The Predictive Value of Working Memory and Creativity in Average Performing and Gifted Children

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Abstract

The association between working memory (WM), intelligence and mathematical performance has been studied repetitively, whereas the association between creativity and these constructs has received far less attention, even though creativity is important in mathematical performance. The aim of the present study was to find the differential associations between creativity, WM and mathematical performance in both average performing and gifted fourth graders. It was hypothesized that WM was related to mathematical performance in both average and gifted students, whereas creativity was only related to mathematical performance in gifted students. A total of 68 children attended the study of which 27 were gifted. These children completed several tests for WM, creativity and intelligence. In a multiple regression analysis the expected positive association was found for WM in average performing students, whereas this association was not found in gifted students regarding mathematical performance. As expected a positive association was found for creativity in mathematical performance in gifted children, however this was also found in average performing children. This suggests that creativity plays an important role in mathematical performance of gifted children, whereas both WM and creativity play an important role in mathematical performance of average performing children. Further research is necessary about the role of creativity in mathematical performance.
Keywords: Intelligence, working memory, creativity, mathematical performance, average performing children, gifted children.

Abstract (Dutch)

De associatie tussen werkgeheugen, intelligentie en rekenvaardigheid is herhaaldelijk bestudeerd, terwijl dit niet het geval is voor de associatie tussen creativiteit, intelligentie en rekenvaardigheid, hoewel creativiteit net zo belangrijk is in rekenvaardigheid. Het doel van de huidige studie was, om de verschillende associaties te onderzoeken tussen creativiteit, werkgeheugen en rekenvaardigheid in zowel gemiddeld presterende als hoogbegaafde kinderen uit groep zes. Als hypothese was gesteld dat werkgeheugen was gerelateerd aan rekenkundige vaardigheid in zowel gemiddelde als hoogbegaafde kinderen, terwijl creativiteit alleen gerelateerd is aan rekenkundige vaardigheid in hoogbegaafde leerlingen. Informed consent was verkregen voor 68 kinderen, waarvan 27 kinderen hoogbegaafd waren. Deze kinderen deden verschillende tests om het werkgeheugen, creativiteit en intelligentie te onderzoeken. Met behulp van een multipele regressie analyse werd de verwachte positieve

associatie gevonden voor werkgeheugen en rekenvaardigheid in gemiddelde leerlingen, terwijl deze associatie niet werd gevonden in hoogbegaafde leerlingen. Zoals verwacht werd een positieve associatie gevonden voor creativiteit in rekenvaardigheid voor hoogbegaafde leerlingen en hoewel onverwacht, ook bij gemiddelde leerlingen. Dit suggereert dat creativiteit een belangrijke rol speelt in rekenvaardigheid van hoogbegaafde kinderen, terwijl werkgeheugen en creativiteit een belangrijke rol spelen in rekenvaardigheid van gemiddeld presenterende leerlingen. Verder onderzoek is nodig naar de rol van creativiteit in rekenvaardigheid.
Keywords: Intelligence, working memory, creativity, mathematical performance, average performing children, gifted children.

The Predictive Value of Working Memory and Creativity in Average Performing and Gifted Children

Children learn how to solve mathematical problems from an early age onwards. They learn to count, acquire number skills and perform different mathematical operations (Friso-van den Bos, Van der Ven, Kroesbergen, & Van Luit, 2013). A key factor that accounts for 25-30% of the variance in school achievement is intelligence (Butcher, 1968; Deary, Strand, Smith, & Fernandes, 2007; Jensen, 1980; Snow & Yalow, 1982). Another important factor, working memory (WM), is thought to play a central role in acquiring mathematical skills (Adams & Hitch, 1997; Bull & Scerif, 2001; Gathercole & Pickering, 2000; Hecht, Torgesen, Wagner, & Rashotte, 2001; Holmes & Adams, 2006; Swanson & Kim, 2007). According to Alloway and Alloway (2010) WM is a more powerful predictor of academic achievement than IQ at the start of formal education. A third factor, although not often recognized, that is thought to play an important role in mathematical performance is creativity (Mann, 2005; Starko, 1994). In the present study the differential associations between WM and creativity are investigated in two groups of different intelligence levels; average performing children and gifted children.

According to Carroll (1993, 2003), cognitive abilities exist at three levels or strata; the first comprises 50 to 60 narrow abilities, the second comprises approximately 8 to 10 broad factors and the highest stratum, the third, consists of one single general intellectual ability (*g*). The ten factors are fluid intelligence (Gf), quantitative knowledge, crystallized intelligence (Gc), reading and writing, short-term memory, visual processing, auditory processing, long-term storage and retrieval, processing speed and decision speed/reaction time. Humans can flexibly adapt their thinking to new problems and situations through Gf whereas a person's ability to use different skills, knowledge and experience is Gc (Cattel, 1971). Children with an above average intellectual ability are called gifted, although it has been argued that also other factors are necessary for the identification of giftedness; creativity and task commitment (Renzulli, 1984, 2011).

Working memory is responsible for storing and manipulating information and needed for example in mental arithmetic (Alloway, 2006). The working memory comprises four different components (Baddeley, 1986, 2000, 2003); the central executive (responsible for control, regulation and monitoring of complex cognitive processes), the phonological loop (stores phonological information), the visuospatial sketchpad (stores visual and spatial information), and the episodic buffer (a temporary multimodal storage component). The coordinating role of the central executive has recently been differentiated further into the subprocesses of inhibition (ability to inhibit dominant responses when necessary), shifting (ability to switch between tasks/operations) and updating (ability to monitor and code information that is relevant for a task; Miyake et al., 2000).

Although researchers don't agree about a definition for creativity, a commonly used definition is, that creativity is a process in which one is becoming sensitive to problems, disharmonies, missing elements, and so on. In this process people are searching for solutions, make guesses, test and re-test hypotheses to finally communicate the results (Torrance, 1966).

Association between working memory, intelligence and mathematical performance

According to a recent meta-analysis all three components of the working memory (i.e. inhibition, shifting and updating) are related to mathematical performance, but updating seems most strongly related in both first and second graders (Friso-van den Bos et al., 2013). Updating is probably involved in the storage and retrieval of partial results in mathematical problems (Deheane, 1997). Therefore when a child has problems with updating, it may forget the intermediate results.

The visuospatial WM (VSWM) is thought to operate on visuospatial information involved in mathematical problems and considered to be related to math preskills in both preschool aged children (Kyttälä, Aunio, Lehto, Van Luit, & Hautamäki, 2003) and children aged 15-16 (Reuhkala, 2001). According to Van de Weijer-Bergsma, Kroesbergen, and Van Luit (2015), both visuospatial and verbal WM predict individual differences in children's level of performance in different math domains in second to sixth graders. For addition, subtraction and multiplication in grade 5, VSWM was no longer a significant predictor. Accordingly it has been shown that WM was less involved in arithmetic once children grow older. This should be the result of changes in selection and strategy efficiency (Imbo & Vandierendonck, 2007). According to Van der Ven, Van der Maas, Straatemeier, and Jansen (2013) there is no decreasing age-trend for multiplication in VSWM in first to sixth graders. The results may differ, because in the first study the children were only tested in one grade, whereas in the second study the children were followed over a six year period.

Gathercole, Pickering, Knight, and Stegmann (2004) found that children with high abilities in mathematics seem to have better scores on working memory than children with low or average abilities at 7- and 14-years of age. The central executive and phonological loop were tested using different tests of the Working Memory Test Battery for Children (Pickering & Gathercole, 2001).

According to Kuusinen and Leskinen (1986) the Illinois Test of Psycholinguistic

Abilities accounted for 32% of the variance in mathematics in ninth grade. Especially Gf is involved in mathematical performance in children in the age of 6 to 19 when using the Woodcock-Johnson III Tests of Cognitive Abilities (Floyd, Evans, & McGrew, 2003). Which suggest that intelligence is an important predictor for mathematical performance.

Studies about the relationship between WM and Gf in children suggest that the constructs are strongly related, but distinct (e.g. Alloway, Gathercole, Willis, & Adams, 2004; Fry & Hale, 2000). People high in intelligence score usually high on WM.

Concluding, many components of the WM are linked to mathematical performance, but it depends on the mathematical task and age if this association is significant. Intelligence is an important factor in mathematical performance and children with higher scores on WM seem to have higher scores on mathematical performance as well. This suggest that children high in intelligence, score higher on WM and have better mathematic scores.

Association between creativity, intelligence and mathematical performance

One of the oldest areas of creativity research is the study of the relationship between creativity and intelligence (Silvia, 2008). There are modest relationships between these two constructs. This relationship depends on the nature of the tests. Creativity tests that use convergent thinking (i.e. finding one solution or the best out of a few) typically show a higher correlation with intelligence (Kane et al., 2004; Mednick & Andrews, 1967), than tests that use divergent thinking (i.e. finding as many solutions for a problem as you can; Plucker, 1999; Preckel, Holling, & Wiese, 2006).

Some researchers (e.g. Starko, 1994) suggested that to develop mathematical ability, mathematical creativity is important. When using the Discover method, Bahar and Makar (2011) found that in first to fourth graders mathematical creativity is significantly correlated to mathematical performance. The mean scores for creativity differ for the different grades, but in every grade the scores are significant. Fluency, flexibility, originality and elaboration are all significant predictors of mathematical ability (Bahar & Maker, 2011). However, Baran Erdogan, and Çakmak (2011) found no statistical significant correlation between mathematical ability and creativity. They used a general creativity test (Torrance Test of Creative Thinking) and a mathematical test for informal and formal mathematics in 6-year old students. Differences may exist because of the use of both general creativity tests and domain-specific (mathematical) creativity tests.

According to the threshold theory a moderate level of intelligence is needed to be creative (Runco, 1991). There are medium size correlations between intelligence and creativity below IQ 120 and hardly any correlations above IQ 120 (Barron, 1963, 1969).

Other studies found negligible differences in correlations in the different ability groups (Mednick & Andrews, 1967; Preckel et al., 2006; Runco & Albert, 1986). These differences are partly due to methodological differences (e.g. using different types of assessment like expert judgement or assessment) and the use of different samples with different cut off points (Preckel et al., 2006). However, two studies by Nusbaum and Silvia (2011) suggest that intelligence plays a larger role in creative thought. One study showed that individual differences in Gf significantly predicted creativity, partly due to the effects of Gf on executive switching during the task. The other study showed that people high in Gf benefitted more from an abstract task strategy that people low in Gf. Divergent creativity was tested by giving as many uses for a brick and a knife and subtests of the Ravens Advanced Progressive Matrices to test Gf. Participants were adults enrolled in an introductory psychology class.

Concluding, it appears that mathematical creativity is related to mathematical performance. Which suggests that children with high mathematic score are high in mathematical creativity.

The present study

Although many studies have focused on the association between WM, intelligence and mathematical performance, fewer have focused on the association between creativity, intelligence, and mathematical performance and there is even a lack of studies that focus on the association between mathematical creativity and mathematical performance. According to Kattou, Kontoyianni, Pitta-Pantazi, and Christou (2013) the use of a divergent test of mathematics is necessary to investigate this association.

It is interesting to know what constructs are responsible for children's mathematical performance and if there are differences between different levels of intellectual ability. Therefore the main objective of this study is to investigate whether working memory and creativity are both predictors for mathematical performance and whether the predictive value is the same in gifted and average performing children. VSWM plays an important role in mathematical performance (Van de Weijer-Bergsma et al., 2015) and people with high intellectual abilities appear to be high in creative thought (Nusbaum and Silvia, 2011). It is therefore expected that working memory plays an important role in both groups and creativity only in the gifted group.

Method

Participants

The population of this study contains average performing and gifted primary school children in fourth grade. The sample used is of children attending primary school in

Amersfoort, the Netherlands. The sample comprised 68 children (34 boys and 34 girls). Among the participants 27 were gifted (age M = 10.07, SD = .27; 12 male, 15 female) and 41 were average performing children (age M = 10, SD = .39; 22 male, 19 female). The children were divided in these two groups by calculating percentile scores of the NIO for all 262 participants that participated in the study. The children with percentile scores between 30 to 70 (scores of 31 -38) were average performing children and the children with a percentile score above 85 (scores of 42-54) were gifted children.

Measures

Intelligence. To measure intelligence, two subtests of the *Nederlandse intelligentietest voor onderwijsniveau* ([NIO] Dutch IQ test for educational level) were used (Van Dijk & Tellegen, 2004). Only two subtests were used, due to limited time in the classrooms. Verbal intelligence was measured with the subtest categories and spatial awareness with the subtest fold-out. Verbal intelligence is an important aspect of general intelligence and the fold-out test is related to tests that measure performance IQ. The result of all the subtests is usually an indication of the IQ. However, the test has norms for children in sixth to nine grade, so no IQ scores can be measured, but the total scores are used as an indicator for intelligence. Therefore the scores have to be interpreted with care. The subtest fold-out consists of 8 items (Van Dijk & Tellegen, 2004). Each item shows a figure and five fold-out figures. One or more of these fold-out figures can be used to compose the shown figure. The subtest categories consists of 30 items. Two words are shown and the children will have to choose how these words are connected. They are either the same, the opposite, types of something, a part of the other, a cause or a mean to do something (Van Dijk & Tellegen, 2004). The internal consistency of the subtest decomposing is Cronbach's α = .82 and test-retest score is .70. The internal consistency of the subtest categories is Cronbach's α = .86 and the test-retest score is .68 (Van Dijk & Tellegen, 2004). The quality, norms, reliability and validity of the NIO is qualified as good by the committee of test matters the Netherlands (*commissie testaangelegenheden Nederland;* COTAN, 2004).

Working memory. The Lion Game is used as a visual-spatial complex span task to measure working memory (Van de Weijer-Bergsma, Kroesbergen, Prast, & Van Luit, 2014). Children have to remember the last location of an increasing number of lions in different colors and click on that location when the screen is empty in five levels of four items. The children see a screen with 16 bushes in a 4x4 matrix. In the first level only one color has to be remembered and in every additional level an additional lion has to be remembered. The tasks mostly taps into updating skills, but probably also into set shifting and inhibition, because of the different colors used and the ability to inhibit the previous shown locations. The total score consists of proportion correct recalled items in the correct order. The internal consistency varies between α = .82 and .86 and test-retest reliability scores vary between .64 and .80 (Van de Weijer-Bergsma et al., 2014).

Mathematical creativity. To measure mathematical creativity the mathematical creativity test is used which consists of five open-ended mathematical tasks which have multiple solutions (Kattou et al., 2013). The tests ultimately leads to four different scores; a fluency score (total correct answers), a flexibility score (total use of distinctive solutions), a creativity score (answer that peers did not provide) and a total score which combines the three scores. The total score is used in this study. The internal consistency is Cronbach's α = .78 (Kattou et al., 2013). To assess inter-rater reliability the tests of 10 children were copied for three raters. The three raters were in agreement regarding 90 out of the 100 scaled scores. Cohen's kappa was calculated with this data, and found to reflect a high level of inter-rater agreement (K=.91).

Mathematical performance. To measure mathematical performance the *CITO* test mathematics is used. This is a test used in Dutch schools to keep track of the performance of individual students using the CITO student follow-up system. These tests are used throughout the whole country and performed twice a year. Different scores are measured; a raw score (total correct answers) and a skill score, this last one is used in the current study. By using norm scores, the level of mathematical performance can be calculated. The internal consistency was calculated for the CITO scores medium fourth grade and is Cronbach's α = .94 (CITO, 2015).

Procedure

Participants were recruited through a longer standing arrangement with ten primary schools in Amersfoort, the Netherlands. All parents of the students in fourth grade were given an informed consent letter. The procedure was approved by the ethical committee of the Faculty of Social Sciences of the Utrecht University. A total of 340 children were eligible, but only 262 received parental consent. Due to missings in the data, data of only 68 children were used in this study.

Prior to starting the different tests the children were told that the tests would be used to study the different ways that children learn. The participants did not receive any compensation for participating. No risks were involved for participants. This study was part of a larger project in which 9 tests were administered. Four different tests were conducted classwise and five more in small groups of four or five children on a computer outside of the classroom. First of the children made two subtests of the NIO, for 15 minutes. Next, the Test for Creative Thinking – Drawing Production was administered, a test for creativity for 15 minutes. After this the mathematical creativity test was conducted for 45 minutes. The last classwise test was a questionnaire about *beelddenken* [visual-spatial thinking]. At most schools all the tests were administered in one session, but at some schools the test to measure mathematical creativity was conducted after a short break. Following the session was a break and after the break groups of four or five children were taken outside of the classroom to conduct the computer tests.

The first two computer tests, tested the working memory; the lion and monkey game. After that three short number sense tasks were conducted, to measure processing speed and spatial awareness.

Analysis plan

The main objective of this study is to investigate whether working memory and creativity are both predictors for mathematical performance and whether the predictive value is the same in gifted and average performing children. It is expected that working memory plays an important role in both groups and creativity only in the gifted group.

To assess the size and direction of the correlation between the study variables, bivariate Pearson's correlation coefficients (*r*) were calculated. To test the hypotheses two multiple regression analysis were performed. The dependent variables in the first multiple regression analysis were the CITO scores of the averages performing students and of the second the CITO scores of the gifted students. The predictor variables were the scores on the working memory test and the creativity scores of both groups.

Results

Descriptive Statistics

The means and standard deviations for the variables intelligence, mathematics, working memory and mathematical creativity are presented in Table 1 for the average performing and gifted children. The average performing children are the children who had an intelligence score between 31 and 38 (percentile scores between 30 to 70) and the gifted children are the children who scored up and above 42 (percentile scores above 85). These percentile scores were calculated using all children with informed consent, whereas the children that were selected were the ones without any missing data.

Independent-samples t-tests were conducted to test for differences between the two subgroups for the variables intelligence, mathematics, WM and mathematical creativity (see

Table 2). Gifted children scored higher than average performing children on intelligence, mathematics and mathematical creativity. Differences on WM were not significant.

Table 1

Descriptive Statistics

	Average performing children			Gifted children		
	M	*SD*	*n*	*M*	*SD*	*n*
Intelligence	35.15	2.30	41	46.04	3.38	27
Mathematics	85.49	11.07	41	99.15	10.43	27
Working memory	.73	.11	41	.73	.07	27
Mathematical creativity	4.73	1.69	41	6.68	1.96	27

Table 2

Results of Independent Samples t-tests

	95% CI for Mean Difference	*t*	*df*	*p*	Cohen's *d*
Intelligence	9.39, 12.39	14.66	41.72	.01	3.77
Mathematics	8.31, 19.02	5.09	66	.01	1.06
Working memory	-.04, .06	.28	66	.78	.07
Mathematical creativity	1.05, 2.84	4.36	66	.01	1.27

To assess the size and direction of the relationship between the study variables (i.e. intelligence, mathematics score, WM and mathematical creativity) of the subsample with no missing data, bivariate Pearson's correlation coefficients (*r*) were calculated. The results are presented in Table 3.

Intelligence was significantly and positively correlated with mathematics and mathematical creativity. The correlation between WM and mathematics was significant and positive. Mathematics was significantly and positively correlated to mathematical creativity. There were no significant correlations between intelligence and WM and WM and mathematical creativity.

Table 3

Pearson Correlations among the Study Variables

	1.	2.	3.
1. Intelligence			
2. Mathematics	.51*		
3.Working memory	.05	.41*	
4.Mathematical creativity	.45*	.64*	.16

Note: **p* <.01

Regression Analyses

To test the hypotheses regarding the relation between mathematics, WM and mathematical creativity, two multiple regression analysis were performed using the two subsamples of average performing and gifted children. The results are presented in Table 4. The small number of cases have to be taken in account when analyzing the results. Six outliers were left out of the sample, three average performing and three gifted children, as these cases were highly influential on the results. All other assumptions were met.

It was found that WM and mathematical creativity explain a significant amount of the variance in the value of mathematics in both average performing ($F(2,38) = 15.72$, $p < 0.001$, $R^2 = .45$, adjusted $R^2 = .42$) and gifted children ($F(2,24) = 7.15$, $p = 0.004$, $R^2 = .37$, adjusted $R^2 = .32$).

The analysis shows that WM is significantly and positively associated with mathematics in average performing children ($\beta = .46$, $t(36) = 3.75$, $p = .001$) and not significantly associated with mathematics in gifted children ($\beta = .25$, $t(22) = 1.49$, $p = .149$). Average performing children who score higher on WM tend to score higher on mathematics.

Mathematical creativity is significantly and positively associated with mathematics in both average performing ($\beta = .44$, $t(36) = 3.59$, $p = .001$) and gifted children ($\beta = .51$, $t(22) = 3.05$, $p = .006$). Individuals who score higher on mathematical creativity tend to score higher on mathematics. It can be concluded that WM and mathematical creativity are both predictors for mathematic scores in average performing children and mathematical creativity is a predictor for mathematic scores in gifted children.

Table 4

Regression Analyses Predicting Mathematics Score

	Average performing children (N=41)				Gifted children (N=27)			
	B	*SE B*	β	95% CI	*B*	*SE B*	β	95% CI
Working memory	44.71*	11.92	.46	[20.58-68.83]	36.36	24.39	.25	[-13.97-86.70]
Mathematical creativity	2.85*	.79	.44	[1.24-4.46]	2.68*	.88	.51	[.87- 4.50]

Note: * $p < .01$

Discussion

The goal of the current study was to investigate whether working memory and creativity are both predictors for mathematical performance and whether the predictive value is the same in gifted and average performing children to see if there are differences between the constructs underlying mathematical performance in different ability groups. In contrast with suggestions of previous research, WM is positively and significantly associated with mathematics in average performing children and not in gifted children. There was also no difference between the mean scores of WM in both groups. This seems incongruent with previous studies suggesting that children with high abilities seem to have better scores on WM that children with average abilities (e.g. Gathercole et al., 2004). This non-significant association may be due to the fact that there is low variance within the gifted group on WM (SD = .07), which makes it difficult to perform analyses and show effects that are dependent on the variance (Van den Bergh, n.d.). This result was also found by Van de Weijer-Bergsma and colleagues (2015); there was low variance in WM scores in children in grades 4 to 6.

A remarkable result was found regarding the correlation between WM and intelligence. In contrast to earlier results (Colom, Flores-Mendoza, & Rebollo, 2003), there seems to be no correlation between these two constructs. According to Hornung, Brunner, Reuter, and Martin (2011) VSWM and Gf were strongly related constructs. This result is due to the fact that no difference was found between the means of the two groups on WM. These differences could be partly due to methodological differences, use of computerized tests that could be measuring different parts of the WM than the results found earlier.

As suggested by previous studies, mathematical creativity is positively and significantly associated with mathematics in both average performing and gifted children (Mednick & Andrews, 1969). Mathematical creativity is needed for mathematical performance in both average performing and gifted children. Although schools primarily value analytical abilities and memory, creativity and practical abilities are as important to success in life (Sternberg, 2003). Divergent creativity is very important in life; as it is important to efficiently tackle the challenges you meet (Kattou et al., 2013). Creativity may be more important than previously thought and it should be encouraged in students. When teachers invest in the development of mathematical creativity, mathematical ability may be enhanced (Kattou et al., 2013).

Creativity and WM are therefore important for results in average performing students, whereas creativity is most import for results in gifted students. This suggests that different constructs underlie mathematical performance in children of different abilities. It is important to emphasize this result, because creativity is usually not stimulated at schools, whereas it is an important predictor of mathematical performance. An important conclusion that can be drawn is that creativity should be stimulated more in children.

In terms of limitations of this study, the choice of using a convenience sample may not ensure that the results can be generalized to the Dutch population of fourth grade students. Not all the children were allowed to participate in the study because of the use of informed consent. It may be that parents with only a certain set of characteristics gave informed consent.

A second limitation may be that some of the children had motivational problems once reaching a higher level in the tests. Some children got distracted and did not focus on the screen anymore when the test took too long for them. This may have compromised the results.

A third limitation is the use of the NIO to test for intelligence. By using percentile scores, it is not ensured that only gifted children were selected for the sample, above average performing children may have been included in the current sample. Also, the gifted children were only selected based on intelligence scores; creativity and task commitment were not taken into account.

Another limitation is the use of the Lion game to test for VSWM. The predictive value of the Lion game declines with age regarding mathematical performance (Van de Weijer-Bergsma et al., 2015), which is in accordance with the fact that older children generally use verbal WM instead of VSWM (e.g. Friso-van den Bos et al., 2013). This may explain the non-significant relationship between WM and intelligence.

A final limitation is the use of the small sample size (41 average performing and 27 gifted children). A reasonable ratio of cases is needed for a reliable regression analysis. A reasonable “rule of thumb” is using 104 + k (Tabachnick & Fidell, 2007). In the current sample less cases are used, therefore there is a low probability of reproducing these data with another sample.

Conclusion

Generalizations about the entire Dutch population of average performing and gifted fourth graders need to be taken with care, due to the limitations of the study, as these would not be highly accurate. It was remarkable that there was no association between WM and intelligence; a positive association was expected. This result is rather peculiar when taking in account the purpose of the WM, storing and manipulating information. It would be expected that this plays an important role in intelligence, as intelligence is needed so solve problems and to flexibly adapt the thinking to these problems. Future research should focus on the relationship between WM and intelligence to see if these constructs are not associated, as most research suggests they are highly related.

The main goal of this study was to further explore the differential associations between WM, creativity and mathematical performance in both average performing and gifted students. It seems that creativity and WM are predictors for mathematical performance in average performing students, whereas only creativity is a predictor in gifted students. However, these results need to be verified with more representative samples. Further extensive research is needed on the underlying constructs of mathematical performance in children to conclude which constructs are responsible for performance.

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