subscale, which shared only 3 items. Due to the large grade range, there were no common items between versions A and C. Items were scored as 1 for a correct response and 0 for an incorrect response.

7.2.2. Creative skills

Creative skills are those that allow children to adapt successfully to novel situations, to solve new situations in an original way and to generate ideas of high quality (Sternberg, Lubart, Kaufman, & Pretz, 2005). Thus, the creativity test used in this study was composed of five scales, each intended to measure one of the traditional dimensions with which creativity has traditionally been assessed (i.e., fluency, flexibility, originality and elaboration; see Plucker & Renzulli, 1999), and an additional subscale of Sensitivity to Problems was included. In total, the test included 20 open-ended items. Trained raters used a previously developed rubric (partial credit scoring) to score students' responses. No overlap between raters was planned.

For this study, the fluency, flexibility, originality and elaboration scales were considered for the analysis, while the sensitivity to problems subscale was not included due to the low reliability obtained by the 3 items of the scale (Cronbach's $\alpha = .61$). The Fluency scale comprised five items that were scored according to the number of unique responses provided by the students (Cronbach's $\alpha = .76$). For this subtest, students had to write down the highest possible number of words that they associated with different words, as well as write down as many possible unusual or unfamiliar (novel) uses of various objects.

The Flexibility scale had four items that were scored according to the number of different responses the student provided (Cronbach's $\alpha = .75$). Students were asked to generate up to four titles for a story based on two pictures (e.g., a palm tree and the desert), to write up to four things that different logos might symbolize besides their original meaning (e.g., a peace sign), and to use incomplete geometrical forms to draw things that have a meaning using as much creative imagination as possible.

The Originality scale had five items; students' responses were rated on a scale ranging from 0 (*incorrect response*) to 4 (*full mark*) (Cronbach's $\alpha = .69$). One set of items in this subtest required students to generate three implications for each given scenario (e.g., "What would happen if people traded rice grains instead of cash?"). Other items required the students to write a title for a picture showing three objects (e.g., gold bars, a safe, and a desktop computer), and then explain this title in three sentences.

The Elaboration scale comprised three items; responses were rated on a scale ranging from 0 (*incorrect response*) to 3 (*full mark*) (Cronbach's $\alpha = .66$). In this task, students read the title of a story (e.g., book a trip) and then had to imagine and write that story in five lines mentioning all of the possible details reflected in the title of each story. Other items required the students to read a short story and then change one sentence of the story to alter the meaning, outcome or flow of the story.

7.3. Procedure

The data reported in this study was part of a norm study in the KSA. The schools were randomly selected from 17 regions and 3rd to 11th graders were assessed using both the MCAA and creativity test. The objective of the MCAA assessment was to identify students who may be academically gifted. Creativity scores were used to decide whether children close to the MCAA cut-off (i.e., 5% or 1% superior) should be included in the gifted group.

7.4. Data analyses

To examine multiple sources of variance simultaneously and examine both the consistency and generalizability (i.e., representativeness of a specific sample of behavior) of the creativity measure, G (i.e., generalizability) and D (i.e., dependability) studies were conducted (Briesch, Swaminathan, Welsh, & Chafouleas, 2014; Cronbach, Rajaratnam, & Gleser, 1963). Reliability for the creativity subscales and the MCAA subscales were obtained and items with low item-test correlations were deleted. The scores for the creativity subscales were transformed to logit scores and then regressed on age. Next, the MCAA scores on the three different versions of the MCAA were vertically equated (Baker, 1984; Dorans, 2004) using the anchor items to obtain a common scale for cross-grade comparisons. Equating is the process of transforming scores from one scale to a different scale while maintaining the comparability of scores to a degree such that they can be treated as interchangeable (Huggins, 2014). In this study, the equating process was conducted using the ability parameters (i.e., logit scores) obtained for the anchor items (i.e., identical items shared between the parallel forms of the test, A–B items and B–C items) to estimate the scores of the remaining non-anchor items. The same process was conducted to obtain the ability scores across the subscales. First, the ability scores of

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version B in one of the subscales were obtained, and the values of the anchor items were used to obtain the ability scores for non-anchored items in the version A. Then, the B–C items were used to obtain the ability scores of non-anchor items of version C (Boone, Staver, & Yale, 2014). The cut-off of 1.5 logits for the random values of the discrepancies (i.e., the difference between the values freely estimated and those estimated using anchor items) was used to reject an anchor item. After that, the ability scores for each subscale and for each version of the test were regressed on age and rescaled to a mean of 100 and standard deviation of 15 (i.e., the ability scores were multiplied by 15 and added to 100 to rescale the total scores of each subtest). These scaled scores were used to conduct descriptive analyses and to determine the effects of gender and grade on these tests using a multivariate analysis of variance (MANOVA).

To assess the possibility of combining the samples of students across different Grade-Groups, a multi-group CFA was conducted to determine the invariance of one model with two factors (i.e., one factor for the MCAA and a second factor for the creativity test) across groups. For each grade-group, the same model for the MCAA and creativity was specified. The model for the MCAA consisted of a general factor using the total scores of the three subscales as indicators (i.e., MF, VR and MR). The model for the creativity test was constructed based on a general factor estimated by the four subscales (i.e., fluency, flexibility, originality, and elaboration). The overall goodness-of-fit of the models in the multi-group CFA was assessed using the following fit indices: a non-significant Chi-Square-Test (χ^2) (albeit this criterion is often not met with large sample sizes), a χ^2/df ratio less than or equal to 2, the Comparative Fit Index (CFI) and Tucker–Lewis-Index (TLI) ≤ 0.95, and Root Mean Square Error of Approximation (RMSEA) ≤ 0.060 (Byrne, 2010; Cheung & Rensvold, 2002).

Independent factor scores were computed for the MCAA and creativity test for each grade; these scores were used in the regression analyses to obtain the thresholds. The factors were obtained using principal component analysis with oblimin rotation. The factor scores were saved using the regression method then regressed on age; the standardized residuals were saved for subsequent analyses. A segmented regression analysis was conducted to find the breakpoints in the regression. The Davies test (Mueggo, 2008) was performed in order to test for a non-zero difference-in-slope parameter of a segmented relationship. The procedure computes k 'naive' segments and the Wald statistic is used to test for the difference-in-slope. In this study, 8 segments were used following the directions suggested by Mueggo (2008). If the Davis test was significant, the segmented regression was carried-out. To conduct the analysis, the package "segmented" (Mueggo, 2008) for the computer software R (Team, 2010) was used, allowing an estimation of a linear model having one or more segmented relationships in the linear predictor. As the algorithm required a guessing starting point, the value of 100 (i.e., the average level on the MCAA) was selected. The regression function considered creativity as the dependent variable and the MCAA score as the independent variable. Then the correlation coefficients below and above the thresholds were obtained and compared using Fisher's z-test (Fisher et al., 1970). These analyses were conducted for the total score of creativity, for each dimension, for girls and boys and for the complete sample.

8. Results

8.1. Preliminary analysis of the creativity test

According to the generalizability theory (G-theory), two types of studies are conducted, G studies and D studies. The first quantifies the amount of variance associated with the different facets (factors) being examined. D studies provide information about which factors are optimal for a particular measurement situation by generating generalizability (G) coefficients that can be interpreted as reliability coefficients across various facets of the study. This study includes three facets: a) the three raters who scored the items using a rubric; b) the 20 items of the creativity test; and c) the 40 females and 40 males selected from each Grade-Group whose tests were scored as part of this study. Thus, a total of 240 students were randomly selected from the total sample to conduct the study. As seen in Table 1, the largest variance component is that associated with the interaction between students and items (49.90%), representing the unwanted variance. This suggests that certain items are more difficult/easy than others for certain students. The second largest source of variation in this model is due to students (21.24%). This suggests that around a quarter of the variance found in the model is due to the differences among the students who answered the question and this represents the true variance, which should be maximized. This is followed by the interaction component of rater, persons, items and error, which represents the unexplained error, indicating that almost 15% of the variance in the model is not explained. Variance accounted for by the items represents 12.37% of the total variance in the model. This suggests that items are different in terms of their difficulty. Finally, variance due to raters within student scores accounted for only 1.86%, which suggests that the raters did not differ in their ratings for particular students. In other words, raters exhibited high agreement among themselves when they rated students' performance.

In relation to the total variation, a given percentage of the variance is associated with each particular facet. The results for the G-coefficient ranged from .807 for only one rater and 20 items to .863 for three raters, indicating that the scoring was similar across the raters and increasing the number of raters did not increase significantly the G-coefficient.

8.2. Descriptive statistics

8.2.1. Gender and grade differences in creativity and analytic skills

In this section we will explore differences between the Grade-Groups' performances on the MCAA and creativity test, and the correlation between these tests within each Grade-Group. Tables 1, 2 and 3 show the descriptive statistics and the correlations among each subscale (both obtained using the scaled scores) for Grade-Groups 1 (3rd–5th grade), 2 (6th–8th grade), and 3 (9th–11th grade), respectively.

A MANOVA was conducted to compare the three groups' performances on the MCAA subtests. The results showed significant group differences on the scores of each subscale of the MCAA [F_{MF} (2, 4368) = 30.748, η^2_p = .014; F_{VR} (2, 4368) = 25.620, η^2_p = .012; F_{MR} (2,4368) = 16.244, η^2_p = .173; all $ps < .000$]. The pairwise comparison with Bonferroni correction showed that older students exhibited higher performance than younger students. Grade-Group 3 performed better than students of the other two groups on MR, and better than Grade-Group 2 on MF ($ps < .05$). Also, students in Grade-Group 2 scored higher on the MR subscale compared to students from Group 1 ($p < .05$). However, students in Grade-Group 1 showed a better performance in VR compared to the other two groups ($ps < .001$). Regarding gender differences, girls showed better performance on the VR and MF subscales than the boys in Grade-Group 2 [F_{VR} (1, 4368) = 8.1151, η^2_p = .002, F_{MF} (1, 4368) = 16.687, η^2_p = .004, all $ps < .002$].

A second MANOVA was conducted to determine grade and gender differences in creative skills. Results showed a main effect of grade and gender on the scores of the creativity task. Grade-Group 2 had significantly higher scores than Grade-Group 1, and Grade-Group 3 had

Table 1
Variance components for G-study (rater, person) × items.

Effect	df	Variance component	SE	% variance explained
Person	167	.309	.039	21.24
Items	19	.180	.057	12.37
Rater × persons	336	.027	.003	1.86
Persons × items	3173	.726	.020	49.90
Error	6384	.213	.004	14.64

Notes. SE = standard error.

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Table 2
Descriptive statistics, reliability and correlations for analytical and creative cognitive skills for Grade-Group 1.

Grade-Group 1	*N*	M_{Total} (*SD*)	M_{boys} (*SD*)	M_{girls} (*SD*)	α	1	2	3	4	5	6	7	8
1. Elaboration	930	99.8 (15.1)	100.0 (15.5)	99.6 (14.7)	.639								
2. Fluency	1232	98.3 (16.0)	97.7 (15.3)	98.8 (16.6)	.694	.169**							
3. Originality	1223	97.4 (17.0)	93.8 (17.2)	100.6 (16.1)	.589	.130**	.295**						
4. Flexibility	1201	97.9 (16.1)	95.8 (16.0)	99.8 (15.9)	.707	.160**	.378**	.366**					
5. VR	1258	102.0 (13.1)	101.4 (9.0)	102.4 (12.5)	.666	−.020**	.167**	.152**	.113**				
6. MR	1258	101.4 (15.6)	97.3 (11.8)	101.4 (15.9)	.678	−.025	.184**	.179**	.122**	.564**			
7. MF	1258	101.3 (16.1)	101.4 (13.4)	101.4 (15.9)	.724	−.014	.202**	.216**	.142**	.562**	.597**		
8. Total Creativity	1250	97.4 (15.7)	95.0 (15.9)	99.6 (15.1)	–	.420**	.712**	.722**	.760**	.172**	.194**	.227**	
9. Total MCAA	1258	100.0 (15.0)	99.6 (15.9)	100.4 (14.3)	–	−.022	.218**	.216**	.149**	.835**	.853**	.852**	.234**

Notes. VR = Verbal Reasoning; MR = Scientific and Mechanical Reasoning; MF = Mental Flexibility; MCAA = Multiple Cognitive Abilities Assessment. α = Cronbach's Alpha. The correlations were computed using the factor scores for Total Creativity and Total MCAA, and the IRT-derived scores for each subscale (see Method).
** $p < .001$.

significantly higher scores than Grade-Group 2 in every subscale [$F_{Elaboration}$ (2, 4368) = 4.923, η^2_p = .002; $F_{Fluency}$ (2, 4368) = 12.242, η^2_p = .006; $F_{Originality}$ (2,4368) = 29.465, η^2_p = .013; $F_{Flexibility}$ (2, 4368) = 18.418, η^2_p = .008; all *ps* < .000]. In addition, girls had significantly higher scores than boys on all the creativity subscales [$F_{Elaboration}$ (1, 4368) = 17.116, η^2_p = .004; $F_{Fluency}$ (1, 4368) = 15.1945 η^2_p = .003; $F_{Originality}$ (1,4368) = 221.180, η^2_p = .048; $F_{Flexibility}$ (1, 3486) = 65.471, η^2_p = .015; all *ps* < .000]. Furthermore, a significant interaction between gender and group was found for the Elaboration subscale [$F_{Elaboration}$ (1, 4368) = 11.343, η^2_p = .005 *p* < .000]. This interaction was driven by the rather narrow difference between the boys in Grade-Groups 2 and 3 compared to the larger difference between the boys in Grade-Groups 1 and 2. Moreover, the differences between the girls in Grade-Groups 1 and 2, and between the girls in Grade-Groups 2 and 3 were very similar.

8.2.2. Correlations between creativity and analytical skills across grade-groups

As reported in Tables 2, 3 and 4, we found similar correlations between analytical and creative cognitive skills in each Grade-Group. However in Grade-Group 1, the correlation was higher than in Grade-Group 3 (Fisher's *z* = 3.05, *p* = .002). The correlations between the subscales and the total score for creativity were homogenous across the Grade-Groups. The relationship between the total MCAA score and the creativity subscales across the Grade-Groups was similar except for MF. The correlation between mental flexibility and the MCAA total score was considerably lower in Grade-Groups 2 and 3 (Fisher's *z* = 23.72, Fisher's *z* = 28.28, *ps* < .001 respectively) than those observed in Grade-Group 1.

The findings so far indicate that the patterns of correlations between the scales of analytical and creative skills vary across grades (and thus with age). To determine whether the relationship between creativity and MCAA was indeed different across the grade-groups, a multi-group CFA was conducted to refute the invariance of the covariance between analytical and creative cognitive skills. A bi-factorial model was specified separately for each grade-group. The factor for creativity was composed using the total score for each subscale; the factor for MCAA was created using the total scores for MR, MF and VF. Both factors were correlated. Adequate fit indices were observed (Grade-Group 1: $\chi^2(12)$ = 34.893, *p* < .000, χ^2/df = 2.908, CFI = .987, RMSEA = .039, 90%-CI = .024–.054; Grade-Group 2: $\chi^2(12)$ = 19.920, *p* < .069, χ^2/df = 1.660, CFI = .996, RMSEA = .021, 90%-CI = .000–.037; Grade-Group 3: $\chi^2(12)$ = 16.128, *p* < .185, χ^2/df = 1.344, CFI = .998, RMSEA = .015, 90%-CI = .000–.031). In a multi-group approach, the correlations between creative skills and MCAA performance were tested. The overall fit for the multi-group analysis was adequate ($\chi^2(36)$ = 70.944, *p* < .000, χ^2/df = 1.971, CFI = .994, RMSEA = .015, 90%-CI = .010–.020). The correlation between the creativity factor and the MCAA factor for Grade-Group 1 was *r* = .35, for Grade-Group 2, *r* = .64, and Grade-Group 3, *r* = .67. When the correlation between the tested factors was constrained to be equal across the groups, the ΔCFI was bigger than .01 (ΔCFI = .02) and the Chi-Square-Test (χ^2) indicated significant differences between the unconstrained model and the model in which the correlation was constrained ($\Delta\chi^2(2)$ = 12.983, *p* < .002). Considering that Chi-Square is more influenced by the size of the sample, the ΔCFI is considered an adequate index of invariance of the models. Therefore, in light of the results both using the ΔCFI and Chi-Square-Test, the association between creativity and MCAA in the three Grade-Groups cannot be considered invariant.

8.2.3. The relationship between analytical and creative skills: testing the threshold hypothesis

Since the relationship between creativity and analytical skills was not invariant across grade-groups the threshold for each group was determined separately. The threshold for each grade-group was derived using segmented regression analysis. The existence of a threshold was tested using the Davies test and a combination of the three criteria described by Karwowski and Gralewski (2013), in which the correlation

Table 3
Descriptive statistics, reliability and correlations for analytical and creative cognitive skills for Grade-Group 2.

Grade-Group 2	*N*	M_{Total} (*SD*)	M_{boys} (*SD*)	M_{girls} (*SD*)	α	1	2	3	4	5	6	7	8
1. Elaboration	1244	99.2 (14.6)	98.5 (14.9)	99.8 (14.3)	.613								
2. Fluency	1458	100.3 (14.32)	99.4 (14.8)	101.1 (13.8)	.790	.126**							
3. Originality	1446	101.6 (14.6)	98.3 (15.3)	104.4 (13.4)	.598	.249**	.353**						
4. Flexibility	1428	101.3 (15.3)	99.5 (16.9)	102.7 (14.2)	.613	.241**	.399**	.432**					
5. VR	1482	97.9 (14.4)	97.1 (14.2)	98.7 (14.5)	.814	.018	.074*	.094**	.096**				
6. MR	1482	98.3 (14.7)	98.2 (15.4)	98.3 (14.0)	.664	.005	.046	.030	.044	.629**			
7. MF	1482	97.5 (13.9)	96.7 (14.7)	98.2 (13.3)	.792	.150**	.313**	.353**	.351**	.178**	.081**		
8. Total Creativity	1472	101.1 (14.8)	98.6 (15.2)	103.3 (14.6)	–	.482**	.702**	.757**	.794**	.108**	.048	.435**	
9. Total MCAA	1482	100.0 (15.0)	99.3 (15.5)	100.6 (14.6)	–	.042	.127**	.137**	.145**	.897**	.872**	.339**	.171**

Notes. VR = Verbal Reasoning; MR = Scientific and Mechanical Reasoning; MF = Mental Flexibility; MCAA = Multiple Cognitive Abilities Assessment. α = Cronbach's Alpha. The correlations were computed using the factor scores for Total Creativity and Total MCAA, and the IRT-derived scores for each subscale (see Method).
* $p < .05$.
** $p < .001$.

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Table 4
Descriptive statistics, reliability and correlations for analytical and creative cognitive skills for Grade-Group 3.

Grade-Group 3	N	M_{Total} (SD)	M_{boys} (SD)	M_{girls} (SD)	α	1	2	3	4	5	6	7	8
1. Elaboration	1375	100.8 (15.2)	98.4 (14.8)	106.9 (11.84)	.587								
2. Fluency	1628	101.1 (14.7)	99.7 (14.3)	102.3 (11.3)	.710	.181**							
3. Originality	1611	100.5 (13.3)	96.9 (14.3)	103.7 (11.6)	.586	.199**	.418**						
4. Flexibility	1601	100.4 (13.6)	98.5 (15.1)	102.2 (11.7)	.660	.219**	.450**	.482**					
5. VR	1628	100.3 (16.6)	99.7 (15.9)	100.9 (17.9)	.906	.054*	.096**	.102**	.091**				
6. MR	1628	100.4 (14.6)	100.9 (14.8)	100.0 (14.5)	.704	−.008	.010	−.010	−.004	.606**			
7. MF	1628	101.3 (14.7)	99.3 (15.7)	103.1 (13.5)	.844	.189**	.324**	.423**	.360**	.164**	−.024		
8. Total Creativity	1623	99.9 (15.0)	97.7 (14.8)	103.9 (13.3)	–	.482**	.759**	.762**	.792**	.123**	−.003	.467**	
9. Total MCAA	1628	100.9 (14.2)	99.7 (14.8)	100.3 (15.3)	–	.049*	.097**	.102**	.092**	.904**	.875**	.198**	.123**

Notes. VR = Verbal Reasoning; MR = Scientific and Mechanical Reasoning; MF = Mental Flexibility; MCAA = Multiple Cognitive Abilities Assessment. α = Cronbach's Alpha. The correlations were computed using the factor scores for Total Creativity and Total MCAA, and the IRT-derived scores for each subscale (see Method).
* $p < .05$.
** $p < .001$.

coefficients at the breakpoints detected by segmented regression analysis were compared following these criteria: (1) a significant positive correlation between analytical and creative skills in students with scores below the threshold; (2) no significant correlations for students with analytical scores above the threshold; and (3) significant differences in the magnitudes of the analytical-creativity correlations between students above and below the threshold. The correlations between creativity and the MCAA above and below each grade-group breakpoint were computed. Table 5 reports the correlations between the MCAA and creativity factor scores for the different thresholds for each of the Grade-Groups. Additionally, partial correlations were computed to control the effect of mental flexibility, which was found to be significantly related to the creativity tasks. Figs. 1 to 3 show the scatterplot with breakpoint for each Group-Grade.

For Grade-Group 1, the Davies test for MCAA for the complete sample was non-significant for boys and girls. These results are reported in Tables 5 and 6. Regarding the dimensions of creativity, the Davies test for each component was not significant except for Originality (p = .003); the segmented regression analysis identified one breakpoint at 87.3 (SD = 7.28, 95% CI = 79.77–94.99, β = .49, $p < .001$, $R^2 = .05$, β above the breakpoint = .35, β below the breakpoint = −.13). The correlation coefficient below the threshold was r = .055, n = 355, p = ns, and r = .160, $p < .001$, above the threshold was r = .160, n = 903, $p < .001$, and the correlations were not significantly different (Fisher's z = 1.69, p = ns).

For Grade-Group 2, the Davies test was positive in detecting significant differences in 8 segments of the function (p = .019). A breakpoint was detected at an MCAA score of 108.8 (SD = 5.16, 95% CI = 98.65–118.9 points, β = .16, $p < .001$, $R^2 = .05$, β below the breakpoint = .04 and β above the breakpoint = .34). The correlation coefficient below the threshold was r = .022 and above the threshold r = .299, and the Fisher test indicated significant differences between the correlations (Fisher's z = −4.65, $p < .001$). When the correlation was controlled for MF, the correlation below became significant but negative and above the threshold the coefficient decreased but remained significant. A breakpoint was detected for females at 81.9 points and the pattern of correlation was in the opposite direction than proposed by the threshold theory. The Davies test did not detect significant differences in the slopes for males. Regarding the dimension of creativity, the Davies test was significant only for flexibility (p = .020). A significant breakpoint was detected at 105.5 (SD = 5.456, 95% CI = 94.78–116.2, β = .44, $p < .001$, β below the breakpoint = .001 and β above the breakpoint = .29). The correlation coefficient below the threshold was r = .104, n = 844, p = 002, and above the threshold was r = .001, n = 638, p = ns and they differed significantly (Fisher's z = 1.97, p = .024).

For Grade-Group 3 the Davies test was significant ($p < .001$). A breakpoint was identified at 108.4 for the complete sample (SD = 2.45, 95% CI = 103.6–113.2 points, β = .12, $p < .001$, $R^2 = .015$, β below the breakpoint = −.14 and β above the breakpoint = .49 the threshold). The correlation coefficient for below the threshold was r = −.072, p = .015 and above the threshold r = .342, $p < .001$. The Fisher test indicated significant differences between the correlations (Fisher's z = −7.61, $p < .001$). When controlling for MF the correlations above and below the threshold remained significant. The breakpoint for females was 81.46, and the pattern of correlation was in the opposite direction from that proposed by the threshold theory. The same pattern of correlation was observed in the male sample, but the threshold was detected at 105.6. The threshold for females and males were statistically different regarding the confidence interval. Finally, all of the subscales of creativity obtained a significant Davies test ($ps < .001$). For Elaboration a breakpoint was detected at 103.3 points (SD = 6.118, 95% CI = 91.27–115.3 points, β = −.09, $p < .001$, $R^2 = .01$, β below the breakpoint = −.08 and β above the breakpoint = .16). The correlation coefficient below the threshold was r = .062, n = 839, p = ns and above the threshold r = −.10, n = 789, p < ns (Fisher's z = 3.27, $p < .001$). For

Table 5
Coefficients of the bivariate correlations between the MCAA and Creativity (total score and different dimensions).

	Measure	Threshold (CI)	Davies p value	n	n	Correlations			Partial correlations		
				Above	Below	Above	Below	Fisher's z	Above	Below	Fisher's z
G1	Total Creativity	87.3 (72.99–101.6)	ns	1022	236	.216**	.026	2.66	.112*	−.051	2.25
	Originality	87.3 (79.77–94.99)	.003	903	255	.160**	.055	1.69			
G2	Total Creativity	108.8 (98.65–118.9)	.019	354	1128	.299**	.022	4.65	.159*	−.061	3.61
	Flexibility	105.5 (94.78–116.2)	.020	638	844	.001	.104**	1.97			
G3	Total Creativity	108.4 (103.6–113.2)	<.001	431	1197	.342**	−.072*	7.61	.133*	−.064*	3.66
	Elaboration	103.3 (91.27–115.3)	<.000	789	839	−.100	.062	3.27			
	Fluency	108.3 (102.5–114.8)	<.001	494	1134	.060	.077*	.32			
	Flexibility	109.2 (103.0–115.3)	<.001	468	1160	.047	.078*	.57			
	Originality	108.3 (102.4–114.2)	<.001	780	878	.079*	.071*	.73			

Notes. Partial correlations controlling for mental flexibility. MCAA = Multiple Cognitive Abilities Assessment. Fisher's z = z-score derived from Fisher's r-to-z transformation for correlation coefficients above and below the threshold. Values for Fisher's $z > 1.96$ are significant at $p < .05$.
* $p < .05$.
** $p < .001$.

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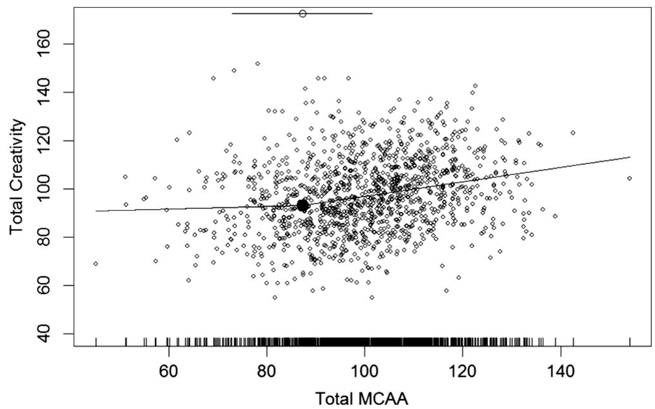

Fig. 1. Scatterplot of scaled factor scores of creativity and Multiple Cognitive Abilities Assessment (MCAA) for Grade-Group 1. The breakpoint (threshold) at a score of 87.3 on the MCAA is indicated with a black bold dot in the figure. The line with the dot in the top part of the figure indicates the confidence interval for the breakpoint.

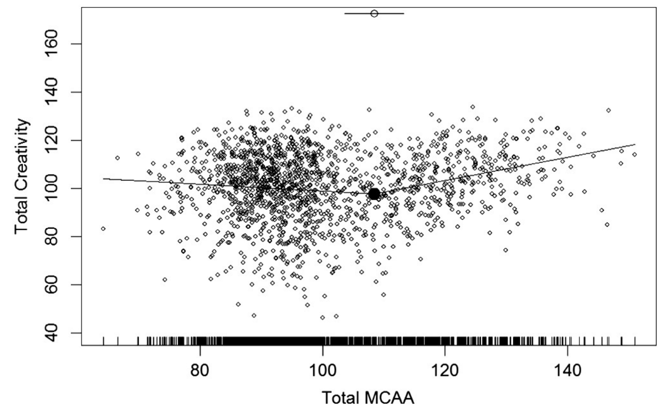

Fig. 3. Scatterplot of scaled factor scores of creativity and Multiple Cognitive Abilities Assessment (MCAA) for Grade-Group 3. The breakpoint (threshold) at a score of 108.4 on the MCAA is indicated with a black bold dot in the figure. The line with the dot in the top part of the figure indicates the confidence interval for the breakpoint.

Fluency, a breakpoint was detected at 108.3 points ($SD = 3.134$, 95% CI = 102.5–114.8 points, $\beta = .09$, $p < .001$, $R^2 = .01$, β below the breakpoint $= -.11$ and β above the breakpoint $= .39$). The correlation coefficient for below the threshold was $r = .077$, n = 1134, $p = .009$ and above the threshold $r = .060$, n = 494, p = ns (Fisher's $z = .32$, p = ns). For Flexibility a breakpoint was detected at 109.2 points ($SD = 3.134$, 95% CI = 103.0–115.3 points, $\beta = .09$, $p < .001$, $R^2 = .02$, β below the breakpoint $= -.10$ and β above the breakpoint $= .36$). The correlation coefficient for below the threshold was $r = .078$, n = 1160, $p = .008$ and above the threshold $r = .047$, n = 468, p = ns (Fisher's $z = .57$, p = ns). For Originality a breakpoint was detected at 108.3 points ($SD = 6.129$, 95% CI = 102.4–114.2 points, $\beta = .04$, $p < .001$, $R^2 = .01$, β below the breakpoint $= -.10$ and β above the breakpoint $= .37$). The correlation coefficient for below the threshold was $r = .071$, n = 878, $p = .035$ and above the threshold $r = .079$, n = 780, $p = .030$ (Fisher's $z = .73$, p = ns). No significant differences between the correlations were observed above and below the threshold for all subscales of creativity.

Taken together, for Grade-Group 1 the breakpoint was not significant, indicating that the threshold hypothesis was not confirmed. However, for Grade-Groups 2 and 3 the breakpoints were significant, which confirms a threshold in the relationship between MCAA and Creativity. Moreover, the correlations below the threshold were non-significant except for Grade-Group 3. For all grade-groups, the correlation coefficients below the threshold were smaller than the correlation coefficients above the threshold. Thresholds for originality as a dimension of creativity were found in Grade-Groups 1 and 3, for flexibility in Grade-Groups 2 and 3, and for fluency and elaboration only in Grade-Group 3 were found. However, no significant differences between the correlation coefficients were found when analyzing the correlations between creativity and the MCAA for different dimensions of creativity with the exception of flexibility in Grade-Group 2. This was the only subscale that met the criteria for the threshold theory. When the grade groups were analyzed by gender, females appeared to systematically obtain a low threshold than males. While the threshold for females was around 80 to 90 points of MCAA, for the male group the detected threshold was around the 100 points of MCAA.

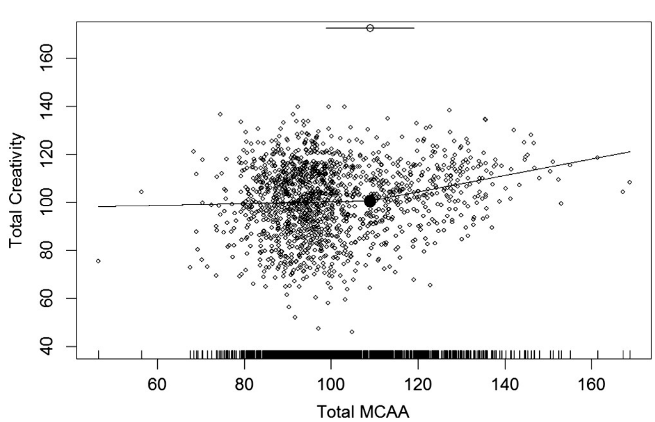

Fig. 2. Scatterplot of scaled factor scores of creativity and Multiple Cognitive Abilities Assessment (MCAA) for Grade-Group 2. The breakpoint (threshold) at a score of 108.8 on the MCAA is indicated with a black bold dot in the figure. The line with the dot in the top part of the figure indicates the confidence interval for the breakpoint.

9. Discussion

The discussion that follows is organized into two sections. First, we will explore the different possible explanations for the patterns of correlations between creativity and analytical skills that we found within the framework of the threshold theory, considering how the verbal or figural nature of the task and the dimension of creativity (e.g., fluency, flexibility, originality and elaboration) being assessed may affect these correlations. Then, we will focus on the patterns of performance we found across both gender and grade, and consider how these differences may be explained by particular aspects of Saudi education and culture.

9.1. The threshold theory in the context of Saudi Arabian students

Creativity is now considered a necessary component of giftedness (Kaufman, Plucker, & Russell, 2012). Thus, the importance of understanding the relationship between creativity and intelligence lies in its potential to shed light on how intelligence may or may not be related to creative outcomes in a gifted population. In this study, we explored the relationship between analytical skills and creativity in a population of students from 3rd to 11th grade in the KSA who were part of a normative study to explore the performance of the MCAA and a creativity test in the population. When we considered the relationships between analytical skills and creativity in the different grade-groups of our sample, the correlation coefficients were similar to others reported in the literature (Jauk et al., 2013; Kim, 2005; Runco & Albert, 1986). However, the correlations across different proficiency groups were different from those predicted by the threshold theory, which proposes that the correlation between creativity and analytical skills becomes weak when analytical skills are higher than a specific "threshold" (Fuchs-Beauchamp et al., 1993; Getzels & Jackson, 1962; Jauk et al., 2013; Yamamoto, 1964). In this study, we did not find a threshold for the younger students (3rd to 5th grade), but did for the older students (6th to 8th and 9th to 11th grades). Specifically, in Grade-Group 2, a threshold was found at 108.8 IQ points in the MCAA test, while in Grade-Group 3, a

Table 6
Coefficients of bivariate correlation between MCAA and Creativity by gender.

	Thresholds (CI)	Davies *p* value	*n*	*n*	Correlations			Partial correlations		
			Above	Below	Above	Below	Fisher's *z*	Above	Below	Fisher's *z*
G1										
Female	87.39 (66.3–94.4)	ns	552	110	.248**	−.009	2.48	.134*	−.076	2.00
Male	122.8 (109.8–135.3)	ns	41	555	−.056	.205**	1.57	−.274	.079	1.94
G2										
Female	81.9 (66.7–97.1)	.012	770	41	.178*	.111	.41	−.039	−.035	0.02
Male	114.7 (95.3–134.1)	ns	105	556	.325**	.049	2.67	.294**	−.026	3.05
G3										
Female	81.46 (66.3–96.9)	<.001	800	46	.101**	.257	1.03	.031	.171	0.91
Male	105.6 (98.96–112.3)	<.001	218	561	.354**	−.029	4.97	.208**	.094*	1.46

Notes. Partial correlation controlling for mental flexibility. MCAA = Multiple Cognitive Abilities Assessment. Fisher's z = z-score derived from Fisher's r-to-z transformation for correlation coefficients above and below the threshold. Values for Fisher's $z > 1.96$ are significant at $p < .05$.
* $p < .05$.
** $p < .001$.

threshold was identified at a score of 108.4 IQ points in the same test. The students who were above the threshold showed a higher correlation between creativity and analytical skills, even when mental flexibility was controlled (in the case of the students in the 9th to 11th grades). Interestingly, for the children who were below the threshold, this relationship disappeared when the correlation was controlled for mental flexibility, but not for the children above the threshold. A similar pattern was found for the subscales of creativity across the groups. The only subscale that met the Karwowski and Gralewski (2013) criteria was flexibility for Grade-Group 2, in which the group below the threshold showed a higher and significant correlation with IQ than the group above the threshold. The results for this subscale were consistent with other studies in finding that creativity measured with divergent thinking tests and analytical skills become distinctly unrelated in high performing students (Fuchs-Beauchamp et al., 1993; Kim, 2008).

Considering the factors that may affect the correlation between creativity and analytical skills, we propose that these outcomes may be a result of the interaction between the type of task used to assess creativity, the dimension of creativity being assessed, and the skills that are promoted in the school by the curriculum or at home. Regarding the type of task, other studies have reported that some tasks generate linear correlations with creativity due to the domain focus or nature of the test, or that they show higher correlations with IQ only in the groups with high ability, as happened in this study. That is, the IQ–creativity correlations in the groups of high ability students may be due to the nature of the task or the type of thinking involved. For example, in the study by Ginsburg and Whittemore (1968), the authors measured creativity and analytical skills with two tasks that were verbal in nature. To measure creativity, the Remote Association Test (RAT) was used, and analytical skills were assessed with the ACT (American College Testing, ACT) verbal task; no threshold was found, the two tasks were positively related across the stratified groups based on performance on the ACT verbal task. Additionally, the authors discussed the type of thinking involved in the RAT task. Unlike other tests of creativity, in which divergent thinking is usually evaluated, the RAT requires convergent thinking, as did the ACT verbal task that was administered. These results resemble the study of Runco and Albert (1986), which showed how the California Achievement test obtained higher correlations only in the 4th quartile group, unlike the IQ test, which showed some significant correlations with some dimensions of creativity (e.g. flexibility and fluency).

In addition to the effects of the type of task (verbal and non-verbal tasks) on IQ–creativity correlations, the dimension of creativity being measured may also influence the strength and direction of the IQ–creativity correlation. Different correlations and thresholds have been found across different dimensions of creativity (Jauk et al., 2013). One of the most common measures used to assess creativity are divergent thinking activities, generally with fluency as an indicator (Kim, 2008). However in this study, the different dimensions of creativity (e.g., fluency, flexibility, originality and elaboration) were measured with distinct tasks and then combined into a unique factor. This combination of dimensions of creativity can generate distinct associations with analytical skills. For example, for Grade-Group 1, the relationship between IQ and creativity was close to linear across the different levels of students' MCAA performance, while for Grade-Groups 2 and 3 a linear relationship was observed only above the threshold. The studies of Runco and Albert (1986) and Jauk et al. (2013) showed how different dimensions of creativity may generate different thresholds and also different tendencies in the relationship with analytical skills. However, for Grade-Groups 2 and 3, a similar pattern was found across the different dimensions of creativity (e.g., fluency, flexibility, originality, and elaboration).

9.2. The cultural environment and the development of skills

In this section, we consider the sources of variation in the performance on both creativity and analytical tasks that may be due to culture. Several studies suggest differences between western and eastern countries concerning the performance of creativity and analytical skills (e.g., Batterjee, 2011). In these studies, performance may be explained or modulated according to the skills that are promoted by the culture, generating differences in performance in the different dimensions of creativity and also, possibly, differences by gender (e.g., Zha, Walczyk, Griffith-Ross, Tobacyk, & Walczyk, 2006) These influences are well-explained by current models of giftedness, which define high performance/ability as a dynamic interaction between individuals' personal factors (such as motivation), cognitive skills, creativity and the environment, all of which may strongly influence both the development and expression of the various components of giftedness (Davidson, 2009; Gagne, 1985; Renzulli, 2005). Hence, environments, both at school and home, might exert a great deal of influence on the development of both analytical and creative skills (Hein, Reich & Grigorenko, 2015b).

In this study we also found gender differences across all grades in the creativity task. The girls had higher scores in creativity than boys. This is not an unusual finding in creativity studies, depending on the task used to assess creativity (Runco, Cramond, & Pagnani, 2010). Our results show that the girls scored higher on all of the measures related with the four dimensions of creativity assessed in this study (fluency, flexibility, originality and elaboration). Girls also performed better than boys in the verbal reasoning task, however, this task is not highly correlated with creativity measures. Some of these gender differences in the context of KSA may be explained by the home environment. For example, it has been found that when mothers had a higher educational background, their gifted daughters tended to be more creative (Hein et al., 2014). The same study also revealed effects of number of boys or girls in the family, with more boys in the family resulting in boys' lower performance on creative tasks, and more girls in the family resulting in girls' lower performance on analytical tasks (Hein et al., 2014). We may also find explanations for gender differences in creativity in the school environment. Because specific experiences in the instructional environment have been found to be closely related to cognitive skills (Christian et al., 2001), it could be that the girls' school environment encourages more exploratory learning whereas boys may develop skills more related to test memorization and recall of facts, resembling the gender roles and the societal role of education in Arab societies (The World Bank, 2008; United Nations Development Programme & Regional Bureau for Arab States, 2005). Although we found that boys and girls tend to perform differently on creativity tasks, there were only negligible differences in verbal, mechanical and scientific reasoning—similar to what has been observed on a verbal intelligence task in an independent sample in KSA (Hein et al., 2015a).

With respect to age and grade, we found that creativity scores were positively related to the grades of the students. Given that a positive correlation between creativity and verbal skills has been reported (Ginsburg & Whittemore, 1968), it is likely that our results reflect a normal age-related improvement of skills.

9.3. Limitations of the study

The limitations of the study are related to the psychometric characteristics of the analytical skills task used in this study. Although the tests were designed to measure the same skills through each Grade-Group, adjusting difficulty and content, there is some evidence that this objective was not completely accomplished. The items from the verbal reasoning test appeared to be easier for the younger students than the older students, and this difference in performance could be more related with the characteristics of the test in each grade than the skill level of the students.

In addition, the most of the literature has explored the threshold using standardized tests of intelligence and creativity, specifically tests of divergent thinking. In this study, both the test to measure analytical skills and to measure creativity are novel tests thus, the results are not, then the results are not directly comparable with the previous literature. Therefore, as discussed above, our results can be explained both by the nature of the test as well as cultural differences.

10. Conclusion

In this study, the threshold theory was explored in a population of students from the KSA. Our results do not support the threshold theory. Specifically, in this study, the threshold was not significant for students from grades 3 to 5 considering the Davies test. For the students in grades to 6 to 11 a threshold was found, but the students who obtained high scores on the test for analytical skills also obtained higher scores on creativity. The subscales of creativity followed the same general pattern with the exception of flexibility in Grade-Group 2.

In this era of globalization, education in the Saudi culture faces the challenge of shifting from conservative and inflexible curricula and teaching methods to fostering creative thinking and cultivating open and individualized education. The present study is a descriptive statement about the necessity of nurturing students' creative skills as early as possible, to facilitate gifted students' development of their talents and to support the country's endeavor to promote creativity in their society. Since studies in creativity in the context of school is an emerging field in Middle Eastern cultures, it remains important to explore what factors may account for individual differences in both creativity and analytical skills. Hopefully, future studies will shed more light on factors that support gifted children's success in school and after.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.lindif.2015.05.005.

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