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# You can(not) count on me

The role of inhibition and (non-)verbal intelligence in mathematical skills in primary school children from the 3rd, 4th and 5th grade (age 8-12)

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Abstract

It is thought that intelligence and inhibition contribute to mathematical skills. However, conflicting results exist in the literature regarding the relation between inhibition, intelligence and mathematical skills. In addition, research mainly studied general intelligence and was often not focused on the two specific domains (verbal and non-verbal intelligence). To examine the role of these components in mathematical skills in primary school children, current research aims to investigate possible links between inhibition, verbal and non-verbal intelligence and mathematical skills and whether there are interaction-effects between these three components on mathematical skills. Inhibition was measured by a computerized neurocognitive task. Verbal and non-verbal intelligence were measured by two subtests of different intelligence tests. Mathematical skills are measured by the mathematical section of the Citotest. The sample existed of 119 primary school children from the $3^{rd}$, $4^{th}$ and $5^{th}$ grade (age 8-12). First, Pearson correlations showed a significant positive relation between verbal intelligence and mathematical skills. Similarly, linear hierarchical regression analyses showed a positive relation between verbal intelligence and mathematical skills, when controlled for gender and age. However, no relation was found between non-verbal intelligence and mathematical skills nor an interaction-effect between non-verbal intelligence and inhibition on mathematical skills. Of note, there was a significant negative interaction-effect between verbal intelligence and inhibition on mathematical skills. In conclusion, emphasis should be less on inhibition and more on verbal intelligence/skills, as it seems to play an important role in mathematical skills in primary school children. Findings of current study are discussed in this paper.


*Keywords:* inhibition, mathematical skills, (non-)verbal intelligence, primary school children

What role do inhibition and (non-)verbal intelligence play in mathematical skills in primary school children from the 3rd, 4th and 5th grade (age 8-12)?

It appears that having well-developed mathematical skills is much-needed in western societies (Ancker & Kaufman, 2007). In fact, data from a literature review with a wide age span (7-46 years old) and approximately 37.337 participants suggest that having poor mathematical skills has a bigger impact on life chances than having poor literacy (Parsons & Bynner, 2005). Mathematics is necessary in daily life, because it provides individuals with a set of skills, such as problem-solving and abstract-thinking. These skills are essential for understanding the world. An example of daily use of these skills for children is to make choices on how to deal with pocket money and to make sure you arrive on time for sports training (DfES, 2004; Taylor, 2013). Hence, mathematical skills appear to be important in everyday life. However, a study showed that 21% of 11-year-olds who leave primary school did not reach the mathematics level expected from them. Moreover, 5% of children fail to achieve the numeracy skills expected for a 7-year-old child (Gross, 2007). A similar trend can be seen in adults. It is estimated that 20% of adults have numeracy skills below the basic level needed in everyday situations (Williams, Clemens, Oleinikova, & Tarvin, 2003). Underachievement of children in mathematics appears to be a consistent, significant problem (Dowker, 2009).

**Executive functions, including inhibition, in relation to mathematical skills**

A large number of studies show a relationship between executive functions (EFs) and mathematical skills (for example: Blair & Razza, 2007; Kroesbergen, Kolkman, & Bolier, 2009; Kroesbergen, Luit, Lieshout, Loosbroek, & Rijt, 2009; Sikora, Haly, Edwards, & Butler, 2002). EFs refer to underlying cognitive processes that control and monitor actions and behaviors and support goal-orientated behavior (Burgess, 1997). The one EF central in this study is inhibition, because of conflicting results in the literature (Berch, 2005; Bull, Andrews Epsy, & Wiebe, 2008; Jordan, Kaplan, Locuniak, & Ramineni, 2007). Inhibition is the ability to suppress a dominant, automatic or powerful response (Miyake et al., 2000). The other EFs are shifting (the ability to flexibly switch between mental states, tasks and operations) and updating (the ability to incorporate new information in working memory). These subcomponents of EFs are separable but related to each other (Lehto, Juujärvi, Kooistra & Pilkkinen, 2003; Miyake et al., 2000; Nigg, 2006). The studies of Luria (1966) and Stuss and Benson (1986) showed that EFs are important predictors for mathematical achievement. The role of the EF inhibition remains less clear (Berch, 2005; Bull et al., 2008; Jordan et al., 2007). Research of Harvey and Miller (2017) shows that inhibitory control has a unique contribution to children's early mathematical skills (3 and 4 years of age) in the domain of numeracy, arithmetic, spatial reasoning and logical relations/patterning. A study, including children with arithmetic or reading difficulties and those with no academic difficulties showed that children with weaker mathematical skills tend to score weaker on inhibition (Sikora et al., 2002). Other research, among 3 to 6 year old children, also showed that inhibition has a unique contribution to children's early mathematical skills and that inhibition is even a more important predictor for mathematical performance than intelligence (Harvey & Miller, 2017; Kroesbergen et al., 2009). The study of Sikora et al. (2002) also showed a positive relation between inhibition and mathematical skills. Conversely, some studies identified two latent EF skills, the updating and the inhibition-switching factor, and only found that updating was a significant predictor for mathematical achievement in 8 to 13 year old children (Agostino, Johnson, & Pascual-Leone, 2010). The meta-analyses of Friso-van den Bos, van der Ven, Kroesbergen and van Luit (2013) supported these results. In addition, research of van der Sluis, de Jong, and van der Leij (2007) found support for an updating and a shifting factor in mathematical skills, but they failed to load on a common factor of inhibition in their study among 9 to 12 year olds. To conclude, literature shows many contradictions about the effect of inhibition on mathematical skills in primary school children. However, it is expected that there is a positive relation between inhibition and mathematical skills. Because inhibition is the ability to suppress a dominant or automatic reaction which, logically, plays a role in mathematical skills (Miyake et al., 2000).

**Intelligence in relation to mathematical skills**

Another possible underlying factor for mathematical skills is intelligence. Intelligence is defined as the generic mental capacity which, among others, includes (abstract) reasoning, planning, problem solving and gaining new knowledge (O'Reilly & Carr, 2007). Study shows that fluid intelligence is, in particular, involved in mathematical skills (Floyd, Evans, & McGrew, 2003). Several other studies suggest a significant positive relation between intelligence and mathematical skills (Deary, Strand, Smith, & Fernandes, 2007; Eaves, Williams, Winchester, & Darch, 1994). In most of these studies the correlation is found to be moderate (Siegel, 2003). In contrast, other research shows that intelligence does not directly influence mathematical skills in children from the 3rd or 4th grade (Andersson, 2008; Bull & Scerif, 2001). Kroesbergen and colleagues (2009), for example, showed that EFs explained a significant part of variance in children's counting skills, and that intelligence could not add any further explanation to this variance. The role of inhibition and intelligence in mathematical skills in primary school children remains unclear up to now. In addition, intelligence could also be divided in two separate domains, known as verbal intelligence and non-verbal intelligence.

**Verbal intelligence.** It is thought that verbal and mathematical skills are related. The effect of verbal behavior between the teacher and pupil in the learning process of mathematics may explain this relation (Aiken, 1971). Muscio (1963) suggested that high performance on mathematics does not depend on mathematical skills, but depends on high general intelligence and high verbal skills (Wrigley, 1958). Furthermore, there may be a positive relation between verbal and mathematical tests. This can be explained by the common relation of these two variables with general intelligence. Verbal skills that are not included in general intelligence do not seem to be of importance for mathematical performance (Muscio, 1963).

**Non-verbal intelligence.** Research by Kyttälä and Lehto (2008) showed a strong significant relation between non-verbal intelligence and mathematical skills. Non-verbal intelligence was associated with mathematics in general and with both mental arithmetic and geometry (specific mathematical skills), respectively. Other research showed that a linquistic intelligence test was a predictor for later mathematical performance (Kuusinen & Leskinen, 1986). Non-verbal intelligence is associated with knowledge of mathematical concepts (quantitative concepts) and arithmetic ability. Non-verbal intelligence seems to be a good predictor of performance in mathematics skills, which requires knowledge of quantitative concepts and solving word arithmetic problems (arithmetic) (Pina, Fuentes, Castillo, & Diamantopoulou, 2014).

In conclusion, existing literature suggest a relation between both verbal and non-verbal intelligence and mathematical skills, respectively. However, little research into (non-)verbal intelligence and mathematical skills is conducted, or is outdated, which underlines the relevance of studying these specific domains of intelligence in relation to mathematical skills.

**Current research**

Conflicting results exist in literature regarding the relationship between EFs, intelligence and mathematical skills. Several studies have shown that EFs are more important predictors for math performance than intelligence. These studies also found that IQ levels do not directly influence mathematical skills (Kroesbergen et al., 2009) or future academic achievement (Alloway & Alloway, 2010). Of note, however, EFs and intelligence may take part in different mathematical skills, which was studied in 3$^{rd}$ and 4$^{th}$ graders (Andersson, 2008; Bull & Scerif, 2001). Research in college students shows that intelligence and inhibition are positively related (Benedek, Franz, Heene, & Neubauer, 2012). Additionally, the study of Duan (2009) showed that gifted children do have better accuracy, which also indicates a positive relation between intelligence and inhibition. Hence, available literature is not conclusive about the influence of intelligence and EFs on mathematical performance (Lee, Lee, Ang, & Stankov, 2009).

In conclusion, many studies can be found with regard to EFs (including inhibition explicitly), intelligence and mathematical skills. Several studies show that there are positive relations between these three variables (for example: Andersson, 2008; Bull & Scerif, 2001; Kroesbergen et al., 2009; Lee et al., 2009). Other studies show no significant relations between the above mentioned variables (Deary et al, 2007; Eaves et al., 1994; Kroesbergen et al., 2009). Thus, conflicting results regarding inhibition, intelligence and mathematical skills can be found in literature. Furthermore, these variables have not previously been jointly studied in primary school children from the 3$^{rd}$, 4$^{th}$ and 5$^{th}$ grade. Children's mathematical skills are strongly developing during the advanced stage in primary school, so it is important to do research in this age group. Given these conflicting results in the existing literature, the aim of the current study was to investigate the following research question: "What role do inhibition and (non-)verbal intelligence play in mathematical skills in primary school children from the 3$^{rd}$, 4$^{th}$ and 5$^{th}$ grade (age 8-12)?". Based on conflicting results in empirical research on inhibition, (non-)verbal intelligence and mathematical skills previously found in the literature the following hypotheses were posed:

H1: There is a positive relation between inhibition and mathematical skills.

H2: There is a positive relation between verbal intelligence and mathematical skills.

H3: There is a positive relation between non-verbal intelligence and mathematical skills.

H4: There is an interaction-effect between inhibition and verbal intelligence on mathematical skills.

H5: There is an interaction-effect between inhibition and non-verbal intelligence on mathematical skills.

This study may contribute to fundamental knowledge about inhibition, (non-)verbal intelligence and mathematical skills. In addition, this study may have practical relevance. Primary school teachers can use this research to gain more insight into the relations between inhibition, (non-)verbal intelligence and mathematical skills. Possibly, future research can aim at training programs that could contribute to more fundamental help for problems within mathematical skills in children who lag behind in mathematics.

# Method

## Research design and procedures

To investigate the relation between inhibition, (non-)verbal intelligence and mathematical skills a (quantitative) cross-sectional study design was employed. Children participated in two test sessions, which were divided in two days. The two sessions together took about 125 minutes for the children. The current study was part of a larger study investigating creativity, mathematical skills, and EFs. Therefore, not all the performed tests were used for current study. Specific tests which were used for this research will be explained under *measuring instrument* below.

First sessions took place in the classroom and the entire class completed the tasks, individually, at the same time, which took approximately 60 minutes. The second session also took place at and during school. The children performed three computerized tasks individually in small groups (four to six children), for about 35 minutes. There also was a plenary task, of 30 minutes, inside the classroom with all the participating children.

Three individual computerized tasks were used to investigate the executive functioning in primary school children, but results of only one of these tasks were analyzed for current study. Mathematical skill-scores were requested to investigate mathematical skills in primary school children. The conceptual model of this study is depicted in Figure 1.

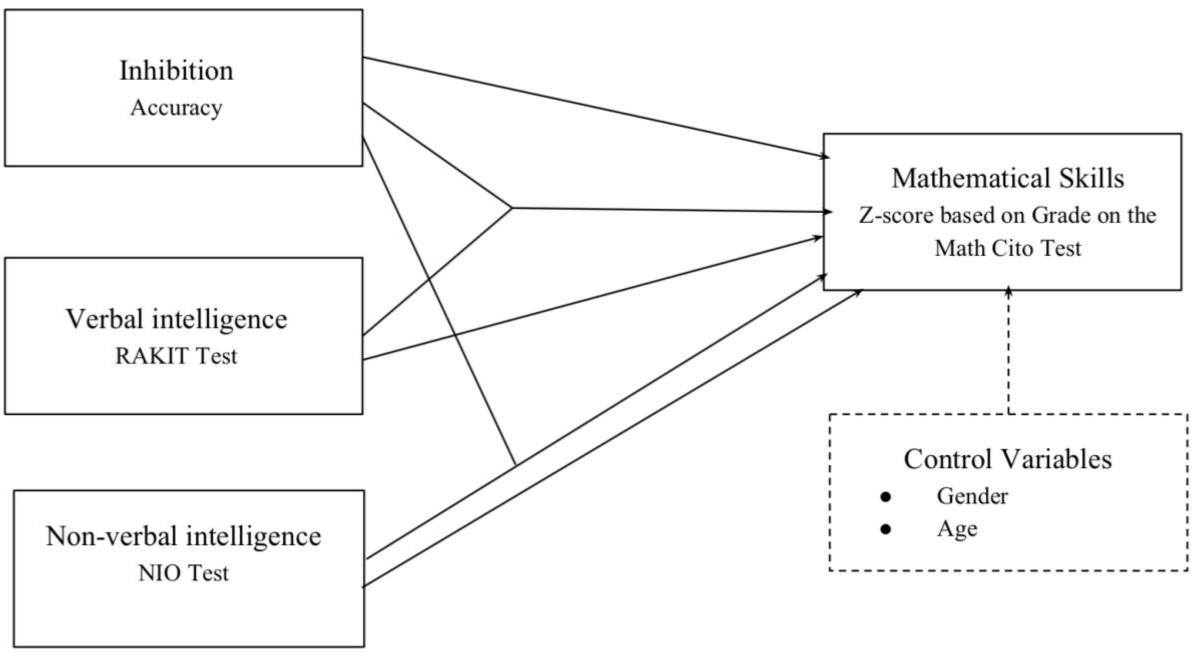


*Figure 1.* Conceptual model of this study.

## Population and sample

This study focused on a population of Dutch primary school children in the 3rd, 4th and 5th grade. The sample consisted of 119 children after removal of the children with missing data on the model variables. Inclusion criteria for participating in this study were (1) aged 8-12 years; (2) participating in regular primary education with or without a mental-, learning or physical disability (since children also attend primary education with certain disabilities and this, therefore, provides a realistic picture of the population); and (3) informed consent from the parents. Exclusion criteria for the schools were emphasis on creative teaching or schools for special education. Active informed consent was obtained by informing parent(s)/legal caregiver(s) about the study and they were given the opportunity to sign a declaration for the participation of their child.

## Measuring instruments

**Inhibition.** Inhibition was operationalized by using the computerized task 'the Fishgame'. The inhibition part of this game is based on the Flanker-task (Erikson & Erikson, 1974). Task instructions were presented on the screen. There are 20 congruent trials (trials where the middle fish is looking the same direction as the other fish), 20 incongruent trials (trials where the middle fish is looking the opposite direction of the other fish) and 16 neutral trial (trials with only one fish), which were randomly presented. Examples of (in)congruent trials follow below.

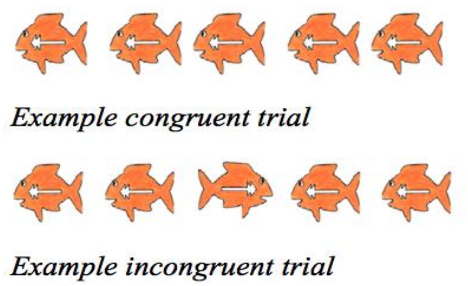


*Figure 2.* Examples (in)congruent trial of the Fishgame.

The response deadline is 2 seconds. The Fishgame exists of two parts and 5 practice trials. During the practice trials, feedback was given about the children's response. The children were told to try to respond as quickly and as accurately as possible. If the children were too slow, they would hear a beep. The duration of the task is 7 till 10 minutes. Outcome measure for the inhibition consisted of average on accuracy (percentage) for the incongruent trials. Only incongruent trials have been chosen, since they make greater use of inhibition in children. The reliability of this test, measured by Cohen's alpha, is between .836 and .878. The reliability for the incongruent trials is .878.

**Verbal intelligence**. Verbal intelligence of the children was measured by using the subtest 'Word Meaning' of the RAKIT (Revision Amsterdam Children Intelligence Test, Dutch: Revisie Amsterdamse Kinder Intelligentie Test). Outcome measure used for verbal intelligence in this study is the total score of the task. The RAKIT is developed for individual use, but is taken in class for this study. This subtest involves 65 multiple choice items. This subtest has a crystallized character and is meant to measure the knowledge of concepts and words. The task increases strongly in difficulty. This task took about 15 minutes, and the children started with assignment 16 (Dek & Kooij, 2012). The Test Affairs Committee Netherlands in Dutch: 'Commissie Testaangelegenheden Nederland' (COTAN) rated the RAKIT as good on all but one criterium, the norms (COTAN, 2017).

**Non-verbal intelligence.** Non-verbal intelligence was measured by using the subtest 'results' of the NIO (Dutch intelligence test for educational level, Dutch: Nederlandse Intelligentietest voor Onderwijsniveau). Outcome measure used for non-verbal intelligence in this study is the total score of the task. This task appeals to spatial awareness. It tests the skills to imagine three-dimensional objects two-dimensional and vice versa. It contains two examples and eight items. For each item five alternatives were given to choose from. The time for this subtest was 10 minutes. The COTAN has rated the NIO good on every component (COTAN, 2017). The reliability of the NIO-total score is .95. The test-retest reliability for the subtest 'results' is .82. This means this subtest is a reliable measuring instrument (Dijk & Tellegen, 2004).

**Mathematical skills.** The outcome of the mathematical section of the Citotest was used to determine mathematical skills of the children. The Citotest is a multiple choice test for primary school children to form an image of the most appropriate follow-up education (Janssen, Scheltens, & Kraemer, 2007). This test consists of different sections which, among others, includes mathematical skills. This section consists of ten mathematical categories, namely arithmic, measuring, time, money, fractions, percentages, decimal numbers, proportions and a combination of these categories. An example question in the category money is: *"Janneke and Karlijn will sell tickets for a theater performance. The tickets cost €3,50. They have raised € 185.50 at the end of the week. How many tickets have they sold?".* Another example of a mathematical question in the Citotest in the category percentages is: *"Two out of five children in our class play hockey. What percentage is that?".* The outcome of the mathematical part of the Citotest is a mathematical skill-score (Centraal Instituut voor

Toetsontwikkeling [Cito], Hollenberg & Lubbe, 2017). The mathematical skill-scores of the Citotest, which they took at the end of last year and halfway through this year, were requested from the teachers by the researchers. The average of these scores was calculated. To take the effect of the grade of the participant into account, z-scores were calculated split by grade. These calculated z-scores were used in this measurement of the level of mathematical skills. Study shows that the Citotest has a good reliability (Janssen, Verhelst, Engelen, & Scheltens, 2010). The Citotest is positively rated by the COTAN, the subtest 'mathematics' is also individually positively rated (COTAN, 2017).

### Validity and reliability

There was a test protocol, as a result of which the tests were taken similarly. The test leaders were trained in conducting and scoring the tests and to interpret the outcomes. Individual computerized tasks were taken (playfully) in a closed, quiet room. These measures were taken for the purpose of obtaining results which are not dependent of external factors and to minimize the impact of unforeseen factors. As mentioned above, active informed consent was obtained. Reliability of the measuring instruments is outlined in the description of the individual measuring instruments.

## Results

Data obtained in the present study were analyzed by employing descriptive statistics, Pearson correlations, and linear hierarchical regression analyses to answer the overarching research question "What role do inhibition and (non-)verbal intelligence play in mathematical skills in primary school children from the 3$^{rd}$, 4$^{th}$ and 5$^{th}$ grade (age 8-12)?".

### Descriptive statistics

Three schools participated, which included 119 children from the 3$^{rd}$, 4$^{th}$ and 5$^{th}$ grade. Table 1 presents the means and standard deviations of age and number of girls and boys per grade. Table 2 presents the means, standard deviations and minimum and maximum score of the measured variables.

Table 1

*Means and standard deviations of age and number of boys and girls per grade*

| | *M* | *SD* | Girls | Boys |
|---|---|---|---|---|
| 3$^{rd}$ grade | 8.26 | 0.51 | 12 | 19 |
| 4$^{th}$ grade | 9.21 | 0.45 | 30 | 26 |
| 5$^{th}$ grade | 10.09 | 0.39 | 19 | 13 |

Table 2

*Means and standard deviations for the independent and dependent variables*

| | *M* | *SD* | Min | Max |
|---|---|---|---|---|
| NIO-score | 27.14 | 5.29 | 17.00 | 39.00 |
| RAKIT-score | 40.26 | 8.44 | 26.00 | 59.00 |
| Accuracy (percentage) | 0.94 | 0.05 | 0.78 | 1.00 |
| Math Cito score | 171.53 | 73.56 | 68.00 | 299.00 |

**Assumptions**

In this study, primary school children from non-randomly selected primary schools participated, making it a select sample. The independent variables inhibition and (non-)verbal intelligence were checked for outliers by means of z-scores. A score with a z-score lower than -3 or higher than +3 was seen as an outlier. Outliers were removed from the dataset. The dataset was also checked on homoscedasticity by using scatterplots. This assumption was not fully met. In addition, the dataset was checked on linear relations between variables and if the assumption of normality was met. This assumption was met, albeit not for accuracy, which means that results with the variable for inhibition must be interpreted with some caution. This may be explained by the ceiling effect of the outcome measure of inhibition. Data was also checked for multicollinearity, which has been met, except for model 3 of the linear hierarchical regression analysis. This may be explained by adding the interaction-effects, since these are based on the individual predictors, which makes it plausible that it correlates (Field, 2015).

**Pearson Correlations**

Pearson correlations, displayed in Table 3, shows the relations between all variables. Only one significant correlation will be discussed. There was a significant positive relation between the RAKIT-score and the score on the Math Citotest ($r = .58$, $p < .001$). This indicated a positive relation between verbal intelligence and mathematical skills and no significant relation between inhibition and mathematical skills or non-verbal intelligence and mathematical skills.

Table 3

*Pearson correlations between the independent and dependent variables*

| | NIO-score | RAKIT-score | Accuracy (percentage) | Standardized Math Cito Score by Grade |
|---|---|---|---|---|
| NIO-score | 1 | | | |
| RAKIT-score | -.01 | 1 | | |
| Accuracy (percentage) | .11 | .04 | 1 | |
| Standardized Math Cito Score by Grade | -.11 | .58* | -.04 | 1 |

Note: * $p$ < .001.

**The effect of inhibition and intelligence on mathematical skills**

The hypotheses of this research were investigated by means of a linear hierarchical multiple regression model. In the first model the control variables age and gender were included. In the second model, the main effects of the NIO, RAKIT and accuracy were investigated. Finally, in the third model, all interaction terms were added. An overview of the results can be found in Table 4.

Model 1 explains 16,7% of the variance in mathematical skill-score and was statistically significant ($F$(2,116) = 11.61, $p$ <.001). Adding verbal and non-verbal intelligence and inhibition explains 55,4% of the variance in mathematical skill-score ($F$(3,113) = 32.72, $p$ <.001). This increase is due to a significant positive effect of the RAKIT-score on the mathematical score. The other two added variables show no significant effect. This suggests that only verbal intelligence has a positive relation with mathematical skills.

Model 3 containing all the interaction terms explains 2% more of the variance in math score and was not significant ($F$(2,111) = 2.82, $p$ =.06). Nevertheless, this model does show trend significance. It can be concluded that there is an interaction-effect between verbal intelligence and inhibition on mathematical skills, but no interaction-effect is found between non-verbal intelligence and inhibition on mathematical skills. Indicating that if verbal intelligence increases, the negative effect of inhibition on mathematical skills decreases (or vice versa).

Table 4

*Results of the linear hierarchical multiple regression model*

| | *B* | *SE* | *Beta* | *t* | *p* |
|---|---|---|---|---|---|
| Model 1 | | | | | |
| Constant | 447.92 | 71.52 | | 6.26 | <.001 |
| Gender | -31.39 | 12.63 | -0.21 | -2.48 | .01 |
| Age | -28.29 | 7.84 | -0.31 | -3.61 | <.001 |
| Model 2 | | | | | |
| Constant | 323.50 | 97.58 | | 3.32 | .001 |
| Gender | -25.42 | 9.41 | -0.17 | -2.70 | < .01 |
| Age | -35.50 | 5.98 | -0.39 | -5.94 | <.001 |
| NIO-score | -0.48 | 0.89 | -0.03 | -0.54 | .59 |
| RAKIT-score | 5.46 | 0.55 | 0.63 | 9.87 | <.001 |
| Accuracy (percentage) | -20.44 | 93.22 | -0.01 | -0.22 | .83 |
| Model 3 | | | | | |
| Constant | -941.20 | 627.89 | | -1.50 | .14 |
| Gender | -29.10 | 9.41 | -0.20 | -3.09 | < 01 |
| Age | -35.42 | 5.91 | -0.39 | -6.00 | <.001 |
| NIO-score | 15.53 | 20.14 | 1.12 | 0.77 | .44 |
| RAKIT-score | 26.37 | 10.36 | 3.03 | 2.55 | .01 |
| Accuracy (percentage) | 1323.43 | 660.91 | 0.91 | 2.00 | .05 |
| NIO-score*Accuracy | -16.83 | 21.18 | -1.23 | -0.79 | .43 |
| RAKIT-score*Accuracy | -22.28 | 11.02 | -2.50 | -2.02 | <.05 |

Note: Model 1: $R^2 = .17$, $p < .001$. Model 2: $\Delta R^2 = .39$, $p < .001$, Model 3: $\Delta R^2 = .02$, $p = .06$.

## Discussion

To gain more insight into the role of inhibition and (non-)verbal intelligence in mathematical skills in primary school children, the present study investigated this particular role in primary school children from the 3rd, 4th and 5th grade (age 8-12). Results suggest a significant positive relation between verbal intelligence and mathematical skills and a significant negative interaction-effect between verbal intelligence and inhibition on mathematical skills. Contrary to what was expected, no significant relation between inhibition or non-verbal intelligence and mathematical skills was found. In addition, no interaction-effect between inhibition and non-verbal intelligence on mathematical skills was found. The most important conclusions and discussion points will be outlined below.

First, a positive relation between inhibition and mathematical skills was expected. No significant relation was observed in this study, which contrasts with results from a research review of 29 studies showed a significant, yet medium-sized, correlation between inhibition and mathematical skills. However, significance decreased when specific type of tests were included (Friso-van den Bos et al., 2013). Because a specific mathematical task was used as measuring instrument, this may explain differing results from the research review and current research. Other research did not found inhibition to be a significant factor in mathematical skills (Agostino et al., 2010; Sluis et al., 2007). This may be explained by several difficulties in executive functioning and not specific inhibition (Shallice & Burgress, 1996). Another possible explanation may be the use of the inhibition-task, which also measured ‘shifting’.

Secondly, a positive relation between both verbal and non-verbal intelligence and mathematical skills was expected. The current study showed a significant positive relation between verbal intelligence and mathematical skills. No significant relation between non-verbal intelligence and mathematical skills was observed. Several studies suggest a significant positive relation between general intelligence and mathematical skills (Deary et al., 2007; Eaves et al., 1994). However, only a moderate relation between these variables was found in other studies (Siegel, 2003). In addition, other studies indicate no direct relation between intelligence and mathematical skills because this relation is probably mediated by executive functioning (Andersson, 2008; Bull & Scerif, 2001; Kroesbergen et al., 2009). A possible explanation for this finding may be the use of measuring instruments for non-verbal intelligence and mathematical skills. Non-verbal intelligence is only measured by one subtask of an intelligence task. This task specifically appealed to the spatial awareness and not on a range of problem-solving skills. In addition, mathematical skills were only measured by the Citotest scores. Little (and/or outdated) research has been done in the separate domains of intelligence in relation to mathematical skills, so little is known about these relations. This study suggests that verbal intelligence is positively related to mathematical skills; children with high verbal intelligence should have better mathematical skills. This may be due to the effect of verbal behavior between the teacher and pupil in the learning process of mathematics (Aiken, 1971). Another possibility is the frequent use of math word problems in primary education and the Citotest. Sufficient verbal intelligence is needed to solve these sums. The contribution of non-verbal intelligence is less important in these kinds of sums.

Thirdly, an interaction-effect between inhibition and both verbal and non-verbal intelligence on mathematical skills was expected. Contrary to what was hypothesized, the current study did not find an interaction-effect between non-verbal intelligence and mathematical skills. These results are in line with some other studies. Research from Kroesbergen and colleagues (2009) showed that EFs explained a significant part of variance in children's counting skills and that intelligence did not add any further explanation to this variance. In addition, there is still debate about the general relation between executive functioning and intelligence; some studies claim there is no such relation, while others found a relation between EFs, inhibition in specific, and intelligence (Benedek et al., 2012; Crinella & Yu, 1999; Duan, 2009; Duncan, Emslie, & Williams, 1996). Moreover, inconsistency of research results may also be explained by the different use of statistical procedures and techniques, such as the use of regression or SEM analysis or by the different populations or measuring instruments for example (Lee et al., 2009). In line with expectations of current research a significant (negative) relation was found between verbal intelligence and inhibition on mathematical skills. This indicates that when verbal intelligence increases the negative effect of inhibition on mathematical skills decreases (or vice versa). Which means verbal intelligence is more important than inhibition in mathematical skills.

The main question of this study was "What role do inhibition and (non-)verbal intelligence play in mathematical skills in primary school children from the 3rd, 4th and 5th grade (age 8-12)?". The answer to this is that verbal intelligence plays an important role in mathematical skills. Current research found a significant positive relation between verbal intelligence and mathematical skills and a significant negative interaction-effect between verbal intelligence and inhibition on mathematical skills. This indicates that verbal intelligence is more important in mathematical skills than inhibition or non-verbal intelligence. Little research has been done into the specific domains of intelligence and the relation with mathematical skills. This research has made a start in understanding the links between (non-)verbal intelligence and mathematical skills.

**Limitations and recommendations for follow-up research**

This study has several strengths. Only children from regular primary schools participated, thereby causing no influence on study results. By following the well-prepared protocol, reliability was also guaranteed. Another strength of this research was the use of measuring instruments with good reliability.

However, current research also has some limitations. Given the limited time frame in which this study was undertaken and workload for the researchers, a select sample was selected. Therefore, results of this study may not be readily generalizable. Repetition of current research or, preferably, follow-up research with a randomized control sample and more participants, may contribute to internal and external validity, reliability and generalizability of the present results. Current research only used a small number of measuring instruments for chosen variables. To obtain a better picture of the construct of (non-)verbal intelligence and mathematical skills, a larger test battery should be put together in follow-up research. Additionally, follow-up research can take place aimed at training programs that could contribute to more fundamental help for problems within mathematical skills in children. Such as, strengthening the verbal abilities of these children. Future research could also focus on an older target group to see if there are differences or similarities between these target groups. Furthermore, the norms of the RAKIT are aged (COTAN, 2017). As a result, outcome results of the subtest ‘Word Meaning’ must be interpreted with some caution. Moreover, not all assumptions were met. The assumption of normality was not met for the variable accuracy, which may be explained by the ceiling effect of the measuring outcome. Also, the assumption of multicollinearity was not met for model 3. This may be explained by adding interaction-effects, since they are based on individual predictors, which makes it plausible that it correlates.

In conclusion, the present study shows a significant relation between verbal intelligence and mathematical skills and a significant negative interaction-effect between verbal intelligence and inhibition on mathematical skills. Teachers who support verbal intelligence may possibly expect a positive effect on mathematical skills in the children. In primary education, mathematics and language are often offered separately. Possibly, a combination of these two components will stimulate and enhance the effect on mathematical skills and/or verbal intelligence. Training programs could focus on integrating language and mathematical skills to enhance children's performance in this area. In conclusion, emphasis should be less on inhibition and more on verbal intelligence/skills, as it seems to play an important role in mathematical skills in primary school children.

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