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Spatial thinking and memory in Russian high school students with different levels of mathematical fluency

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Abstract

In the current study Russian high school students with different levels of mathematical fluency were asked to complete the Mental Rotation Task and the Corsi Block-Tapping Task. We found significant differences between the groups with different levels of mathematical fluency in efficiency of spatial thinking and the level of visuo-spatial memory. Also, we revealed differences in the number and density of the relationships within the structure of spatial memory and thinking between the groups with different levels of mathematical fluency. Gender had a minor effect on the number of correct answers.

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Keywords: spatial thinking; mental rotation; spatial memory; mathematical fluency; gender differences; high school age.

1. Introduction

Research on mathematical fluency, the ability to perform basic mathematical operations quickly and accurately (Haughton, 1980), is of great social and practical importance due to the requirements of state educational standards. It has been shown that individual differences in mathematical fluency at school age are associated with success in mathematical disciplines (Singer-Dudek & Greer, 2005). At the same time, it is necessary to focus on cognitive functioning of students with different levels of mathematical fluency. The existing studies emphasize the importance of spatial thinking and spatial memory (Bull, Espy, & Wiebe, 2008).

The most informative indicator of spatial thinking in the context of the relationship with mathematical success is

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mental rotation (Shepard & Metzler, 1971). It was found that mental rotation performance predicts success in many mathematical disciplines, for example geometry (Delgado & Prieto, 2004).

In the context of the relationship with mathematical success, spatial memory has traditionally been considered as a component of the working memory associated with the processing of shapes of stimuli and their location in space; it can be measured with tasks, in which a participant is asked to recall a particular sequence of objects (Baddeley & Hitch, 1994). A number of studies have indicated that low success rates in solving mathematical tasks correlate with the low scores on spatial memory in the Corsi Block task (e.g., Bull, Johnston, & Roy, 1999). It was also shown that the spatial memory performance can be associated with various aspects of mathematical knowledge – from understanding arithmetic operations to assessing non-symbolic quantities (e.g., Zorzi, Priftis, & Umilta, 2002).

It should be noted that the studies of sex differences in spatial thinking consistently ascertain the superiority of men in the Mental Rotation task with the effect size of one standard deviation (Halpern, 2000). It is also noted that the gender effect on the Mental Rotation scores is the most significant among various cognitive measures.

Thus, the theoretical analysis showed 1) the importance of studying spatial thinking and memory and their relationship with speed indicators of mathematical success; 2) the relevance of the study on an extended sample of high school students; 3) the need to assess the effect of gender on the performance on the Mental Rotation task and the Corsi Block task. Accordingly, the main purpose of our study was to examine the structure of the relationships between spatial thinking and memory in groups of students of the senior school age with different levels of mathematical fluency.

2. Methods

2.1. Participants

The sample included 426 students (48.8% male) of 9th grades of Russian educational institutions aged from 14.50 to 17.75 years (mean = 15.77, SD = 0.38). Data collection was conducted in educational institutions strictly following the protocol under the constant supervision of a researcher. Analysis of the results was carried out on the basis of anonymized personal data.

2.2. Procedure

The participants were administered a Russian-language online version of the test battery Spatial Abilities developed by InLab (Goldsmiths, University of London) and adapted at the Russian-British laboratory of behavior genetics at the Psychological Institute of Russian Academy of Education. The test battery includes a number of tasks aimed at measuring the level of cognitive performance and mathematical fluency (Tosto et al., 2013).

Problem Verification Task (PVT), mathematical fluency. The test includes two training tasks and 48 test tasks involving solved arithmetic examples. The participants had to decide whether the answer was correct or not and press the appropriate key on the keyboard within 10 seconds. If no response is given in time, the program automatically goes to the next task, and the answer is defined as incorrect. The computer program records the number of correct answers.

Corsi Block-Tapping Task, visuo-spatial memory. The participants were presented a set of square blocks lighting up one after another. The test begins with a sequence of 4 blocks; the maximum possible number of elements in a sequence – 9. During the presentation the blocks light up for 1 second at intervals of 1 second. The participants were asked to repeat the presented sequence by clicking the blocks with a computer mouse. The test is automatically discontinued if a participant does not correctly reproduce the sequences at a particular level of difficulty. The program records the number of correct answers.

Mental Rotation Task, spatial thinking. In this test the participants were asked to decide which of the pictures at the bottom of the screen is a replica of the ‘target’ at the top of the screen. The participants were asked to solve as many tasks as possible within 3 minutes. The test consisted of 7 training tasks with feedback and 181 test tasks presented with an interval of 1 second. It is assumed that not all the tasks can be completed within this limited time period. The program records the total number of completed tasks and the number of correct answers.