The Importance of Updating and Inhibition in Mathematical Performance

Research on the relationship between verbal- and visual-spatial updating, inhibition, and mathematical performance in children aged 8-12.

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Abstract

Background: According to research, mathematical performance is strongly related to executive functions (EFs). Children at risk for mathematical problems could be detected early on by analyzing their EFs. However, no consensus has been reached regarding the exact relationship between the EFs (verbal updating (VU), visual-spatial updating (VSU), and inhibition) and mathematical performance. Also, if advanced EFs relate to advanced mathematical performance, like poor EFs do to poor mathematical performance, more emphasis on establishing good EFs could be placed in the classroom practice. **Method:** First, this study examined if children with advanced VU and VSU skills also showed advanced mathematical performance. Second, the relationship between advanced inhibition and advanced mathematical performance was researched. Third, the relationship between advanced VU, VSU, and inhibition skills was examined. Lastly, the study analyzed the predicting part of VU, VSU, and inhibition skills in mathematical performance. **Results:** No significant results were found regarding the relationship between (advanced) EFs and mathematical performance or between advanced VU, VSU, and inhibition scores. This study did, however, find a positive relationship between VU and VSU/inhibition. **Conclusions:** The relationship between advanced EFs and mathematical performance was not found. This implies that EFs are important up to a certain level, but other factors are involved when reaching excellence. Future research should focus on the different factors that contribute to reaching advanced mathematical performance and the possible difference of importance of EFs with age.

Keywords: mathematical performance, verbal updating, visual-spatial updating, inhibition.

Word count: 239

The Importance of Updating and Inhibition in Mathematical Performance

Not only in the workplace, but in multiple aspects of our everyday life (e.g. for cooking and grocery shopping) understanding and using mathematics is indispensable (Ferrini-Mundy & Martin, 2000). Education is designed to prepare children for this demand. Although not all children acquire the same level with schooling, mathematical education has the intention to give children enough proficiency to effectively participate in society (SLO, 2009).

From the moment children start formal schooling, they develop arithmetical skills (Bull & Lee, 2014). The way mathematical performances progress, is influenced by a number of factors (Bull, Espy, & Wiebe, 2008). For example: early numeracy skills (Aunio & Niemivirta, 2010; Bull & Lee, 2014), child motivation and teacher instruction (Aubrey, Dahl, & Godfrey, 2006). Recently, more emphasis has been put on the influence of cognitive capacities on academic performance in general, hence also for mathematical performance. A combination of knowledge and cognitive structures may provide a good estimate of the child's ability to learn (Gathercole, Alloway, Willis, & Adams, 2006). Gathercole et al. (2006) and Gathercole, Lamont, and Alloway (2006) argue that children with low cognitive capacities may not meet the demands of learning activities, resulting in missed learning opportunities and practicing skills in all subjects.

Many studies report that executive functions (EFs), crystallized intelligence, and processing speed directly influence mathematical performance (e.g. Cragg & Gilmore, 2014; Espy et al., 2004; Mazzocco & Kover, 2007; Taub, Keith, Floyd, & Mcgrew, 2008). However, after controlling for processing speed (Clark, Sheffield, Wiebe, & Espy, 2012) and crystallized intelligence (Bull, Espy, Wiebe, Sheffield, & Nelson, 2011), EFs are still strongly related to mathematical performance. EFs are processes that control and regulate thought and action (Friedman et al., 2006). EFs include inhibition (e.g. inhibiting impulses enabling goal-directed behavior), shifting (e.g. replacing irrelevant strategies by more appropriate ones), and updating (e.g. controlling and updating mental representations; Bull et al., 2008; Diamond & Lee, 2011; Miyake et al., 2000). Deficits in EFs could influence engaging behavior in class negatively (Fitzpatrick, 2012). Consequently, well-developed EFs provide an advantage in the development of mathematical skills (Bull, Espy, & Wiebe, 2008; Espy et al., 2004).

Multiple studies have looked into the individual contributions of EFs on mathematical performance (e.g. Bull & Scerif, 2001; Miyaki et al., 2000). They have, however, not reached a consensus. Contesting findings regard implications of inhibition as the only accounting factor (Espy et al., 2004), updating as a unique contributor (Lee, Bull, & Ho, 2013; St. Clair-

Thompson & Gathercole, 2006), and both updating and inhibition as predictors of mathematical performance (Bull & Lee, 2014; Monette, Bigras, & Guay, 2011). Yeniad, Malda, Mesman, IJzendoorn, and Pieper (2013) also report a relationship between shifting and mathematical performance, they have however, not been able to differentiate the exact influence of shifting when considering its correlation with intelligence. Davidson, Amso, Cruess, Anderson, and Diamond (2006) argue that shifting has not been fully developed until children are 13 years old.

Several possible explanations for contrasting results on inhibition are reported. Firstly, Davidson et al. (2006) report that inhibition is already shown by younger children as long as rules remain constant. Lee et al. (2013) and Van der Ven, Kroesbergen, Boom, and Leseman (2012), on the other hand, argue that inhibition is not yet a separate skill in primary school children. In lower grades, mathematical tasks are less complex. It is therefore possible that those tasks do not require children to inhibit irrelevant information (Toll, Van der Ven, Kroesbergen, & Van Luit, 2011). The importance of updating and inhibition in mathematical performance is consistently being reported (e.g. in Bull & Lee, 2014). However, the exact contribution, especially at advanced level, has not yet been determined. The current study will focus on the relationship between mathematical performance, inhibition, and updating in 8-12 year-olds.

Updating

Updating includes the process of encoding and evaluating incoming information for relevance to the task at hand and the subsequent reconsideration of the information held in memory (Bull et al., 2008; Carretti, Cornoldi, Beni, & Romanò, 2005; Morris & Jones, 1990). This ability is considered important in order to acquire complex skills during education (Gathercole, Tiffany, Briscoe, Thorn, & ALSPAC team, 2005), especially for mathematical performance (Cragg & Gilmore, 2014). Updating consists of both verbal (VU) and visual-spatial updating (VSU; Friso-van den Bos, Van der Ven, Kroesbergen, Van Luit, 2013).

Updating is regularly referred to as working memory (Bull et al., 2008). While some authors only refer to Baddeley's model of working memory (Baddeley, 1992) when discussing the brain system that provides temporary storage and manipulation of information (Friso-van den Bos et al., 2013). Others, like Cragg and Gilmore (2014) and Willoughby, Wirth, and Blair (2013) use the term working memory, whilst discussing the EF updating. In this research only the term updating will be used to refer to this specific EF.

Inhibition

Inhibition is the skill children use to stay focused and work on tasks (Bull & Lee, 2014). It is the ability to avoid distractions, habits, show self-discipline (Duckworth & Seligman, 2005), and suppress distracting information and unwanted responses (Cragg & Gilmore, 2014; St Clair- Thompson & Gathercole, 2006). Inhibitory control is associated with better learning and behaving in class (Vuontela et al., 2013; Wright, 2006). According to Vuontela et al. (2013) inhibition is clearly detectable in 8-12 year olds.

According to Davidson et al. (2006), young children can already inhibit a dominant response if rules remain constant and the inhibition skills that are required stay the same. However, if inhibition is continued or takes more effort, children experience more difficulties compared to adults. It is therefore explicable that inhibition has been reported as having a relationship with school readiness (Diamond, Barnett, Thomas, & Munro, 2007) and academic performance (Daley & Birchwood, 2010; Duckworth & Seligman, 2005).

Relationship inhibition and updating

Diamond (1998) reports that updating, even though it is required for success, cannot explain success alone. In order to make the relationship between updating and inhibition more clear, it is necessary to regard the unifying function of inhibition (Bull & Scerif, 2011). According to Barkley's model (1997), inhibition is essential for the effective performance of other EFs, which, in turn, influence the quality of inhibition in novel situations (also in Panaoura & Philippou, 2006). When updating demands are high, it is more plausible that inhibiting unsuitable strategies fails (Diamond, 1998). Further research also finds correspondence between advanced updating and inhibition skills (Lan et al., 2011).

Relationship with mathematics

Updating. Research shows that children with poor updating skills also have difficulties with mathematics (Passolunghi & Pazzaglia, 2004). Updating might be important for holding and manipulating relevant information, as well as in the storage and retrieval of partial results (Bull & Lee, 2014; Toll et al., 2011). Therefore, updating is argued to be a good predictor of mathematical performance, especially for complex tasks (Lan et al., 2011; Toll et al., 2011). However, although the relationship between updating and mathematical skills has been established (e.g. Friso-van den Bos et al., 2013), the relationship between advanced updating and advanced mathematical skills has yet to be determined.

Kroesbergen and Van Dijk (2015) report a significant, although possibly different, relationship between both VSU and VU with mathematical performance. According to Friso-van den Bos et al. (2013) and Van de Weijer-Bergsma, Kroesbergen, Prast, and Van Luit

(2015), VU shows the strongest association with mathematical performance. This association may be explained by the different strategies used with verbal and visual-spatial tasks; VU strategies are more frequently involved with problem solving, since subsequent answers in numbers have to be updated and processed (Dehaene, 1997). Kroesbergen and Van Dijk (2015), contrarily, have not found a correlation between VU and problem solving when VSU was taken into account. They also report a significant relationship between poor VSU and poor mathematical performance. Given the fact that both updating skills use different strategies and both are argued to be significant in their relationship with mathematical performance, this study will focus on the updating skills separately.

Inhibition. Avoiding distractions, staying on task and inhibiting responses are important factors of inhibition in academic performance (Daley & Birchwood, 2010). Even though research implies the presence of separate inhibition skills in children (Davidson et al., 2006; St Clair- Thompson & Gathercole, 2006), research is not clear on the influence of inhibition on mathematical performance (Friso-van den Bos et al., 2013).

In mathematics, inhibition may be needed to suppress unsuitable strategies (e.g. not using the strategy for addition, when the strategy for subtraction is appropriate), the retrieval of number associations, or the usage of irrelevant information for solving the problem (Bull & Lee, 2014; Passolunghi & Pazzaglia, 2004). Gilmore et al. (2013) report the influence of inhibition in the relationship between congruent/incongruent tasks and mathematical performance. This might not be detectable when mathematical tasks are relatively simple (Toll et al., 2011). Even though much research has analyzed the relationship between poor inhibition skills and mathematical performance, very little research has been conducted on the relationship between advanced inhibition skills and advanced mathematical performance.

Aim of Research

In this research the following question will be answered: What is the relationship between verbal- and visual-spatial updating, inhibition, and the mathematical performance of children aged 8-12? To answer this research question, the following hypotheses will be tested.

I. There is a positive relationship between advanced VU, VSU, and advanced mathematical performance.
II. There is a positive relationship between advanced inhibition skills and advanced mathematical performance.
III. Children with advanced inhibition skills also are also advanced in VU and VSU.
IV. Part of the variance in mathematical performance can be explained by the independent variables VU, VSU, and inhibition.

Method

Participants

This study's population consists of 376 children aged 8-12. Participants have been obtained from mainstream primary schools in the Netherlands through a convenience sample. A total of eight schools participated. This sample is not restricted to children with diagnosed learning difficulties, therefore the link can be made to the general population. The sample does, on the other hand, exclude children with diagnosed disorders (e.g. ADHD, autism, dyslexia, and dyscalculia), whereas EF-deficits are characteristic for several disorders (Happé, Booth, Charlton, & Hughes, 2006; Rubinsten & Henik, 2009). According to CBS (2015) 2.8% of 2-11 year olds show symptoms of ADHD and of 4-12 year olds 2.8% show symptoms of autism. In this study 50 children (i.e. 13.33% of the sample) have been excluded due to showing symptoms of a disorder. From the sample of primary school children, 158 are from year five (girls n=79, M_{age}=8.84), 115 from year six (girls n=58, M_{age}=9.75), and 100 from year seven (girls n=49, M_{age}=10.80).

Measuring Instruments

Executive functioning skills. Two computerized tasks were used to measure the EF updating: The Monkey game and the Lion game (see Figure 1). The Monkey game (Van de Weijer-Bergsma, Kroesbergen, Jolani, & Van Luit, 2016) is a computerized, backward word span-task. The game consists of five levels with each four items. The first level contains two words and builds up to six words in the fifth level. In each item, after hearing a number of words, children have to remember and recall the words backwards from a list of nine. The results on each item, either correct or incorrect, are combined to one proportion correct score. The Monkey game is a reliable and internally consistent (α =.87) task (Van de Weijer-Bergsma et al., 2016).

The Lion game (Van de Weijer-Bergsma et al., 2015) is a computerized VSU task in which children have to remember the location of the last, for example red, lion. The Lion game consists of five levels with each four items. Lions of different colors appear continuously in a 4x4 matrix of bushes. In the first level children have to remember the location of the last red lion. With each level the difficulty increases until in level five children have to remember the location of the last red, blue, green, yellow, and purple lion. As with the Monkey game, the Lion game combines the results on each item to one proportion correct score. The Lion game has an internal consistency of α =.87 and is test-retest reliable (p = .70 (p<.001; Van de Weijer-Bergsma et al., 2015).

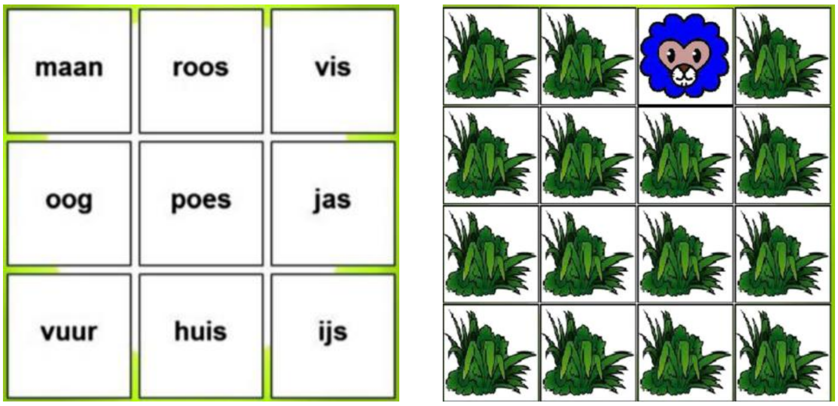

Figure 1. On the left a the Monkey game response format for year 4-8 (Van de Weijer-Bergsma et al., 2016) and on the right a matrix with bushes from the Lion game (Van de Weijer-Bergsma et al., 2015).

The recently developed Fish game was used to measure inhibition. The game is based on the Erikson Flanker task, that requires students to respond to a certain stimulus that is named before starting the task (Erikson & Erikson, 1974). In the Fish game children have the task to feed fish by pressing the correct button. Before each block children receive instruction and feedback on practice trials. The first block consists of 16 neutral, practice trials for familiarization with the task stimuli, and only shows one fish. During the second block five fish appear on screen. Children have to focus on the middle fish. This part of the Fish game consists of 20 congruent and 20 incongruent trials (see Figure 2). In congruent trials all fish swim in the same direction and in incongruent trials the middle fish swims in an opposite direction. In all trials there is a response deadline of two seconds. When the deadline is not reached, children hear a beep. The task takes 7 to 10 minutes to complete. Results on the task show the reaction time and accuracy on neutral, congruent, and incongruent trials. In this research an interference score is conducted by subtracting the congruent accuracy score of the incongruent accuracy score. The Fish game is reliable in this research (neutral trials α=.84; congruent α=.87; incongruent α=.88).

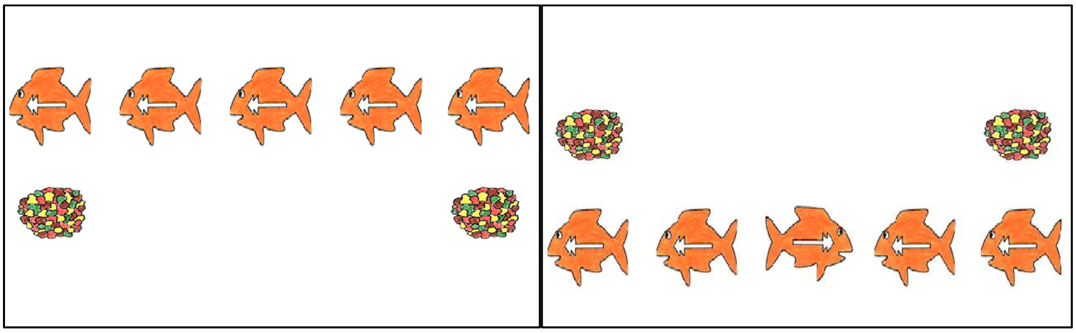

Figure 2. On the left a screenshot of a congruent and on the right of an incongruent trial from the Fish game.

Mathematical skills. To monitor the development of children at primary schools, children complete tests developed by the Dutch Central Institute for Test Development (Centraal Instituut voor Toetsontwikkeling [Cito], Hollenberg & Lubbe, 2017). Cito's are developed for spelling, reading comprehension, vocabulary, and mathematics. For this research, only the ability scores of mathematics were provided by the primary schools. The Cito math test contains age- and year-appropriate exercises regarding numeracy, mental calculation, geometry, and complex applications of mathematics (Cito, n.d.). The reliability coefficient varies from α=.91 to α=.94 between school years 5-7 (Janssen, Verhelst, Angels, & Scheltens, 2010).

Procedure

This study was part of a larger study investigating the relationship between creativity, mathematics, creative mathematical problem solving, and executive functioning with children aged 8-12. In this study all 383 students participated in two test sessions divided over two days. Prior to testing, parents received a consent letter informing them about the aim and content of the study. Only with a returned written consent, children were allowed to participate. There were no risks associated with these tests.

The entire class completed the tasks simultaneously in approximately one hour and 15 minutes the first day and 30 minutes the second day. During that time, teachers completed two-minute-questionnaires about each one of their students. Children also completed three computerized executive functioning tests outside the classroom in small groups in approximately 30 minutes. Ultimately, parents filled in a short questionnaire about their child's creativity, strengths and difficulties, the home environment, and social economic status.

Data analysis

To answer the research question and associated hypotheses, several tests were used. In this study all tests were considered statistically significant when $\alpha < .05$ at two-tailed level. In order to answer the first three hypotheses, Pearson correlation tests were conducted. Finally, to test whether a part of the variance in mathematical performance can be explained by the independent variables VU, VSU, and inhibition, a standard multiple regression analysis was conducted.

Prior to conducting the analyses, all assumptions were checked. Except for outliers, the data complied to all assumptions regarding multiple regression. Considering that an outlier can drastically influence the value of the correlation (Gravetter & Wallnau, 2013), 50 standardized values over $z = \pm$ 3.29 were excluded from the sample (Field, 2015). Due to incomplete data, another seven participants were excluded. Table 1 shows the sample of 319 participants after the exclusion.

Table 1

Descriptive Analysis of Participants after Exclusion

	n	Boys	Girls	Min_{age}	Max_{age}	M_{age}
Year 5	134	60	74	7.46	10.66	8.84
Year 6	102	51	51	9.05	10.99	9.65
Year 7	83	40	43	9.45	12.26	10.65
Total	319	151	168	7.46	12.26	9.65

Results

The distribution of results on the Monkey Game (VU), Lion Game (VSU), Fish Game (inhibition), and Cito (mathematical performance) are displayed in Table 2. Table 2 also displays the number of children with advanced scores. Scores were considered advanced when children scored above the 75th percentile, which corresponds with a $z > 0.67$. Children from different learning years completed the same tests. Therefore, their scores were first compared to their peers and transferred into standardized scores, after which the scores could be used to compare children between years. From here on participants will not be grouped by their school years, but as part of one sample that is controlled for age.

Table 2

Descriptive Statistics of the Variables Updating, Inhibition, Mathematical Performance

	n	Minimum	Maximum	M	SD	$n_{advanced}$
VU	305	-3.24	2.11	0.00	1.00	81
VSU	291	-2.95	2.03	0.03	0.94	75
Inhibition	306	-3.08	2.35	0.06	0.82	55
MP	295	-2.88	3.15	0.02	0.95	85

Note: VU=Verbal Updating, VSU=Visual-Spatial Updating, MP=Mathematical performance

In order to reach an answer to the first three hypotheses, Pearson correlation tests were conducted with participants that score advanced on at least two variables (Table 3). From the sample of participants 197 scored advanced on at least one variable, however only 77 scored advanced on two or more. Of those 77 participants, 58 scored advanced on two variables, 17 on three variables and two on all four variables.

Table 3

Number of Participants Scoring Advanced Values

	1	2	3	4
1.VU	_			
2. VSU	23	_		
3. Inhibition	20	13	_	
4. MP	29	26	15	_

Note: VU=Verbal Updating, VSU=Visual-Spatial Updating, MP=Mathematical performance

Although reliable research regarding advanced scores is questionable, it was still interesting to conduct exploratory tests to examine the relationship, with and without concentrating on the advanced scores. The results in Table 4 indicate there is no significant relationship between advanced VU, VSU, inhibition, and mathematical performance. The results in Table 5 on the other hand, indicate a significant positive relationship between VU and both VSU and inhibition in general. The effect size is considered small. The results also indicate there is no significant relationships between either EF and mathematical performance.

Table 4

Results of the Pearson Correlation Test Between Advanced Independent Variables and Mathematical Performance (n=77)

	1	2	3	4
1.VU	_			
2. VSU	.07	–		
3. Inhibition	.15	-.30	–	
4. MP	.28	.28	-.23	–

Note. VU=Verbal Updating, VSU=Visual-Spatial Updating, MP=Mathematical performance

* *p* <.05.

Table 5

Results of the Pearson Correlation Test Between Independent Variables and Mathematical Performance in General (n=319)

	1	2	3	4
1.VU	_			
2. VSU	.20**	_		
3. Inhibition	.13*	.09	_	
4. MP	.10	.11	.05	_

Note. VU=Verbal Updating, VSU=Visual-Spatial Updating, MP=Mathematical performance

* *p* <.05. ** *p* <.01.

Table 6 shows the results of the multiple linear regression analysis for predictors of mathematical performance in general. This analysis did not focus on advanced scores. According to the results on the Durbin-Watson statistic d = 0.71 (model 1) and d = 0.68 (model 2) there is no definite reason for concern whether the parameters are good. The results show that none of the predictors are significant, both models explain very little variance in the dependent variable (1, r^2=.004; 2, r^2=.006) and are non-significant (1, F=0.49, p=.61; 2, F=0.50, p=.69). This indicates that VU, VSU and inhibition are no significant predictors of mathematical performance at ages 8-12 years.

Table 6

Predictors of Mathematical Performance in General (n=319)

	Model	*b*	*SE B*	Beta	*p*
1	Constant	0.04	0.06		.47
	VU	-0.04	0.06	-.05	.47
	VSU	0.05	0.06	.05	.43
2	Constant	0.04	0.06		.55
	VU	-0.05	0.06	-.05	.41
	VSU	0.05	0.06	.05	.42
	Inhibition	0.04	0.07	.04	.57

Note: VU=Verbal Updating, VSU=Visual-Spatial Updating

R^2 =.004 for model 1, ΔR^2=.002 for model 2

Discussion

This current study focused on the relationship between VU, VSU, inhibition, and mathematical performance in children aged 8-12. Research is relatively consistent on the relationship between poor EFs and poor mathematical skills (Bull & Lee, 2014). The relationship between advanced EFs and advanced mathematical skills however, has not been researched. Therefore, the aim of this study was to find more evidence on the individual contributions of the EFs on mathematical performance and their relationship with each other on advanced level. If advanced EFs relate to advanced mathematical performance, like poor EFs do to poor mathematical performance, more emphasis on establishing good EFs could be placed in the classroom practice.

First of all, this study showed that advanced VU and VSU scores did not relate to advanced mathematical performance. This is in contradiction to the findings of Passolunghi and Pazzaglia (2004), who found a positive relationship between high memory-updating ability and better performance in problem solving and recalling problems. They did however not find a significant relationship for word span tests, which is the test that was used in this study. Also, Passolunghi and Pazzaglia (2004) found evidence for better scores on average, not for advanced performance. This again indicates that poor EFs correlate with poor mathematical performance. Potentially, several other variables are important when reaching excellence in mathematics.

This study found no relationship between VU, VSU scores and mathematical performance, which is not in line with research either (Friso-van den Bos et al., 2013; Kroesbergen & Van Dijk, 2015; Van de Weijer-Bergsma et al., 2016). None of these researches used Cito-results as a measurement for mathematical performance. Because Cito requires children to not only use their mathematical skills, but also asks for reading comprehension, it could explain the difference between this study's results and other research. Further research should analyze the different requirements of EFs in different mathematical assignments, in order to avoid invalid interpretations of different test results.

Additionally, this study indicated that advanced inhibition accuracy skills do not relate with advanced mathematical performance. Neither does this research confirm a relationship between mathematical performance and inhibition skills in general. Toll et al. (2011) argue that inhibition skills are not needed when mathematical tasks are not complex. However, when children are facing multistep problems with irrelevant information the importance of inhibition grows. But, if this is the case and Cito indeed does not only focus on mathematical performance but also reading comprehension, should this not require more inhibition from children? Perhaps, as Censabella and Noël (2007) point out, is the influence of inhibition not as actively present as theorized?

Gilmore et al. (2013) argue, that not only accuracy, but more specifically the difference in reaction time on accurately-answered incongruent and congruent trials is an indicator of inhibition. It is therefore arguable, that Davidson et al.'s (2006) argument, that children stay constant in their reaction time, but become less accurate, is not of importance in this research. More interesting is, how much more time children need when using their inhibition skills in order to respond correctly on incongruent trials in relation to congruent trials. Further research should focus on the meaning and exact importance of inhibition when performing mathematics.

This study showed that advanced inhibition skills did not relate to advanced VU or VSU. This is in contrast to the research of Lan et al. (2011) and could be due to the small sample of children having both advanced inhibition skills and VU or VSU skills. This research showed a significant relationship between inhibition and VU in general. Indicating that further research should be conducted on the exact relationship between VU and inhibition with a larger sample. Remarkable, is the negative, weak and not significant correlation between inhibition and VSU, which implies that advanced VSU correlates with poor inhibition and vice versa, rather than a positive relationship. This indicates that either inhibition or VSU might be less relevant when discussing EFs and mathematical performance or that both skills develop separately.

Finally, it is argued that inhibition, VU, and VSU are significant predictors of mathematical performance. This study shows that the model does not explain a significant part of the variance in mathematical performance. This is in contradiction to the research of Lan et al. (2011), who found a positive relationship. They however, argued that EFs are differently used when looking at simple math and complex math. And therefore, the relationship may be task-dependent. This is in line with research from St Clair-Thompson and Gathercole (2006), who found a close link between VU, VSU, inhibition, and mathematical performance. Again, further research should focus on the complexity of mathematical tasks and their relationship to EFs.

Limitations

The results of this study must be considered with caution because of several limitations. First of all, considering the small sample size of advanced results, the power of the analyses is constraint and therefore the conclusions that are drawn cannot be generalized to all children aged 8-12. Additionally, when transforming the variables into advanced variables, the number of advanced scores on multiple variables appeared to be small. Although this exploratory study did not provide significant results, further research seems useful to investigate the relations with larger samples.

Furthermore, even though the sample was corrected for age, children who repeated a year were still included in the sample. Therefore the sample is only corrected for year at primary school and not also for age. This might be of negative influence to the validity of the study given the fact that children develop EFs over time (Davidson et al., 2006). It is however argued that EFs are in relation to academic achievement (Gathercole et al., 2006). Children who repeated a year, show poor academic achievement. EFs could therefore be in relation to year, rather than age. Further research should investigate the relationship between EFs and age. Because, if EFs are related to academic achievement, and children who repeat a year show poor EFs, shouldn’t schools focus more on EFs rather than tutoring different subjects to prevent academic failure? Also, if EFs develop over time, it is also possible that children in different school years show different relations. Therefore, further research should also focus on analyzing the difference in EFs for different ages.

In summary, research continuously reports the relationship between poor updating and inhibition skills and poor mathematical performance. The relationship between advanced skills and performance is less examined. This research shows no significant relations between advanced skills and performance. This could indicate that EFs are of influence in a certain way, but more variables influence the advanced outcome of mathematical performance. Meaning, that EFs can be used and developed to increase mathematical performance upto a certain level, but reaching excellence requires more than that (e.g. early opportunities to experience mathematics, intelligence, or teacher instructions). A certain level of EFs seems important to work on task, process incoming information, etc., but after reaching a certain, perhaps average level of EFs, the influence becomes less substantial in the tasks that are given to children. Therefore, research should focus on the exact influence of EFs on mathematical performance and if EFs are indeed the driving factor behind mathematical performance, this could change the way we teach mathematics to our students.

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