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Full Length Research Paper

A predictive model for mathematical performance of blind and seeing students

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The main objective of this study was to explore the relationship among working memory, mathematics anxiety, mathematics attitude and math performance in order to examine their effects on seeing and blind students. A sample of 97, middle school blind and seeing students were assessed on (a) Digit Span Backwards Test (DBT) (b) Mathematics Anxiety Rating Scale (MARS) (c) Math attitude test and (d) Math exam. The Results indicated that seeing students showed more achievement in math performance, and much more positive attitude toward math than blind students. But there was no significant difference between blind and seeing student in working memory capacity and math anxiety. These findings could help provide some practical implications for improving blind students' math performance and studying their math disabilities.

Keywords: Mathematical Performance, Working Memory Capacity, Math Anxiety, Math Attitude, Blind Students

INTRODUCTION

Mathematics is a universal subject and as a part of our life, anyone who is a participating member of society should know basic concept of mathematics. Students' mathematical achievement, however, is ultimately determined and limited by the opportunities they have had to learn. Mathematics is not restricted to a selected group of students (Moenikia and Zahed-Babelan, 2010)

"All students must learn to think mathematically, and they must think mathematically to learn" (Kilpatrick et al., 2001). In this study, the effect of following factors on the math performance of blind and seeing students was studied: working memory capacity (WMC), mathematics anxiety and mathematics attitude. To this end, a model was developed and the contribution of each of these psychological factors to mathematical performance of the group in question was included.

Working memory

Working memory is one of the main concepts of cognitive psychology that has played a growing role over the past decades in accounting for cognitive processes (Baddeley, 1990; Baddeley and Hitch, 1974).

Short-term memory was originally construed as a somewhat buffer of seven plus or minus two storage units (Miller, 1956). Researchers also demonstrated the need for a more dynamic conceptualization of short-term memory, that Baddeley called it working memory (Baddeley and Hitch, 1974; Baddeley, 1986, 1998).

Baddeley and Hitch (1974) advocated that temporary memory processes, despite of involving dedicated memory systems, should be viewed within the context of more general cognitive mechanisms. For many researchers this calls toward a more functional view of memory, matched by the adoption of the term 'working memory,' that marks the start of a modern era of research into the characteristics of memory and its role in a range of mental activities. Remarkably, working memory has almost become a universal phrase among researchers in cognition and indeed in neuroscience.

The working memory (WM) has a limited capacity system being responsible for the manipulation and storage of information during the performance of cognitive tasks such as comprehension learning, problem solving, and reasoning (Baddeley, 1986). The multi-

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component model of WM proposed by Baddeley and Hitch (1974), is arguably the most widely cited model which comprises four sub-components. The phonological loop (Baddeley, 1986) and the visuo-spatial sketchpad (Logie, 1995) are two sub-components which are assumed to be responsible for storing and manipulating verbal or visuospatial information. They are co-ordinated by a domain-general limited capacity system, the control executive (the third sub-component), which commands some of functions including planning, inhibition, switching attention, and monitoring the processing of temporarily held information (Baddeley, 1986, 1996; Baddeley and Logie, 1999). The forth added part, the episodic buffer (Baddeley, 2000), is considered to be responsible for the integration of information from the subcomponents of WM and long term memory (LTM).

More definitions of working memory have been suggested:

The functional definition of working memory results from the assumption declared that WM is involved in many real-world activities (e.g. Baddeley and Hitch, 1974). In other words, working memory is a necessary construct because a great amount of daily activities involve activity holding in mind, manipulating, and integrating information in memory. For example, mathematical problems often involve remembering the totals of certain calculations while performing other mathematical operations and then combining the outcomes.

Working memory refers to the ability to hold information in mind while manipulating, and integrating other information in the service of some cognitive goal (Kane and Engle, 2002; Roberts and Pennington, 1996).

Working memory capacity is widely measured by using complex memory paradigms, in which participants are required to combine memory for sequences of items whose presentation is interleaved by processing activities. The number of items to be remembered is increased until the maximum length at which memory accuracy is maintained.

According to the working memory model advanced originally by Baddeley and Hitch (1974) and developed subsequently by Baddeley and colleagues (Baddeley, 1996, 2000; Baddeley and Logie, 1999), working memory reflects multiple resources associated with distinct capacity-limited sub-systems. This model incorporates the central executive, which is associated with attentional control, high-level processing activities and coordination of activities within working memory.

An important role has been ascribed to working-memory capacity in reading comprehension, little consensus exists in its conceptualization, operationalization, measurement, and assessment (Friedman and Miyake, 2004; Juffs, 2004; Koda, 2005; MacDonald and Christiansen, 2002; Traxler, 2006; Waters and Caplan, 1996).

There are some considerable evidences suggesting that WM may be important for mathematics learning and problem solving. For example, Adams and Hitch (1998) suggested that mental arithmetic performance relies on the recourses of working memory. Significant associations have been found between the phonological loop and mental arithmetic performance in children (Adams and Hitch, 1997, 1998; Javris and Gathercole, 2003; Holmes and Adams, 2006). More specifically, Holmes and Adams, (2006) reported a significant association between children's WM ability and their mathematics attainment. They found that WM could predict national curriculum-based mathematical skills. In addition, the result of their study confirmed pervious findings that the central executive is an important predictor of children’s mathematical performance. The phonological loop showed a stronger association with the older children’s mental arithmetic performance.

Moreover, Alamolhodaei (2009) and also others (Ekbia, 2000) have found that the students with high WMC (hWMC), regardless the gender, are more capable of solving math word problems compared to those with low WMC (LWMC). Individuals differ in their working memory space; Any overload leaves students with no space for thought and conceptual organization, so faulty learning takes place (Johnstone and El-Banna 1989; Johnstone 1984; Johnstone and Al-Naeme 1991; Johnstone et al. 1993; Harel and Kaput 1991; Cowan 2005).

Mathematics Attitude

Attitude is an important concept for learning mathematics also it is a mental set or disposition of readiness to respond and the psychological basis of attitudes, permanence, learned nature and character evaluative. It includes peoples, places, ideas or situations. Attitudes are not just a passive result of past experience; instead they impel behavior and guide its form and manner. The components of attitudes are: (i) a cognitive component (opinion information or strength of belief or disbelief; (ii). an affective component (emotional component of like (or) dislike) and (iii) an action (co nature behavioral component of habit or readiness to respond) (Guimaraest, 2005).

The attitudes of students towards lesson effects on their success, interests and job selection (Koc and Sen, 2006). Especially some students have quite negative opinions about math because of negative behaviors of teachers or wrong experiences. These students have some prejudice such as mathematics is a complicated lesson and only those who have math intelligence can learn it. This situation is continuies during the school years and students’ self-confidence disappears as a result. Changing the negative attitudes of students into positive can be provided if the teachers increase the positive experiences of students towards Math. The Fennema-Sherman Mathematics Attitude Scales were developed in 1976 and it has become one of the most popular instruments used in research over the last three decades. The Fennema-Sherman Mathematics Attitude Scales consist of a group of nine instruments: (1) Attitude Toward Success in Mathematics Scale (2) Mathematics as a Male Domain Scale (3) and (4) Mother/Father Scale (5) Teacher Scale (6) Confidence in Learning Mathematics Scale (7) Mathematics Anxiety Scale (8) Effectance Motivation Scale in Mathematics, and (9) Mathematics Usefulness Scale.

Mathematics attitude should be viewed as a predisposition to respond in an unfavorable or favorable way to mathematics. By accepting this view, mathematics attitude includes relevant beliefs, behaviors and attitudinal or emotional reactions. Researches indicated that, there is a positive relation between mathematics attitude and mathematics achievement (Ma and Kishor, 1997a; Saha, 2007; Thomas, 2006).

Researchers have revealed that some variables mediating the effect of math attitude and mathematics achievement (Kabiri and Kiamanesh, 2004; Kiamanesh et al., 2004). Some of these variables are intelligence quotient (Blair et al., 2005; Bull and Scerif, 2001; Evans et al., 2002; Grissmer, 2000) and motivation for mathematics (Khoush et al., 2005; Yunus and Ali, 2009).

Many students taking math courses have a negative attitude toward math that can be described as math anxiety or feeling of tension or fear interferes with math performance.

Mathematics anxiety

Mathematics anxiety is one of the common attitudinal and emotional factors that has attached attention in recent years. Over the past thirty years, studies have shown mathematics anxiety is a highly prevalent problem for students (Baloglu and Koçak, 2006; Betz, 1978; Jain and Dowson, 2009; Ma and Xu, 2004; Rodarte-Luna and Sherry, 2008, Alamolhodaei, 2009). Although there is no general consensus about mathematics anxiety among researchers regarding its definition, dimensions, causes and effects. It has been directly or indirectly, affecting all aspects of mathematics education as one of the most commonly investigated constructs in mathematics education (Çatlıoğlu et al., 2009).

A great number of definitions has been suggested for mathematics anxiety. Some are as follows:

Mathematics anxiety is first introduced as "the presence of a syndrome of emotional reactions to arithmetic and mathematics" (Dreger and Aiken, 1957, p. 344).

Mathematics anxiety is defined as a feeling of tension, apprehension, or fear that interferes with math performance (Richardson and Suinn, 1972).

According to Tobias and Weissbrod, mathematics anxiety is the panic, feeling of unassistedness, paralization and mental disorders when students wish to solve an arithmetical problem (1980).

Mathematics anxiety is a situation which shows itself with emotional stress and anxiety when the individual is faced with cases such as solving arithmetical problems or doing operations with numbers in either his school or everyday life. This anxiety state can cause amnesia and loss of self confidence (Tobias, 1993).

Math anxiety usually arises when students are faced with unknown or ambiguity and find it frightening rather than enjoyable challenging. Math anxiety is not an isolated phenomenon as it originates and persists within a complex learning process with serious long-term effects (Bessant, 1995).

A number of studies had been done over the last decades on mathematic anxiety; some of these are presented below:

According to the results of a meta-analysis including 151 studies, Hembree (1990) found that mathematics anxiety is related to poor performance on mathematics. He also found significant differences in mathematics anxiety levels across ability, grade level, and fields of study

Chipman and others (1992) reported that mathematics anxiety is negatively correlated with students' interests in a scientific career regardless of their level of mathematical skills or gender.

Ashcraft and colleagues (Ashcraft and Faust, 1994; Faust et al., 1996) found that math anxiety had little effect on simple addition and multiplication problems. The solving of more complex arithmetic problems (e.g., arithmetic with carrying), however, was affected by MA. The most dominant theory of MA, posited by Ashcraft and colleagues, claims that MA individuals have difficulty with complex mathematical problem solving because MA induced ruminations occupy their working memory (WM; see Ashcraft, 2002).

The symptoms of math anxiety can be diverse, including nausea and stomachache, a 'blank' mind, extreme nervousness, inability to hear the teacher and/or noise sensitivity, inability to concentrate, and negative self-talk (Kitchens, 1995).

Individuals' high mathematics anxiety have been shown to perform worse than their low-mathematics anxious peers in solving difficult mathematical problems (Ashcraft and Kirk, 2001; Ashcraf et al., 1998; Ashcraft et al., 2007, Alamolhodaei and Farsad, 2009).

Students accustomed to solving problems without time restrictions might develop anxiety if told they need to solve problems quickly (Ashcraft and Moore, 2009).

The goal of the current study was to determine the role of math performance, math anxiety, math attitude and working memory space in blind and seeing students.

The first objective of the study was to discover whether there would be relationship between students WMC and math performance.

The second objective of this research was to discover whether there would be a relationship between math performance and blind or seeing students.

The third objective was to compare working memory capacity of blind and seeing student.

The fourth objective was to compare math anxiety of blind and seeing student

The fifth objective was to compare math attitude of blind and seeing student and the last objective was compare math anxiety of genders.

MATERIALS AND METHODS

Participants

58 middle school seeing students including 24 girls and 34 boys and 39 middle school blind students including 21 girls and 18 boys were selected from schools of Khorasan Razavi Province using random multistage stratified sampling design.

Procedures

The participants were required to take the following tests:
1- Digit Span Backwards Test (DBT)
2- Mathematics Anxiety Rating Scale (MARS)
3- Math Attitude Test
4-Math Exam

Digit Span Backwards Test (DBT)

For the measurement of the students' working memory capacity (WMC), DBT has been quoted as the normal test (Case 1974; Scardamalia 1977; Al-Naeme 1989, Niaz 1988; Talbi 1990; Johnstone et al. 1993, Alamolhodaei, 2009). The digits were read out by an expert and the students were asked to listen carefully, then turn the number over in their mind and write it down from left to right on their answer sheets. Students were tested by DBT two times within 2 months as a test and retest.WMC was originally has seven plus or minus two storage unit as pascual leoni described. In this study, the students who scored less or equal to four were labeled as low WMC, those group who scored more than 4 and less than 5 were labeled as intermediate WMC group and those who scored more than 5 were labeled as high WMC group.

Mathematics Anxiety Rating Scale (MARS)

Level of anxiety was determined by the score attained on the Math Anxiety Rating Scale (MARS), which has been used recently in the Faculty of Mathematical Sciences, Ferdowsi University of Mashhad. The MARS for this research was newly designed by the researchers of this study according to the inventory test of Ferguson (1986). It consists of 19 items, each of which item presents an anxiety arousing situation. The students were assigned degree of anxiety and abstraction anxiety aroused using a five rating scale ranging from very much to not at all (5–l). The five items were hypothesized to measure a new component of math anxiety being distinctive from those already identified by others (Suinn 1970; Richardson and Suinn 1972). These items were used to identify abstraction anxiety, according to Ferguson (1986). Cronbach's alpha, the degree of internal consistency of (MARS) items for this study, was estimated to be 0.87. The score ranged from 23 to 83 with the mean of 55.44. The sample was divided into high/medium/low MA groups based upon the previous study (Clute, 1984; Alamolhodaei, 2009).

Math Attitude Test

Level of attitude was determined by math unpublished attitude test which has been used in Faculty of Mathematical Sciences, Ferdowsi University of Mashhad. It consists of 18 items about attitude toward math based on Fennema-Sherman Mathematics Attitude Scales. The students were assigned the degree of math attitude aroused using a three rating scale ranging from high to low (3–l). Cronbach's alpha, the degree of internal consistency of attitude items for this study, was estimated to be 0.77. The sample was divided into high/medium/low math attitude groups.

Math Exams

The effectiveness of these tests was evaluated by determinig the students' performance in mathematical problem solving. Math exam was consisted of 20 questions base on middle school math syllabi. Here is a typical question of math exam of this study:
For producing one kind of bread we should combine material A and B with the ratio 2 and 5.
For producing 42 grams of this bread, how much gram from material A and B would be needed?

RESULTS

Comparing math performance and Working Memory Capacity

The result of one-way ANOVA for three groups of working memory capacity showed that all were significantly different in terms of mean scores obtained in Math exam with p-value less than 0.001 (Table 1).
Graph error bar has shown significant difference among math learners performance according to working memory capacity (Figure 1)

The circle in the graph represent the mean of the response variable and each of shows upper and lower boundaries with a 95 percent confidence interval which means that the mean of variable with 95 percent probability is in the range that the graph denoted and also we should say that two or more mean's groups haven't significant difference if there is a horizontal line that intersects corresponding vertical lines.
As can be seen in this graph, Students with low WMC had less achievement in math performance than medium WMC. Also they had less achievement in math performance than high WMC. Students with medium WMC had less achievement in math performance than these in high WMC group.

Table1. Comparing math performance and WMC

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	121.688	2	60.844	11.904	.000
Within Groups	480.440	94	5.111		
Total	602.128	96			

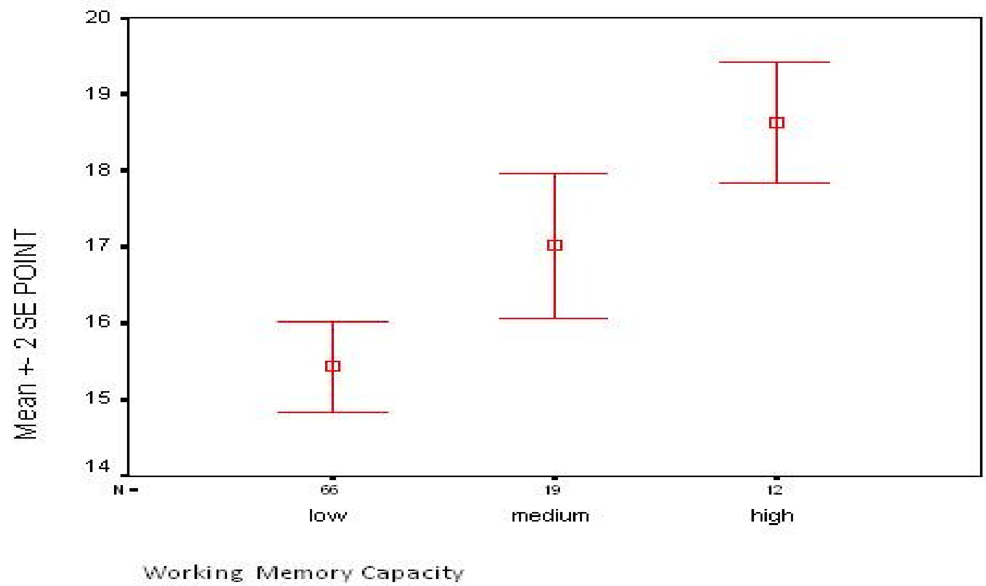

Figure 1. Graph comparing math performance and WMC

Table 2. Comparing math anxiety and gender

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Anxiety	Equal variances assumed	.003	.956	-2.209	94	.030	-6.24	2.825	-11.851	-.632
	Equal variances not assumed			-2.213	91.928	.029	-6.24	2.821	-11.844	-.639

Comparing math anxiety and gender

The result of t-test for two groups of male and female students showed that they had significant difference in terms of mean scores obtained in Mathematics Anxiety Rating Scale with p-value 0.030 additionally it was shown that female students had more mathematics anxiety than male ones (Table 2).

Comparing math performance of blind and seeing students

The result of t-test for two groups of blind and seeing student showed that they had significant difference in terms of mean scores obtained in Mathematic performance with p-value less than 0.001. It was found that seeing students had more achievement in math

Table 3. Comparing math performance of blind and seeing students

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
POINT	Equal variances assumed	12.072	.001	8.936	95	.000	3.4339	.38428	2.67101	4.19681
	Equal variances not assumed			8.099	55.341	.000	3.4339	.42398	2.58435	4.28346

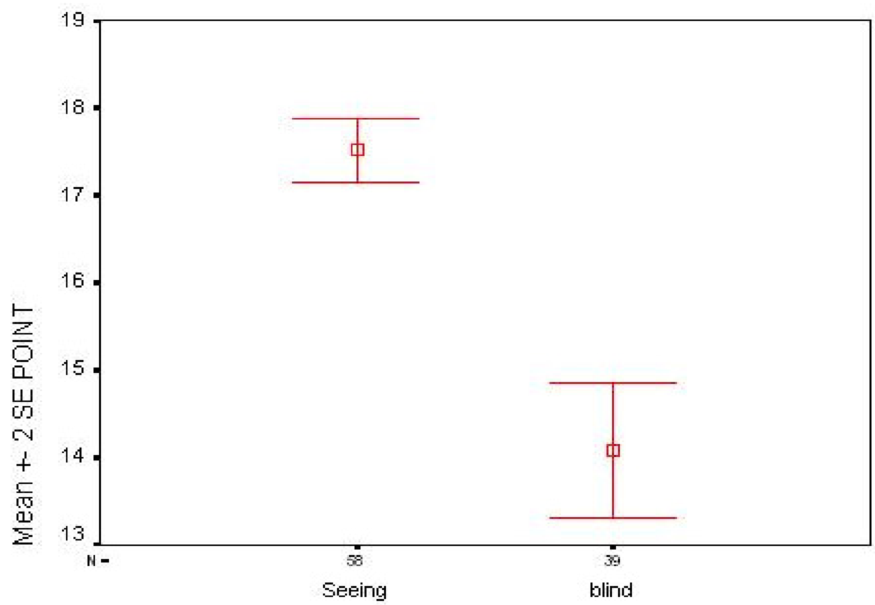

Figure 2. Graph comparing math performance of blind and seeing students

Table 4. Comparing math attitude in blind and seeing students

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Attitute	Equal variances assumed	1.783	.185	1.997	95	.049	2.46	1.233	.014	4.910
	Equal variances not assumed			1.936	72.717	.057	2.46	1.272	-.073	4.997

performance than blind students. Graph error bar showed this difference much better (Table 3 and figure 2).

Comparing math attitude in blind and seeing students

The result of t-test for two groups of blind and seeing students showed that they had significant difference in terms of mean scores obtained in Mathematics attitude exam with p-value 0.049 also seeing students were found to have much positive attitude toward math than blind students (Table 4).

Table 5. Comparing working memory in blind and seeing students

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
working memory space	Equal variances assumed	1.879	.174	1.681	95	.096	.43	.255	-.078	.936
	Equal variances not assumed			1.718	87.424	.089	.43	.250	-.067	.926

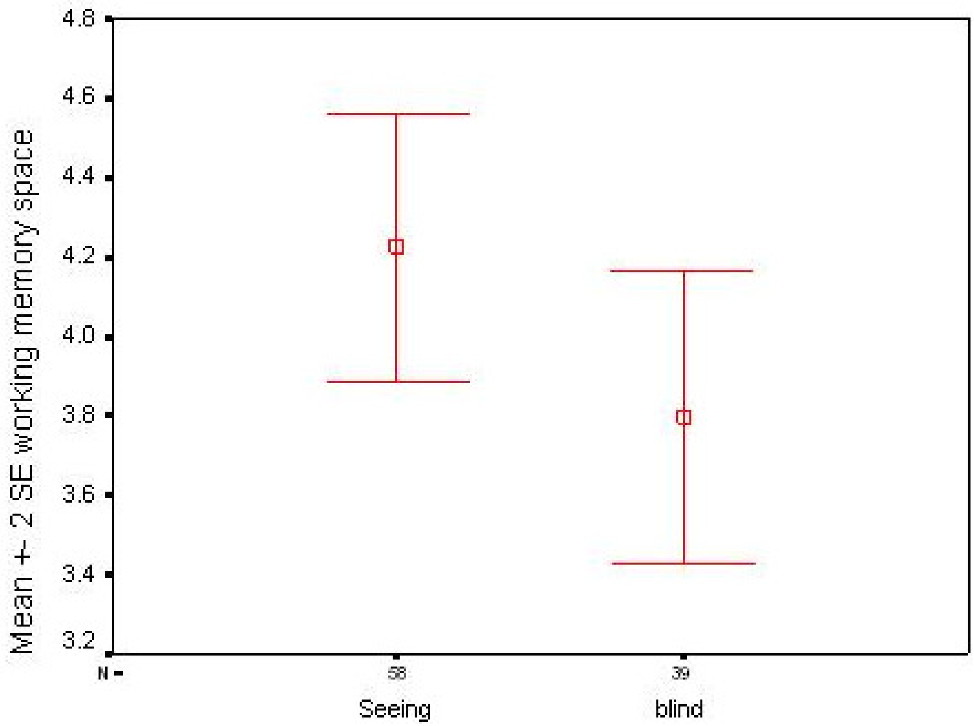

Figure 3. Graph Comparing working memory in blind and seeing students

Comparing working memory in blind and seeing students

The result of t-test for two groups of blind and seeing students showed that they hadn't significant difference in terms of mean scores obtained in Digit Span Backwards Test with p-value 0.096 although graph error bars shown that in this study seeing students had more WMC than blind students (Table 5 and Figure 3).

Comparing math anxiety in blind or seeing students

The result of t-test for two groups of blind and seeing students showed that they had not significant difference in terms of mean scores obtained in Mathematics Anxiety Rating Scale with p-value 0.598, although graph error bars showed that in this study blind students had more math anxiety than seeing students (Table 6 and Figure 4) .

DISCUSSION

As mentioned earlier, in this research, the authors studied the effect of Working memory capacity, mathematics anxiety and mathematics attitude on math performance of blind and seeing students. The main aim of this study was to study the different size of effect of these factors among blind and seeing students.

Many researchers reported that, there is significant difference between high WMC students and low WMC

Table 6. Comparing math anxiety in blind or seeing students

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Anxiety	Equal variances assumed	.003	.954	-.529	94	.598	-1.55	2.935	-7.380	4.276
	Equal variances not assumed			-.535	84.873	.594	-1.55	2.903	-7.324	4.220

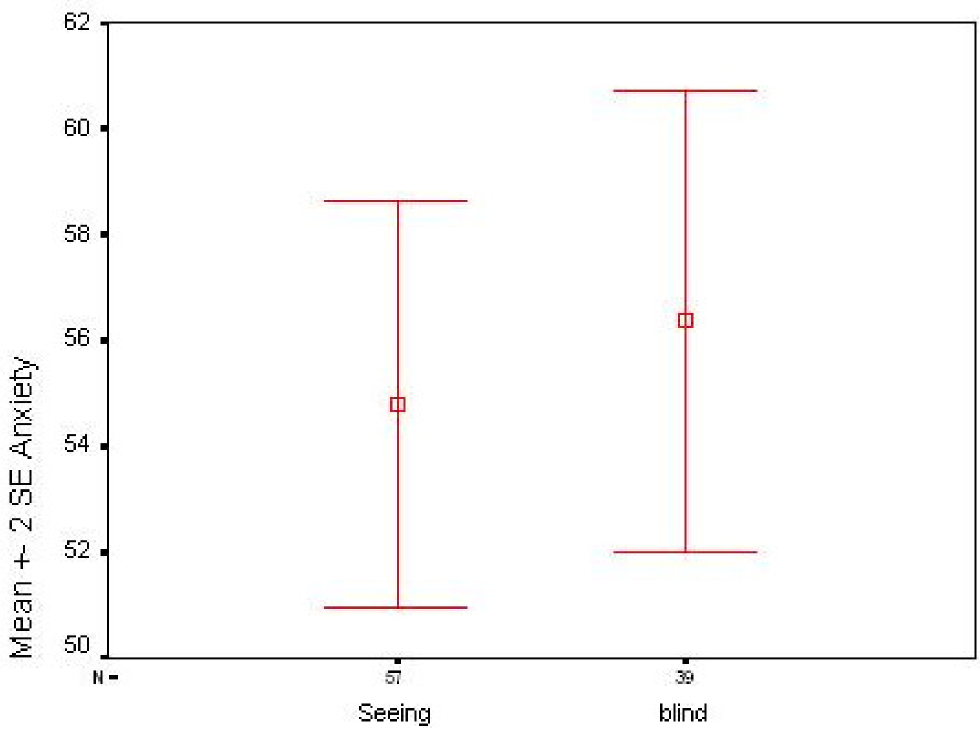

Figure 4. Graph comparing math anxiety in blind or seeing students

ones in math performance (Adam and Hitch 1998; Ekbia, 2000; Alamolhodaei, 2009). Also in the sample of this study that included both blind and seeing students, different math performance (between students with high WMC and low WMC) was seen (P-value less than .001).

In some of previous studies, math anxiety between male and female students was studied. The results indicated that females display more math anxiety than males(Alamolhodaei, 2009; Woodard, 2004). In the present study same results were obtained and confirming females show more math anxiety than males.

When dealing with math problems, Blind students face many difficulties for example they do not know how to get the information of problems, cannot draw the schemata of math problems and cannot provide the instrument for solving math problems. Also the lack of guiding math book for blind student is another problem that they have.

These problems are possible causes for the differences shown in this study. It was found that seeing students had better performance than blind students (P-value less than .001) and this deference is very much according to graph error bars.

The inferior achievement that blind students showed in math performance and the problems that they have in problem solving caused math attitude of blind students to be more negative than seeing students (P-value .049).

Another important finding of this study was that, there was no significant difference between WMC of blind and seeing students. Accordingly, it would be valuable to reconsider educational method and mathematical curriculum for blind students. In other words, based upon WMC blind and seeing learners may have roughly the same performance in mathematical problem solving.

As it was found in this study, no significant difference was found between math anxiety of blind and seeing students, despite the higher mean of blinds. After interviewing blind learners, authors found that a lot of failure in the previous math exams and their inferior achievement caused them to feel that the achievement of good math result would not so important for them. Therefore, this belief and lack of anxious about math exams caused them to be far from rigid math anxiety

Considering these results, as a math teacher, we should pay attention to how learners think and learn, therefore making the necessary opportunity for all learners, in particular, blind ones. Blind students should be encouraged to change their views about math lessons so they can perform on math problem solving the same as ordinary students, if they want.

It would be valuable to continue this study in other areas and with more Blind students to find how well the model of this research would work.

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