Visual processing and attention abilities of general gifted and excelling in mathematics students

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University of Haifa, Haifa, Israel, rozal@edu.haifa.ac.il

The present study examined the visual perception and attention abilities associated with general giftedness (G) and excellence in mathematics (EM). The research involved four groups of 16–18 years old participants varying in levels of G and EM. 190 participants were tested on a battery of visual processing tasks: visual-spatial memory (VSM), visual speed of information processing (SVIP),Visual-perception (VP) and Visual attention (VA). The results support the notion that the differences between the groups are task depended. On the VSM (Backward visual-spatial memory span) test, differences in performance were associated only with EM factor, while on the visual-perception (Pattern-recognition test) and attention (D2-CP score) tests only the G factor had a main performance effect. SVIP was associated with both G and EM factors.

Keywords: Visual processing, attention, visual speed of information processing, visual-spatial memory, giftedness, excellence in mathematics.

INTRODUCTION

The literature regarding visual processing and attention, in relation to both general G and EM, is limited. Up to now, most studies have examined G and EM factors separately, while leaving out EM students who are not gifted (Benbow & Minor, 1990) or G students who are not EM (e.g., Johnson et al., 2003; Zhang, et al., 2006). This study is part of a larger investigation aimed at defining mathematical-giftedness in mathematics. In a previous study (Leikin, Paz-Baruch, & Leikin, 2013; Paz-Baruch, Leikin, Aharon-Peretz, & Leikin, 2014) we compared relations between G and EM factors and other cognitive abilities such as: memory and speed of processing abilities. In this study, we examine these same relations with regard to visual processing and visual attention abilities.

BACKGROUND

Visual processing, giftedness and excellence in mathematics

Generally, visual processing ability is defined as the ability to generate, store, retrieve and transform visual images and sensations; visual processing is also related with the ability to recall the location of stimuli or to recall, identify or reproduce a design (McGrew, 2009).

Several studies suggest that visual speed of information processing (SVIP) abilities are related to intellectual giftedness (Dark & Benbow, 1991; Jensen, Cohn, & Cohn, 1989; Kranzler et al., 1994). Research has also demonstrated that visual-spatial ability is associated with general intelligence and academic achievement (Johnson & Bouchard, 2005). Gifted children have been found to respond more quickly than those with average IQ on a variety of SVIP (Deary, 2000; Duan, Dan, & Shi, 2013; Johnson et al., 2003) and visual-spatial tasks (Rizza, McIntosh, & McCunn, 2001).

Studies also showed a connection between SVIP and mathematical performing. Taub and colleagues (2008) demonstrated that visual processing speed is significantly related to quantitative knowledge for children. Moreover, Fuchs and colleagues (2006) found that in a group of third grade children, processing speed was a predictor of arithmetic ability when assessed by crossing-out tasks, and perceptual motor speed tasks. Geary (2011) revealed that processing speed, predicted achievement in mathematics, especially in numerical operations.

The ability to understand visual representations is considered by researchers as an important tool for mathematical learning and problem solving (Deliyianni, Monoyiou, Elia, Georgiou, & Zannettou, 2009). Excelling in mathematics students understand the problem by constructing and employing a diagram or a picture to help obtain a solution (Bishop, 1989).

Visual attention, giftedness and excellence in mathematics

The relationship between measures of attention and intelligence has been investigated repeatedly (e.g., Crawford, 1991; Rockstroh & Schweizer 2001; Schweizer, Zimmermann, & Koch, 2000; Schweizer & Moosbrugger, 2004). Few studies examined connection between sustained attention or divided attention and intelligence and showed that they are correlated with intelligence (Scheweizer et al., 2000; Schweizer & Moosbrugger, 2004). Being able to maintain attention for a long time at a high level is important whenever complex mental activities are to be performed, like problem solving and reasoning, which are closely associated with intelligence (Schweizer & Moosbrugger, 2004). Gifted individuals have swifter access to relevant knowledge due to faster automation of thought processes. As a result of which, they retain available attention capacity to tackle additional tasks (Memmert, 2008). Correlation between intelligence and divided attention depends on the tasks to be performed. Higher demanding tasks seem to yield higher correlations between measures of attention and intelligence than less demanding tasks (Scheweizer et al., 2000).

Most of the literature about mathematical ability and attention focus on children with learning disabilities and on the inhibition of irrelevant stimuli. Children who are less proficient in math have difficulties to suppress irrelevant information under high processing demand conditions (e.g., De Beni et al., 1998; Swanson, 2006). Anobile, Stievano, and Burr (2013) showed that attention and numerosity perception predict math scores. Individuals with higher math ability have less difficulty than average achievers in reducing accessibility of less relevant information that could overload and interfere during processing (Agostino, Johnson, & Pascual-Leone, 2010).

Accordingly, the goal of this study was to examine the connection between visual processing, attention and G and EM factors. We examined the hypothesis that G and EM factors are related differently to different visual processing abilities.

METHOD

Participants

We report herein our findings on 186 10th–12th grade students (16–18 years old) right-handed male and female students who were recruited for the study (see Table 1). The participants were subdivided in four experimental groups, determining the research population by a combination of EM and G factors: G-EM group: students who are identified as generally gifted and excelling in mathematics; G-NEM group: students who are identified as generally gifted but do not excel in mathematics; NG-EM group: students excelling in mathematics who are not identified as generally gifted; NG-NEM group: students who are neither identified as generally gifted nor excelling in mathematics.

Tasks and materials

Visio-Spatial Working Memory test (Corsi, 1972)

This block recall task consists of ten blocks arranged randomly on a wooden board. The test involves two parts: during the first part the researcher points at a sequence of blocks at a rate of one per second. After the researcher completes indicating the sequence, the participant is asked to replicate the sequence. If the

	Gifted (G) Raven > 27	Non-Gifted (NG) Raven < 26	Total
Excelling in mathematics (EM) SAT-M >26 or HL in mathematics with math score > 90	41	40	81
Non-excelling in mathematics (NEM) SAT-M <22 and RL in mathematics with math score > 90 or HL in mathematics with math score < 80.	53	56	109
Total	94	96	190

Table 1: Description of study groups

participant recalls the sequence of blocks correctly, another trial is administered. Successive trials are administered adding one more block each time and so forth until the participant fails two successive attempts. The maximum possible span is ten blocks.

During the second part, the researcher points at a sequence of blocks at a rate of one per second. After the researcher completes indicating the sequence, the participant is asked to replicate the sequence backwards. If the participant recalls the sequence of blocks correctly, another trial is administered. Successive trials are administered adding one more block each time and so forth until the participant fails two successive attempts. The maximum possible span is ten blocks. The measure of both test parts was a standard score according to the accepted Israeli scale (from Hebrew version of Visio-Spatial Working Memory test).

Visual- matching test (Woodcock-Johnson Tests of Cognitive Ability, 2001)

The test consists of rows that include one target symbol and 19 additional symbols. The participant has to circle all the symbols that are identical to the target symbol. The time limit for the assignment is 120 seconds.

Digit-symbol test (WISC III, 1997)

The test consists of a code table displaying pairs of digits and symbols, and rows of double boxes with a digit on the top box and nothing on the bottom box. The participant has to use the code table to determine the symbol associated with each digit (the test consists 133 digits), and to write as many symbols as possible in the empty boxes below each digit. The time limit for the assignment is 120 seconds.

Symbol-search (WISC III, 1997)

The test consists of rows marked by one target symbol and five additional symbols. The participant has to decide if the target symbols appear in the row of symbols and to mark YES or NO accordingly. The test consists of 60 items and the participant has to mark as many items as possible within 120 second.

Pattern recognition test (Thorndike, Hagen & Sattler, 1986)

The test consists of two columns of cross patterns: Pattern A is hidden in the larger pattern B. The participant has to draw a line around the crosses in B which make the same pattern as those in A. The test consists of 18 patterns and the time limit is nine minutes. The measure was accuracy (in %) of correct answers.

D2 Test of attention (Brickenkamp, 1994)

The D2 is a timed test for selective attention. The items are composed of the letters “d” and “p” with one, two, three or four dashes arranged either individually or in pairs above and below the letter. The participant is given 20 seconds to scan each line and mark all “d’s” with two dashes. There are 14 lines of 47 characters each for a total of 658 items. Measures of performance include total number of items processed (TN), Total number of items correctly processed (TN-E) number of errors (E), an index of concentration performance (CP), and fluctuation rate (FR) across trials.

Data analysis

To investigate the questions addressed in this study, multivariate analysis of variance tests (MANOVA) were used to compare the scores of participants in each test. The between-subjects factors were: G and EM factors and the within-subjects factors were the scores on each visual processing and attention tests.

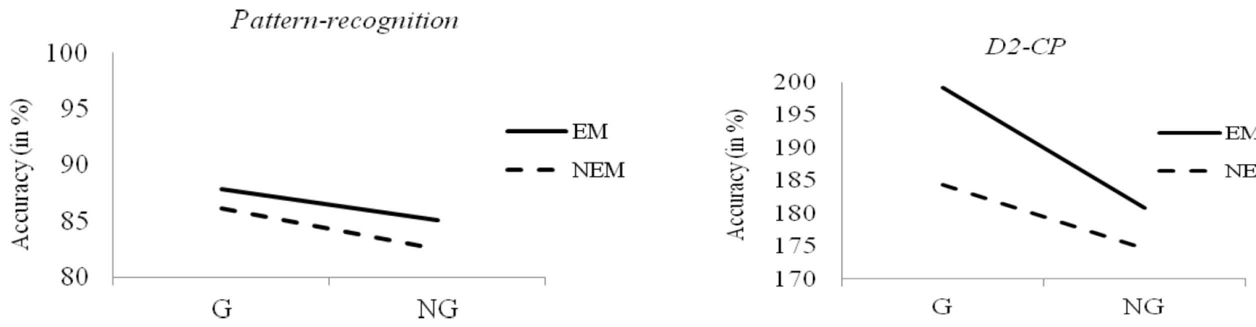

Figure 1: Significant main effect of G factor on VP and VA tests

RESULTS

Between groups differences on visual processing tests

MANOVA revealed an overall significant main effect for G factor ($F(12,167)= 2.31$, $p< .01$). Following univariate ANOVA tests showed that the sources of differences between the groups are the Pattern-recognition test ($F(1,178)= 5.15$, $p<.05$), D2-CP ($F(1,178)= 9.63$, $p<.05$). G student's accuracy on Pattern-recognition test ($M= 87.04$, $SD= 9.33$) and their D2-CP scores ($M= 191.80$, $SD= 35.80$) were significantly higher than NG students (Pattern-recognition M= 83.74, $SD=11.62$; D2-CP $M=177.64$, $SD= 21.10$) (Figure 1).

In addition, Univariate ANOVA tests revealed a significant main effect for EM factor in Symbol-search (F(1,178)= 4.64, $p<.05$) and Backward Corsi-span ($F(1,178)= 3.96$, $p<.05$) tasks. As shown in Figure 2, EM students outperformed NEM students on Symbol-search (EM: $M= 73.62$, $SD= 10.22$; NEM: $M= 70.64$, $SD= 11.22$) and Backward Corsi-span (EM: $M= 6.29$, $SD= 1.04$; NEM: $M= 6.04$, $SD= 0.98$).

CONCLUSIONS

The present study evaluated visual processing abilities linked to G (general giftedness), EM (excelling in mathematics). Between-group differences in visual processing were found to be task-dependent. On the VSM (Backward visual-span) test, differences in performance were associated only with EM factor, while on the visual-perception (Pattern-recognition test) and visual attention (D2-CP scores) tests only the G factor had a main performance effect. Visual SIP tasks were associated with both G and EM factors.

The results regarding visual-perception revealed that G students performed significantly better on this task regardless of their abilities in mathematics. These findings are in line with results of other studies which suggested that a superior visualizing ability characterizes highly gifted individuals (Silverman, 1995). The results regarding visual SIP revealed that G-EM students outperformed on two of the visual SIP tests (Symbol-search and Digit-symbol) compared to the other three groups. These findings are in line with previous studies which reported that processing speed is significantly related both to quantitative knowledge (Berg, 2008; Johnson et al., 2003; Swanson & Beebe-Frankenberger, 2004) and general giftedness (Dark & Benbow, 1991; Johnson et al., 2003; Kranzler et al., 1994), and are also partly reported in our previous study (Paz-Baruch et al., 2014).

Our study also demonstrates that the performance of G students on visual attention task, as regards concentration performance (D2-CP score) was better than

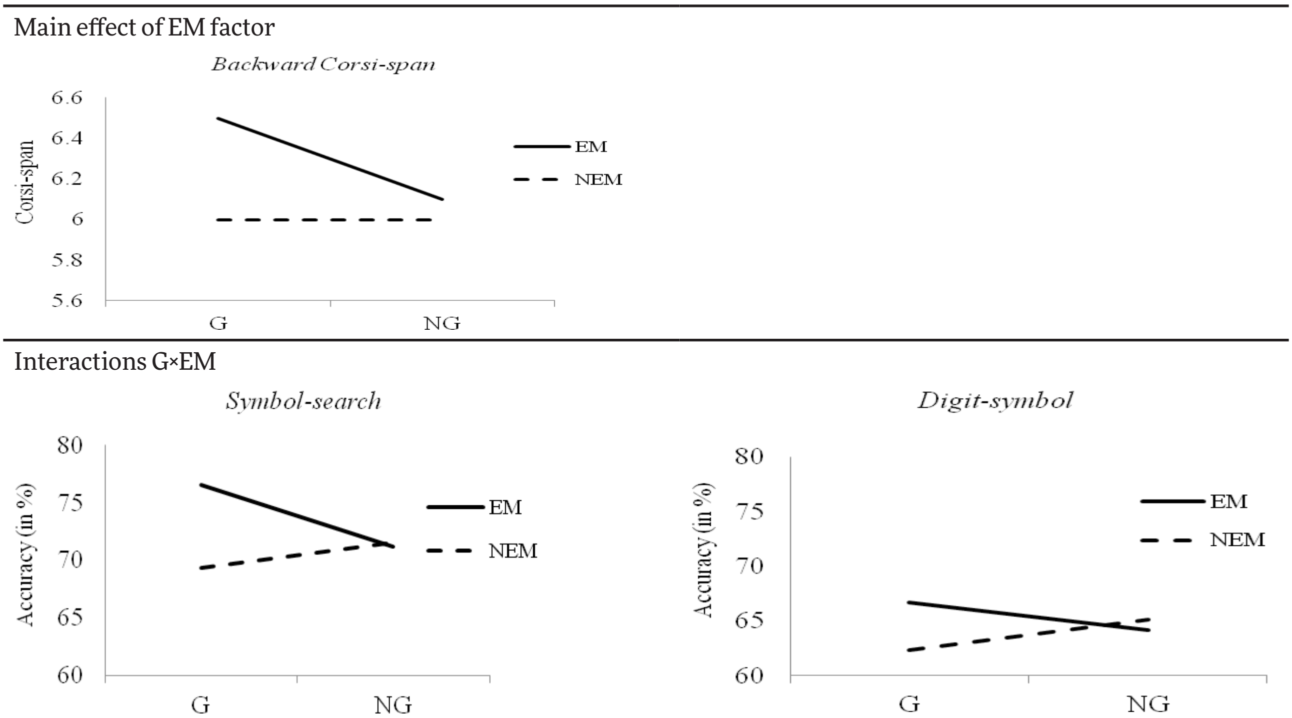

Figure 2: Significant main effects and interactions of G & EM factors on VP tests

that of NG students. It appears that gifted students are able to stay focussed on an assignment for a long time (elements of sustained attention) and are able to selectively attend to relevant stimuli while filtering out irrelevant stimuli in a rapid manner.

In summary, the present study generated data on the visual-processing abilities of adolescents, divided into four groups according to giftedness and excelling in mathematics. The study reveals that G and EM factors are different yet related mechanisms.

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