SUMMARY

Early math skills are a good predictor of later academic success. Finding what factors influence math performance might help educators create better and more efficient math programs. The goal of the present study was to assess the relationship of math achievement and verbal fluency, selective attention, visual-motor integration and inhibitory control. An additional goal was to assess the effect of gender and grade on math achievement.

The sample for this study comprised 210 children from grades 1 to 3 (107 boys, 103 girls). Children were individually administered a math test and tests of various predictor measures. The significant predictors of math achievement were verbal fluency, selective attention, visual-motor integration and inhibitory control. The proposed model explained around 70% of the variance in the math scores. There were no gender differences in the math scores.

Given the fact that all the predictors used in this study are very susceptible to inclusion in instruction, their incorporation in an early age curriculum might significantly improve math skills at a later age.

Key words: math achievement, predictors, school-aged children, gender effects
**BACKGROUND**

Mathematics is one of the most important subjects in the school curriculum. Math abilities are a set of complex skills containing many domains and depending on an integration of a wide range of simpler numerical skills and concepts (Kelley, Hosp, & Howell, 2008; Lyons, Price, Vaessen, Blomert, & Ansari, 2014). Early math skills are a great predictor of later academic success. Studies have shown that math skills in kindergarten predict reading, math and science achievement from kindergarten through to eighth grade (Claesens & Engel, 2013). In a large longitudinal study conducted by Duncan et al. (2006), the authors found that they have the greatest predictive power for later academic success. However, many children have math difficulties. It is estimated that around 6-7% of the school-age population have mathematics disabilities (Fuchs & Fuchs, 2002). Students from disadvantaged families are at an even greater risk of math difficulties. This is best illustrated by the fact that in fourth grade approximately one-third of students from low-income families do not reach basic achievement levels in mathematics (Bachman, Votruba-Drzal, El Nokali & Castle Heaty, 2015). Given the importance of math abilities for later school outcomes, it is of the utmost importance for educators to identify factors that might improve math achievement in early grades. Thus it is of great importance to find out which factors affect math success and to target these factors early in a child’s education, preferably starting in kindergarten. There is a plethora of research that has examined the predictors of math achievement. Some of the factors that were identified to be correlated with math achievement are working memory, processing speed and verbal IQ (Passolunghi & Lanfranchi, 2012) as well as selective attention (Stevens & Bevelier, 2012). In addition to these factors, some non-cognitive factors were also found to be correlated with math skills such as visual-motor integration (Taylor Kulp, 1999) along with some psychological factors that affect math achievement such as anxiety (Ashcraft & Krause, 2007) and motivation (Cleary & Chen, 2009). However, the majority of research on math predictors deals with executive functions (EF). It comes as no surprise given the fact that EF have been studied extensively in relation to education, psychology and neuropsychology over the last 20 years (Memisevic, 2015). Studies examining this link have consistently found a link between working memory and math abilities (Holmes, & Adams, 2006; Reuhkala, 2010). In addition to working memory, another executive function that is related to math achievement is inhibitory control. Lower mathematical abilities were found in children with a lower ability of behavioral inhibition and poor working memory (Bull & Scerif, 2001). From this short overview we can see that many factors affect math skills and finding the best model for predicting math skills can be of great assistance to educators around the world.

Knowing what factors contribute to better math skills will help educators design better strategies in teaching math. The goal of the present study was to examine the relationship of math achievement and several predictor variables.
More specifically, for the purposes of this study we selected the following predictors of math achievement: verbal fluency, inhibitory control, selective attention and visual-motor integration. These predictor variables were selected for two reasons: 1. Previous studies have implicated their association with math skills and 2. All these predictors are amenable to instruction. Moreover, the joint affect of these predictors on math skills remains unknown and it would be very useful to know their independent impact on math skills controlling for other factors. In addition to this, the goal of the present study was to assess math skills in relation to the child’s gender and grade.

The specific research questions in this study are:
• What is the relationship between predictor variables and math skills?
• What is the effect of gender and grade on math achievement in children in grades 1-3?

Method

Participants
The sample for this study consisted of 210 children in grades 1-3 (70 children in each grade, 107 boys, 103 girls) from two schools in the city of Sarajevo. According to the teacher’s report they were free of any developmental disability or other neurological conditions.

Measures

Outcome measure
1. Math achievement test
The outcome measure in this study was math achievement. The math test was the same for all the children and included basic math concepts tasks and calculation tasks as covered by the curriculum for the first and second grades. Children were told to do the tasks that they knew and leave blank the ones they were not familiar with. Thus, we expected to see differences between the first grade students and second and third grade students. This approach allowed a good discrimination in math abilities within the groups as well as between the groups.

Predictors
In this study we used the following predictors: 1. Verbal fluency measured through a semantic fluency and phonological fluency task; 2. A inhibitory control test; 3. A selective attention test; and 4. Visual-motor integration skills.
1. Semantic fluency
Numerous studies examining language and the relationship between language and executive functions have used semantic fluency as an independent variable. In this study we used the semantic category of animals. Children were asked to name as many animals as possible in 60 seconds. The total number of named animals was used as a predictor variable.
2. Phonological fluency

Another test of verbal fluency used in this study was phonological fluency. The procedure is the same as for the semantic fluency task only this time children needed to name as many words as possible in 60s starting with the letter M.

3. Inhibitory Control- Commission errors

The task used for the assessment of Inhibitory Control was a computerized Multiple-Choice Reaction Time Test (Di Nuovo, 2000). In this test, children are required to press the space button on a computer any time they see a star appearing on the screen and to inhibit the response when they see any other object appearing on the screen (go-no/go paradigm). The total number of stimuli presented was 45, out of which 9 are targets. The stimuli were presented randomly to children. The computer program used for this assessment was Attenzione e concentrazione (Di Nuovo, 2000) and had been used previously for measuring inhibitory control in preschool children (Memisevic & Biscevic, 2018). There are four outcome measures on this test: the number of correct answers, the mean reaction time, the errors of omission and the errors of commission. For the purposes of this study we only present the number of commission errors committed as a measure of inhibitory control. Commission errors are seen as a measure of inhibitory control. The other three measures are regarded as the measures of attention control and were not used in this study.

4. Selective attention- Cancellation test

Selective attention was measured through a cancellation test. Cancellation tests are widely used to assess selective attention and visual search abilities. They are commonly used to assess a person’s ability to simultaneously target stimuli while ignoring distracters and these tests tap a wide array of executive function skills such as planning, organizing information, and ignoring irrelevant information (Wu et al., 2017). We used a computerized cancellation task from the program Attenzione e concentrazione (Di Nuovo, 2000). On this task children were asked to cancel out all the stars that appear on the screen. Success in the task is measured through several indices: the number of omissions, the number of correct answers, and the completion time. However, as a predictor variable for this task we used a so-called Performance Quotient (PQ) (Huang & Wang, 2009). This measure accounts for both the speed and accuracy of the performance and was calculated using this math expression:

\[
PQ = \frac{\text{correct responses}}{\text{total target}} \times \frac{\text{correct responses}}{\text{completion time}}
\]

5. Visual-motor integration

Visual motor integration, defined as the coordination of fine motor skills and perceptual abilities, is a very good indicator of a child’s level of functioning and academic performance (Memisevic & Djordjevic, 2018). In this study we used the Purdue Pegboard Test (Tiffin, 1948). In this test children are required to insert 25 keys into the holes. The time needed to finish the task was used as a predictor variable.
Procedure

We selected two elementary schools in Canton Sarajevo and provided teachers with the consent forms for the children’s parents. Although the schools were not randomly selected, we have no reason to believe that they are in any way different from the rest of the schools in the Sarajevo Canton. After the consent forms were returned, we tested the children on the tests described above. We tested a total of 210 children (70 children who were attending first grades, 70 children attending second grades and 70 children attending third grades). All the children were tested individually, in the morning hours, in the classrooms that were available for the testing. The order of testing was the same for all children. The approval for this study was obtained from the Canton Sarajevo Ministry of Education and the Ethical Committee Board at the Faculty of Educational Sciences at the University of Sarajevo. Only children with written parental consent were tested.

Statistical analysis

Descriptive results (means and standard deviations) are presented for 1st, 2nd and 3rd grade students – both boys and girls. To answer the first research question we performed a multiple regression analysis. For the second research question, we performed a two-way analysis of variance (ANOVA). An alpha level of .05 was used for all the statistical tests.

RESULTS

Our first research question was to examine the effects of various predictors on math scores. In order to answer this question, we performed a multiple regression analysis for predicting math scores. The results are shown in Table 1. This model was statistically significant (F=38.96; p<.001) and explained around 70% of the variance in the math scores.

Table 1. A multiple regression analysis predicting math achievement

<table>
<thead>
<tr>
<th>Predictors</th>
<th>B</th>
<th>SEB</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>0.18</td>
<td>.06</td>
<td>.17</td>
<td>3.2</td>
<td>.002</td>
</tr>
<tr>
<td>SF</td>
<td>0.53</td>
<td>.10</td>
<td>.30</td>
<td>5.03</td>
<td>.001</td>
</tr>
<tr>
<td>INH CON</td>
<td>-0.51</td>
<td>.18</td>
<td>-.14</td>
<td>-2.75</td>
<td>.006</td>
</tr>
<tr>
<td>PF</td>
<td>0.83</td>
<td>.16</td>
<td>-.30</td>
<td>5.0</td>
<td>.001</td>
</tr>
<tr>
<td>VMI</td>
<td>-.05</td>
<td>.02</td>
<td>-.17</td>
<td>-3.04</td>
<td>.003</td>
</tr>
</tbody>
</table>

Note. R²=.70 (unadjusted), R²=.48 (adjusted). SA- selective attention; SF- semantic fluency; INH_CON- inhibitory control; PF- phonological fluency; VMI- visual motor integration.

Table 2. Mean math scores in relation to children’s grade and gender

<table>
<thead>
<tr>
<th>Math mean scores</th>
<th>First grade</th>
<th>Second grade</th>
<th>Third grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Boys</td>
<td>22.6</td>
<td>5.7</td>
<td>32.5</td>
</tr>
<tr>
<td>Girls</td>
<td>21.3</td>
<td>7.6</td>
<td>31.6</td>
</tr>
<tr>
<td>Total</td>
<td>21.9</td>
<td>6.7</td>
<td>32.1</td>
</tr>
</tbody>
</table>
Table 3. Summary of two-way ANOVA for grade and gender effect on math

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1</td>
<td>13.1</td>
<td>13.1</td>
<td>.004</td>
<td>.95</td>
</tr>
<tr>
<td>Grade</td>
<td>2</td>
<td>5703.2</td>
<td>2851.6</td>
<td>95.2</td>
<td>.001</td>
</tr>
<tr>
<td>Gender*Grade</td>
<td>2</td>
<td>146.7</td>
<td>73.3</td>
<td>2.45</td>
<td>.09</td>
</tr>
<tr>
<td>Within cells</td>
<td>204</td>
<td>6109.1</td>
<td>29.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>209</td>
<td>11948.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Our second research question was to examine the effects of gender and grade on math achievement. We first present the descriptive results of the math scores for boys and girls in each grade (Table 2).

We then performed a two-way ANOVA test to see whether gender and grade and their interaction had an effect on math achievement. These results are shown in Table 3.

We can see that grade had a significant effect on math (p<.001), but not gender and the interaction of gender and grade (both p’s>.05). However, the interaction effect of gender and grade, although not statistically significant, appears to have some effect. To illustrate this better, we presented these results in Fig. 1.

We can see that the trends in math achievement are very similar in both boys and girls for the first and second grades. However, the difference seems to appear in the third grade. Again, this difference did not reach a statistical significance (p=.06), but we see a different trend in math development for boys and girls in the third grade.

As the two factorial ANOVA showed, math scores results were statistically significant depending on the grade of the student (F=95.2, p<.001). Thus we...
next performed the TukeyHSD test to examine where these differences are. The results are shown in Fig. 2.

We found statistically significant differences in math achievement between students in grade 1 and grade 2, and students in grade 1 and grade 3. However, there were no statistically significant differences in math achievement between students in grade 2 and in grade 3.

DISCUSSION

The goal of the present study was to examine the effects of several predictors on math achievement. An additional goal was to assess the effects of gender and grade on math achievement. All the predictors we used were significantly correlated with math achievement. Predictors with the largest impact on math achievement were both measures of verbal fluency: semantic fluency and phonological fluency. It is surprising that there are virtually no studies examining the relationship between verbal fluency and math achievement. Earlier studies focused on the relationship between verbal IQ and math (Passolunghi & Lanfranchi, 2012), but researchers have not paid enough attention to verbal fluency. Given the strength of association between verbal fluency and math achievement, it seems warranted to further explore this link and to focus more on verbal fluency skills in preschool years. This might lead to better math skills in elementary school and lead to overall academic success. In addition to verbal fluency, we also found selective attention and visual-motor integration to be significantly related with math skills. Earlier studies have found a link between sustained attention and math performance (Anobile, Stieveno, & Burr, 2013). The results of our study support the claim that different domains of attention deficits, including se-
lective attention, can be implicated in math disabilities. The good thing is that selective attention is very susceptible to training and this training can start at a preschool age. Many simple physical exercises can have a great impact on improving selective attention (Diamond, 2015). This, in turn, can also contribute to better math skills at school age. The relation between visual-motor integration and math performance has also received a lot of scientific attention. Studies have shown that better visual-motor integration skills are related with better math performance (Cameron et al., 2016; Sulik, Haft, & Obradović, 2018; Pachalska, Mac-Queen, Ciełebak, 2018). This finding was confirmed in our study as well. There are two possible explanations for the link between visual-motor integration and math skills. Given the complexity of visual-motor integration, requiring good fine motor skills, visual perception and motor coordination, it is quite possible that these skills are dependent on the same neural correlates as the math skills and that they are actually developing together (Braddick et al., 2016; McClelland & Cameron, 2018). Another, equally likely explanation is the possible mediating role of working memory in the relationship between visual-motor integration and math skills. It has been shown that visual-motor integration and working memory are strongly correlated (Memisevic & Sinanovic, 2013) and it is possible that visual-motor integration exerts its influence on math performance through working memory. This claim needs to be examined in future studies to determine the effect of visual-motor integration on math performance while controlling the influence of working memory. The predictor that had the small impact, although still statistically significant, on math achievement was inhibitory control. Studies to date have shown that inhibitory control is related to math achievement (Keller & Libertus, 2015; McClelland et al., 2007), a finding which was also confirmed by our study.

As for the second research question on the effect of gender and grade on math achievement, the results of this study were expected. We found no gender differences in math scores between boys and girls across grades. Given these results we cannot confirm some earlier findings that gender stereotypes impair girls’ performance on math tasks from kindergarten to grade 2 (Tomasetto, Alparone, & Cadinu, 2011). It is necessary to conduct longitudinal studies to determine the approximate age at which significant differences in math performance start to appear between males and females, if there are in fact any differences. However, it is a fact that males dominate the academic staff at U.S. universities in the field of math but this is by no way a proof that males are superior to females in the field of math (Spelke, 2005).

Overall the model for predicting math achievement described here was highly statistically significant and was able to explain around 70% of the variance in math scores. In order to improve this model, future research should incorporate measures of working memory as well, especially to control for the effect of visual-motor integration. We also found verbal fluency to be highly correlated with math scores and future models should include this measure for predicting math achievement. This study can have great implications in teaching practice as all the predictors we used in this study are highly susceptible to instruction. Thus,
early intervention in all these areas: verbal fluency, selective attention, visual-motor integration, and inhibitory control can have an immense positive effect on future academic success.

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REFERENCES


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