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Comparison of the Working Memory Performance between Literate and Illiterate Adults

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This study compared the working memory performance and its subsystems (phonological loop, visuo-spatial sketchpad and central executive) between literate and illiterate adults. The study was based on a descriptive methodology, using a causal-comparative method. The sample consisted of adult students in the final course of Nehzat Savad Amouzi Organization (NSAO) in Kurdestan, made up of 67 individuals who constituted the literate group and were matched with 67 other students who constituted the illiterate group. The 67 adults in each group were matched for age, gender, job, and intelligence. Based on the last works (Hassanpoor, H. H. 2003, Dutke, S., & Mike, R. 2006, Lee et al. 2007, Swanson, H. L. 1992 & Oberauer, K, et al. 2003) we used a test for each working memory subsystems and administered individually. For investigating the differences between the two groups, multivariate analysis of variance (MANOVA) was used. The results of the MANOVA analysis indicated that there was a significant difference ($p \leq 0.001$) between the groups in working memory performance and all its subsystems. This study suggests that, literacy could be the main factor in improving the working memory performance in adulthood.

***Keywords*:** literacy, working memory, phonological loop, visuo-spatial sketchpad, central executive

Literacy can be considered as one of the most important cognitive processes in adulthood, which often refers to the basic skills of reading, writing and basic mathematics (Sabaghian, 2009, p.3). Literacy can also have personal effects while at the same time affecting society, culture and economy. It has the effect of enhancing adult cognitive processes, with memory playing a key role (Word Bank, 2003).

There are different views about memory and its structure. These views can all be divided into two categories. In one view, memory is not divided into sub-components, for example the views of Craik and Lockhart (1972). Based on another view, memory is categorized into several subsystems (Etkinson & Shifrin, 1968; Baddeley & Hitch, 1974). The working memory (WM) model which has been explained by Baddely and Hitch (1974) categorises temporary memory into several subsystems. In this study, by assuming the model and terminology first used by Baddeley and Hitch (1974) we compared working memory performance and its subsystems (phonological loop, visuo-spatial sketchpad and central executive) between literate and illiterate adults.

The WM model that has been proposed by Baddeley and Hitch (1974) is a theoretical model of temporary memory. They believed that WM refers to the mechanism or system underlying the maintenance and processing of task-relevant information during the performance of a cognitive task. WM is also a subcomponent of the overall memory system and its capacity is limited. Other authors argue that WM is a cognitive system responsible for temporary storage and manipulation of information during cognitive activities (Numminen, Service & Rouppila, 2002). However, storage and processing simultaneously are two fundamental components in WM. The Baddeley and Hitch (1974) model initially included three subsystems but their most recent version of WM consists of four components: phonological loop, visual spatial sketchpad, central executive, and an episodic buffer (Baddeley, 2000).

The Phonological Loop

The phonological loop is a verbal-based subsystem. The system appears to have evolved from the underlying language perception and production systems, probably to facilitate the acquisition of language (Baddeley, 1998). The phonological loop comprises two components, a phonological store, which can hold memory traces for a few seconds before they fade (Baddeley, 2003) and an articulatory rehearsal system that refreshes the information within phonological store (Baddeley, 2002).There is much behavioral and neuropsychological evidence to confirm ~~of~~ the phonological loop for reviews, see (Baddeley, 1966, 2000, 2003; Cowan et al, 1992). The phonological loop, however, has an important role in the learning and processing of verbal subjects.

The Visual Spatial Sketchpad

The visuo-spatial sketchpad is assumed to be capable of temporarily maintaining and manipulating visual spatial information, playing an important role in spatial orientation and in the solution of visual spatial problems (Baddeley, 2002). This subsystem is involved in visual or spatial tasks, such as remembering shapes and colors or the location, imagery, orientations, and speed of objects in space. Therefore, research about this subsystem is more difficult. This subsystem plays a key role in the generation and manipulation of mental images (Swanson & Sachse-Lee, 2001). Some studies show that the system is principally, but not exclusively, dependent on the right hemisphere of the brain for reviews (Della Sala & Logie, 2002; Smith & Jonides, 1997).

The Central Executive

The central executive is one of the basic components in WM model, because the system regulates the flow of information through working memory. This system is assumed to be responsible for the attentional control of working memory (Baddeley, 2003). The system makes decisions as to how the two slave systems* (visuo-spatial sketchpad & phonological loop) should be used. Central executive, therefore, is responsible for attentional control of the working memory when

* The central executive who acts as supervisory system and controls the flow of information from and to its slave systems: the phonological loop and the visuo-spatial sketchpad.

processing and storage need to occur simultaneously. It relies heavily, but not exclusively, on the frontal lobes (Stuss & Knight, 2002).

The Episodic Buffer

The episodic buffer is a new component of Baddeley's WM model. The episodic buffer is assumed to be a limited-capacity temporary storage system that is capable of integrating information from a variety of sources. It is assumed to be controlled by the central executive (Baddeley, 2000). This system is responsible for integrating information in the cognitive system, including both temporary and long-term memory systems (Gathercole, Pickering, Knight & Stegmann, 2004). Therefore, the system connects WM with long term memory. Furthermore, the system integrates information in the other subsystems. Some studies have shown greater right frontal activation for integrated information (Prabhakaran, Narayanan, Zhao & Gabrielli, 2000). The current version of WM model is shown in Figure 1.

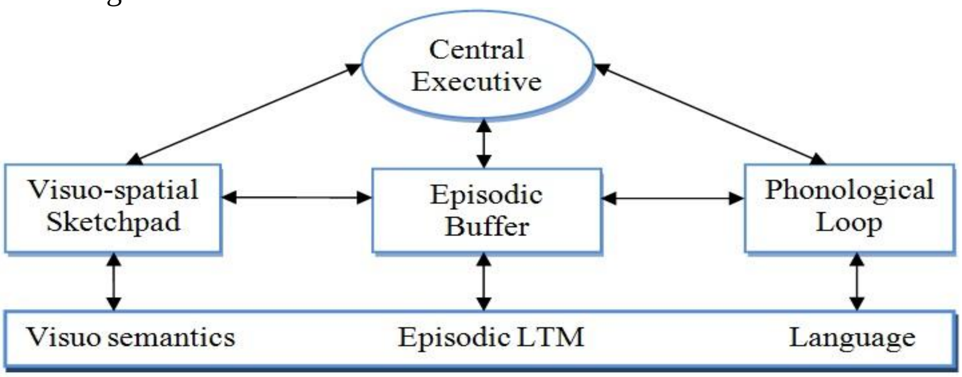

Figure 1. Current Version of WM Model (Adopted by: Baddeley, 2003)

Given what has been said, the question that comes to mind is: To what extent can literacy as an important cognitive process in adulthood, improve the performance of WM and its subsystems in a literate group compared to that of an illiterate group? So to achieve deep understanding of the question, we reviewed the studies that have been conducted in this field. Many studies have found that education in any kind plays a significant role in WM performance.

Carretti, Borella & De Beni (2007) illustrate that strategic training improves performance of the immediate list recall and working memory tasks in younger and older adults.

Other authors have found significant effects of mental abacus and music training on the WM performance in both children and adults (Lee, Lu & Ko, 2007). An experimental study has demonstrated that some instructions, like rehearsal training, increases WM performance (Turley-Ames & Whitfield, 2003).

In contrast, Law, Morrin & Pellegrino (1995) suggested that associative learning improved visual WM performanc*e*. Stratta, Prosperini, Daneluzzo, Bustini & Rossi (2001) investigated the influence of educational level and age in schizophrenic patients on WM. They claimed that educational level significantly correlated with 'working memory' indices of the healthy controls but not in schizophrenics.

McNamara and Scott (2001) recognized that changes in WM are attributed to experience, knowledge and learning.

Based on research studies, there is a relationship between training and working memory capacity. A review of the body of research in this field shows that up to now no research has been conducted in Iran relating to the effects of literacy on the working memory performance of adults. Literacy in Iran refers to three essential skills (reading, writing, and mathematics) which are taught by the Nehzat Savad Amouzi Organization (NSAO) in five levels: primary, supplementary, final course, adult fifth, and permanent groups of literacy, while extension courses in literacy are held annually in the Iranian area of Kurdestan. Therefore, the overall objective of this research involves comparing WM performance between literate and illiterate adults in (NSAO). According to the research objectives, this research will attempt to answer the following hypotheses:

1) The phonological loop performance of the literate group is better than that of the illiterate group.

2) The visuo-spatial performance of the literate group is better than that of the illiterate group.

3) The central executive performance of the literate group is better than that of the illiterate group.

4) The overall–WM performance of the literate group is better than that of the illiterate group.

Method

Research Method

As literacy was the independent variable, our research design was a causal-comparative one. Moreover, because we were comparing the WM of the groups and their subsystems, multivariate analysis of variance (MANOVA) and univariate analysis of variance (ANOVA) were appropriate statistical analysis procedures.

Participants

All of the learners in the final course of (NSAO) were 71, and the illiterate adults were 767 in primary course of (NSAO). Finally, the sample of this study consisted of 67 adult students in the final course of (NSAO) in Kurdestan, who constituted the literate group and were matched for age, gender (only men), job, and intelligence with 67 other students in the primary course of (NSAO) as illiterate group. In Table 1, the sample demographic characteristics are demonstrated:

Table 1
The Sample Demographic Characteristics

variable	N	Mean	Std. Deviation	Mminimum	Maximum
Age	134	41.00	10.00	27	63
IQ	134	96.00	2.00	91	104

Instrument

According to WM model which is explained by Baddeley and Hitch (1974) and based on the last works (Hassanpoor, H. H. 2003, Dutke, S., & Mike, R. 2006, Lee et al. 2007, Oberauer et al. 2003 and Swanson 1992 & 2003) we used five tasks for the measurement of WM and its subsystems. The reliabilities of these five tasks, as our instruments, have been studied by (Hassanpoor, H. H. 2003, in Iran) and the reliability coefficient was 0.77 for non-word and forward digit span, 0.72 for visuo-spatial span, and 0.79 for operation span. Due to the low level of literacy of the adults in the groups, we applied some trivial changes in the tasks and again computed reliability. The Cronbach's Alpha for each task for the present sample was 0.76 for non-word and forward digit span, 0.74 for visuo-spatial span, and 0.81 for operation span.

Two tasks for Non-word and forward digit span. The two tasks included nonsense words and forward digits were designed to measure the phonological loop. Several sequences of nonsense words were presented orally for immediate serial recall. The two non-words were first read aloud by the experimenter at a rate of approximately one non-word per two seconds. After presentation of the last non-word, participants were required to recall the non-words in a correct forward sequence (backward recall for participants was difficult because of their low level of literacy, so, backward recall was deleted). If the recall was correct for two trials, the number of non-words was increased by one. This procedure was repeated until the participants recalled nine non-words accurately. The non-word score was the total number of non-word sequences correctly recalled by participants. Procedures for the digit span were the same, with nine digits replacing the nine non-words. These two tasks measured the phonological loop.

Two tasks for Visuo-spatial span. Two tasks included a set of cards and a picture were designed to measure visuo-spatial span. Several sequences of cards with different shapes were presented increasingly for immediate serial recall. Two cards were first showed by the experimenter at a rate of approximately one card per two seconds, then, the cards were rearranged. After presenting the last card, participants were required to recall and sort the cards in a correct forward sequence. The visuo-spatial score was the total number of card sequences correctly sorted by participants. After the task, a picture that included different fruits was presented. Participants were required to recall the fruits. The visuo-spatial score was the total number of fruits that were correctly recalled by participants.

One task for the operation span. To measure the operation span, some mathematic problems were presented. The experimenter had to first read three different items with special prices, then, participants were required to add and subtract the asked prices. (For example: pen = 550 Rials, pencil = 720 Rials, and ruler = 670 Rials. Pen + ruler =?). If answers were correct for two trials, the number of items was increased by one. This procedure was repeated until the participants answered nine items accurately. The central executive score was the total number of operations that were correctly executed by the participants.

Procedure

After the preliminary study for matching the groups for age, gender, job, and intelligence, all of the working memory tasks were administered to each adult student individually. The students were tested individually in a room at the school and they completed all tests during a single session. For controlling intelligence, participants simultaneously completed the Raven's black-and-white Progressive Matrices (Raven et al., 1996).

Data Analysis

In order to compare the means in WM and its subsystems, multivariate analysis of variance (MANOVA) and univariate analysis of variance (ANOVA) were appropriate statistical analysis procedures using SPSS version 16 software.

Results

The descriptive characteristics for all measures are displayed in Table 2.

Table 2

Descriptive Characteristics of the Research Variables

Variables	Literacy Level	Mean	Std. Deviation	N
	Illiterate	14.8	3.09	67
Central Executive	Literate	19.7	2.99	67
	Total	17.00	3.00	134
	Illiterate	48.3	6.76	67
Phonological loop	Literate	56.7	7.23	67
	Total	52.00	8.00	134
	Illiterate	21.7	2.55	67
Visuo-Spatial span	Literate	27.3	3.05	67
	Total	24.00	3.00	134
	Illiterate	85.01	9.11	67
WM	Literate	103.7	10.96	67
	Total	94.00	13.00	134

In Table 3, results of MANOVA analysis for the groups in all of the variables are shown:

Table 3

Results of MANOVA for the Groups in All the Variables (N = 134)

Tests	Value	F	Hypothesis df	Error df	Sig.
Pillai's Trace	.558	54.68	3.000	130.00	.000
Wilks' Lambda	.442	54.68	3.000	130.00	.000
Hotelling's Trace	1.262	54.68	3.000	130.00	.000
Roy's Largest Root	1.262	54.68	3.000	130.00	.000

According to Table 3 and Hotelling's Trace test result, we can claim that there is a significant difference in the overall performance on each set of dependent measures between the literate and illiterate groups.

For investigating the hypotheses and the differences between the two groups in each WM subsystem, the results of univariate analysis of variance (ANOVA) have been presented in Table 4.

Table 4
Results of Univariate Analysis of Variance (ANOVA)

Variable	Total square	Square error Mean	F	Hypothesis df	Error df	Sig.
Phonological loop	2315.29	49.09	47.16	1	132	.001
Visual-spatial	1038.27	7.9	130.9	1	132	.001
Central executive	802.55	6.2	86.4	1	132	.001
Working memory	11810.17	101.62	116.2	1	132	.001

H1: (The Phonological Loop Performance of the Literate Group is better than that of the Illiterate Group).

According to the findings in Table 4, the univariate analysis of variance (ANOVA) was used to test the hypothesis which indicated that the performance of the literate group in the phonological loop was better than that of the illiterate group. This difference is statistically significant S($F=47.16$, $p<.001$).

H2: (The Visual-Spatial Performance of the Literate Group is better than that of the Illiterate Group).

According to the ANOVA results in Table 4, there is a significant difference in the visuo-spatial performance between the two groups, ($F=130.9$, $p < .001$).

H3: (The Central Executive Performance of the Literate Group is better than that of the Illiterate Group).

The results of ANOVA in Table 4, show a considerably significant difference in the performance of the central executive tasks between the two groups, ($F = 86.4$, $p < .001$). Therefore, this hypothesis was supported.

H4: (The Overall WM Performance of the Literate Group is better than that of the Illiterate Group).

According to the ANOVA results in Table 4, there was a significant difference in the overall WM performance of the two groups ($F=116.2$, $p < .001$). As a result, this hypothesis was also supported.

Discussion and Conclusion

This study has revealed that literacy as a cognitive process can be the main factor for improving WM and its subsystems.

The first hypothesis revealed that the literate group in comparison to the illiterate group has a better performance in phonological items. The main subjects in NSAO are presented in lectures, they probably excite literate group' phonological memory, this group focus more on phonological matters; thus, they performed phonological tasks better than those in the illiterate group. Another reason for the difference between the two groups was that the literate group had more opportunities to perform exercises in phonological tasks (for example: dictation) and as a result they had a high phonological loop span. This result is consistent with the findings in the research literature (Carretti, Borella & De Beni, 2007; Haut, Kuwabara, Moran, Leach, Arias & Knight, 2005; Lee, Lu, & Ko, 2007).

The second hypothesis demonstrated the effect of literacy on visual spatial sketchpad. According to the second hypothesis, we can claim that pictorial training in adulthood can improve visual spatial sketchpad. There are several examples of visual spatial information in NSAO such as pictures, maps, figures, and so forth; as a result, this visual spatial information had the main effect on the visual spatial span of the literate group in comparison to the illiterate group. Also, other researchers have shown the effect of pictorial training in visual spatial sketchpad (Lee, Lu, & Ko, 2007; Carretti, Borella & De Beni, 2007; Haut et al, 2005; Law, Morrin & Pellegrino, 1995; McNamara & Scott, 2001).

In the third hypothesis, the effect of literacy on central executive has been proposed. In NSAO, mathematic skills are a basic lesson, therefore, literate group are involved in computing and calculating constantly, thus, we can argue that these skills have an important effect on the performance in central executive of the literate group. Some studies have confirmed our claim, for example (Passolungi & Siegel, 2004).

In the last hypothesis, we assumed that all of the WM system is influenced by literacy. This hypothesis has also been supported. Since the other hypotheses also have been supported it can be said that literacy is a main factor in improving the subsystems of WM, and it follows that the performances of the literate group were better in all of the WM systems. These findings confirm the suggestion that the WM capacity can be improved by training and instruction in adulthood. On the other hand, WM is related to cognitive abilities like reading ability (Cohen-Mimran & Sapir, 2007), learning in the classroom (Alloway, 2006), mathematics abilities (Passolungi, & Siegel, 2004; Swanson & Sachse-Lee, 2001), and reasoning ability (Kyllonen & Christal, 1990; Meiser, Klauer & Naumer, 2001) and Hence, by improving WM by training (like literacy) in adulthood, the cognitive abilities of adults can be developed.

Finally, we have to say that in this study we couldn’t use experimental research method because the literacy process is so long and only men were our participants. Therefore, we suggest that the future research consider the use both sexes, experimental research method, and random sampling.

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