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RESEARCH ARTICLE

Evaluation of the effects of bilingualism on auditory-verbal working memory using the Persian version of Rey auditory-verbal learning test

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Abstract

Background and Aim: Although recent research has revealed the positive effects of bilingualism on children's cognitive abilities, little information is available on the relationship between bilingualism and working memory. Working memory is generally composed of four distinct parts, among which the phonological loop plays an important role in speech and language development, reading skills, and learning. In the present study, bilingual and monolingual students were compared in terms of auditory-verbal memory performance, using Rey auditory-verbal learning test.

Methods: In this cross-sectional study, the auditory-verbal memory performance of 56 monolingual and 55 bilingual students were assessed, using the Persian version of Rey auditory-verbal learning test. The study samples were selected among students in the fifth and sixth grades of primary school. Finally, the scores obtained on the test were compared between the two groups.

Results: The mean scores of stages 1-5, 7, and 8 of Rey test were 48.71 (SD=6.71) out of 75, 10.25 (SD=2.29) out of 15, and 10.50 (SD=2.27) out of 15 in monolinguals and 53.54 (SD=5.24), 11.80 (SD=2.13), and 11.98 (SD=1.88) in bilinguals, respectively. There was a statistically significant difference between the scores of the two groups ($p<0.001$, $p=0.001$, and $p=0.001$, respectively).

Conclusion: In the present study, the bilingual group showed a significantly better auditory-verbal memory performance, compared to their monolingual peers, based on the Rey auditory-verbal learning test. Therefore, it can be concluded that bilingualism may have a positive impact on auditory-verbal working memory.

Keywords: Working memory; auditory verbal memory; bilingualism; Rey test

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Introduction

Bilingualism or multilingualism refers to the use of two or more languages in everyday life [1]. In recent years, the positive influence of bilingualism has been confirmed in several studies. In fact, exposure to a bilingual social context during early childhood is associated with the improvement of cognitive abilities and mental processes, compared to monolingual environments [2]. This perspective is in opposition to the conventional point of view, which is representative of the negative impact of bilingualism on cognitive development.

It seems that second-language acquisition in early childhood is accompanied with enhanced cognitive functions such as problem solving, creativity, memory performance, and mental processes. Although several recent studies have demonstrated the positive effects of bilingualism on the cognitive abilities of children, little information is available on the relationship between bilingualism and working memory [1,3,4].

The capacity of working memory plays a critical role in the development of academic skills, e.g. reading, language skills (especially second-language learning), and tasks related to learning and cognitive abilities. In addition, working memory, as an important part of short-term memory, holds the most recently activated part of long-term memory and actively transfers information from the temporary memory storage. In other words, working memory contains the available data for problem solving.

According to the literature, thinking ability and problem solving are dependent on the use of working memory. In general, working memory consists of four independent parts: 1) central executive, 2) phonological loop, 3) visual-spatial sketch pad, and 4) episodic buffer. In addition, the phonological loop has been shown to have the most significant correlation with reading skills (encoding, reading comprehension, and reading time).

The phonological loop (auditory-verbal working memory) is a hypothetical mechanism, used to encode auditory information in working memory [5-9]. It refers to the ability of processing oral information, analyzing it, and preserving it for further use [10]. Moreover, the phonological loop plays a key role in language learning and processing. Besides processing and storing auditory information, it forms a long-term representation of the information.

Children compare the newly received auditory information with the available representations in their memory and start to learn and process semantic and syntactic relations. Therefore, any defect in the function of the phonological loop could be associated with difficulties in the normal language development of children; in fact, limited memory capacity can be detected in the majority of speech and language disorders [11,12].

In addition, according to several studies, the phonological loop plays an influential role in the vocabulary development, phonological awareness, improvement of reading and writing abilities, word recall, and use of syntax [11,13]. Although bilinguals have shown a stronger performance in many parts of working memory in comparison with monolinguals [2,14-17], few studies have evaluated the performance of the phonological loop (auditory-verbal working memory) and have reported contradictory results in this area.

Various tests are available for the assessment of the phonological loop, including Rey auditory-verbal learning test (RAVLT), which has been never applied for this purpose. In a study by Soleymani et al. [18], the auditory memory was compared between 60 Persian-speaking monolinguals and bilinguals (Persian as the second language). In addition, in a study by Kuriakose et al. [10], the auditory-verbal working memory of 60 monolinguals and bilinguals was assessed, using the N-Back auditory test.

Furthermore, Blom et al. [17] evaluated the performance of working memory in 120 Dutch-speaking monolinguals and Turkish-Dutch bilinguals, using the Dutch version of Automated Working Memory Assessment (AWMA). On the other hand, several studies have reported contradictory results including those carried out by Cockcroft [19] in South Africa (with English as the first language at schools) and Khashawi [20], which applied AWMA to evaluate the participants.

Considering the high prevalence of bilingualism in our country, defects in the formal education of children (especially in the early years of primary school), strong association between working memory (specially auditory working memory) and learning abilities, and lack of a unanimous agreement on the effectiveness (or ineffectiveness) of bilingualism in auditory working memory, it is important to evaluate the strengths of this phenomenon and aim at improvement in primary schools.

By using the standardized Persian version of RAVLT [21], which is regarded as one of the most common, comprehensive, and standard tools for the evaluation of memory and learning capacity in neuropsychology, we aimed to evaluate the role of bilingualism in the performance of auditory-verbal working memory to promote the available limited information in this area.

Methods

This cross-sectional study was conducted via two-stage random sampling. 12 primary schools were selected in Ahvaz, Iran, and then the participants were selected among fifth- and sixth-grade students, who showed acceptable or excellent educational performance over the past year. It should be noted that bilingual children (with any level of proficiency in Persian language) might show weaker speech, vocabulary, and language skills during the early years of primary school, compared to monolingual children. However, these problems gradually reduce during the first years of school and bilingual children reach the level of their monolingual peers.

According to several previous studies, the differences between bilingual and monolingual students are resolved until the fifth grade of primary school [22]. For this reason, in this study, the samples were selected among fifth- and sixth-grade students in order to be assured about the equal status of speech and language skills in the two groups.

Considering the novelty of this research project and lack of similar studies in this area, the mean and variance of the total score of RAVLT (sum of the scores in the first to fifth stages of RAVLT) were estimated, using a pilot study (n=7 in bilingual and monolingual groups). Afterwards, the sample size was calculated by considering a type I error of 0.05 ($\alpha=0.05$) and type II error of 0.1 ($\beta=0.1$), using the following formula:

$$n = \frac{(Z_{\alpha} + Z_{\beta})^2 \, (S_1{}^2 + S_2{}^2)}{(\mu_1 \quad \mu_2)^2}$$

In total, 111 subjects were evaluated in the present study, 55 of whom were bilingual (Arabic-Persian bilinguals) and 56 were monolingual (Persian speaking). At first, for the assessment of the eligibility of the subjects, a questionnaire, consisting of demographic characteristics and medical records of the students, was completed by the parents, and written informed consents were obtained prior to the study.

The inclusion criteria in this study were as follows: 1) being right-handed; 2) absence of any medical problems affecting the psychological function, such as auditory and visual impairments, speech and language disorders, learning and memory impairments, and behavioral disorders such as aggressiveness; 3) no history of psycho-neurological diseases; 4) no history of trauma or surgery of head and neck regions; and 5) absence of debilitating systemic diseases and mental retardation.

Proficiency in Arabic and Persian languages in the bilingual group (based on the students' remarks and the parents' responses in the demographic questionnaire) and proficiency in Persian language in the monolingual group were also among the inclusion criteria. On the other hand, in case the bilingual students had not learnt Persian before the age of six, they were excluded from the study. Also, proficiency in three languages, unwillingness to cooperate with the researcher, and poor collaboration during the study were among the exclusion criteria.

The hearing ability of the participants was evaluated using a screening audiometer (Pezhvak Ava Co., Iran) to ensure normal hearing thresholds in the participants (better than 15 dBHL). In addition, the Edinburgh questionnaire was used to identify left-handed samples through evaluating the dominant hemisphere of the brain. Following that, phonetics and psychological speech assessments were carried out to ensure the absence of speech disorders in the participants. In case the samples were considered eligible for the study, they were explained on how to complete the questionnaire. RAVLT was completed for each student in one of the school classrooms with minimum distraction (in coordination with the school principal).

Group		Stage 1-5 (recall stage)	Stage 7 (immediately after presenting interference list)	Stage 8 (20 min after presenting interference list)
Monolingual	**Mean (SD)**	48.71 (6.71)	10.25 (2.29)	10.50 (2.27)
	Min	29	3	5
	Max	66	14	15
Bilingual	**Mean (SD)**	53.54 (5.24)	11.80 (2.13)	11.98 (1.88)
	Min	43	7	8
	Max	68	15	15
p		0.001	0.001	0.001

RAVLT was first designed by Edouard Claparede in 1919 and is considered as one of the most widely used measures of verbal memory. Other versions have been also published in other languages such as Finnish, Spanish, Hebrew, Chinese, German, Dutch, and Greek. RAVLT was translated into Persian by Jafari et al. and its reliability and validity have been confirmed [5,21]. This test consists of nine stages, containing three lists of one-syllable words: lists A and B (each containing 15 words) and delayed recall list including 50 words (comprised of all the words on lists A and B plus 20 new words) [21].

Since the aim of this study was to compare the memory scores between the monolingual and bilingual groups, the recognition task (final stage) was discarded. After explaining the study objectives and methods to the students in stages 1-5 (recall stage), 15 one-syllable words were read to each sample (one word per second). By the end of reading, the subjects were asked to name any words they could recall. As soon as the participants could not recall any more words, the next stage was initiated.

Five trials of the recall task were conducted to evaluate the effect of repeated stimuli and assess the individual's learning; the score of each response was then recoded. The total score was determined by summing the scores of each stage. The interference list, which differed from list A, was also presented to the participants under similar conditions as the first stage and their responses were recorded. Then, the participants were asked to recall and repeat the words on list A once immediately after presenting the interference list and once after 20 min (stages 7 and 8).

For statistical analysis, SPSS 18 was used (error rate=0.05). Data are presented as mean±SD deviation. Normal distribution of the data was evaluated using Kolmogorov-Smirnov test. For the comparison of recall stage scores (stages 1-5) with a normal distribution, t-test was used. On the other hand, Mann-Whitney U test was performed to compare the scores of stages 7-8, which did not have a normal distribution.

For ethical considerations, the objectives and method of the study were explained to the students' parents in a formal letter, and written informed consent forms were obtained. In this letter, the parents were assured about the safety of the intervention and confidentiality of the data.

Results

In this study, the mean age of the bilingual and monolingual students was 11.98±0.73 and 11.91±0.75 years, respectively. In addition, 50.45% and 49.55% of the samples were monolingual and bilingual, respectively. Table 1 presents the mean scores of each group in different stages of RAVLT.

As observed in Table 1, the mean score of stages 1-5 was 48.71±6.71 (out of 75) in the monolingual group and 53.54±5.24 in the bilingual group. Data distribution was normal at this stage and a significant difference was observed between the groups in terms of the final score ($p<0.001$). The minimum score (score=29) in the monolingual group was significantly lower than the minimum score (score=43) in the bilingual group.

In the seventh stage, the participants were asked to recall the words from list A immediately after presenting the interference list. The mean scores in the monolingual and bilingual groups were 10.25±2.29 (out of 15) and 11.80±2.13 (out of 15), respectively. Distribution of the obtained data at this stage was not normal and a significant difference was observed between the groups ($p=0.001$). In addition, a significant difference was found at this stage in the minimum scores between the two groups.

In the eighth stage, the participants were asked to recall the words from list A after 20 min of reading the words on the interference list. The mean scores were 10.50±2.27 (out of 15) and 11.98±1.88 (out of 15) in the monolingual and bilingual groups, respectively. At this stage, the data were not normally distributed, and a significant difference was observed between the groups ($p=0.001$). Also, a significant difference was found in the minimum scores between the groups.

Discussion

In the present research, the auditory-verbal working memory was evaluated in the bilingual and monolingual groups using RAVLT, and the results were indicative of the better performance of bilinguals in comparison with monolinguals. According to the results, bilingualism has a positive impact on auditory-verbal working memory, as one of the key parts of memory in language learning and processing. According to the literature review, few studies have exclusively evaluated the auditory-verbal working memory in bilingual and monolingual groups. Therefore, other previous studies on memory performance, specifically auditory memory, were also compared.

As discussed earlier, in the present study, the mean scores of different stages of RAVLT were significantly higher in the bilingual group in comparison with the monolinguals. Our findings were in line with various previous studies, which have revealed the better performance of auditory memory in bilinguals, compared to monolinguals [10,17,18,23,24]. Nevertheless, the sample size was limited in the majority of these studies, whereas in the present research, a larger sample size was included. In addition, RAVLT, which is a neuropsychological test, was used in our study, which differs from the tools applied in previous research.

Additionally, Lindberg conducted a study to evaluate memory in 45 monolingual and bilingual (Swedish-English) students, using word recognition tasks. According to the results, bilinguals obtained higher scores, compared to monolingual students, which is indicative of improved memory skills, owing to the use of two languages [23].

Language and memory have been shown to be co-dependent in the structure of human intelligence. Language acquisition depends on the proper function of memory in decoding and retrieving information. On the other hand, language is required for information decoding and storing [25].

As mentioned earlier, language and memory have a co-dependent relationship. According to the literature, those who are exposed to a bilingual social context show more favorable memory functions [26]. On the other hand, the crucial role of working memory has been confirmed in second-language learning [27]. In fact, bilinguals' attempt at separating two acquired languages (i.e. to speak a language without showing any traces of another language) leads to memory enhancement [24]. In a study by Soleymani et al. [18], the auditory memory of 60 bilingual and monolingual samples was evaluated, using the Persian version of dichotic word listening test. According to the results, better scores were reported in the bilingual group, compared to the monolinguals.

In another study by Kuriakose et al. [10], the auditory-verbal working memory of the participants was exclusively evaluated. In their research, 60 English-Malayalam (mostly spoken in Kerala, India) bilinguals and monolinguals were assessed. As the findings revealed, bilinguals showed better performance on two-back tasks, compared to monolinguals. Therefore, it can be concluded that bilingualism positively affects the development of cognitive processes, such as auditory working memory in early bilinguals. Overall, bilinguals show better auditory working memory performance, compared to monolinguals.

In addition, Blom et al. evaluated the working memory of 120 Dutch monolinguals and Turkish-Dutch bilinguals, using the Dutch version of AWMA. According to the results of this study, the bilingual group showed a better performance on the visual-spatial and verbal parts of working memory, compared to monolinguals [17].

Research has revealed that use of two or more languages can cause structural changes in the organization of some brain regions [10,28]. In addition, the auditory system as the main system involved in the acquisition and development of language skills can be influenced by bilingualism [18]. In this regard, several studies have been conducted to evaluate event-related potentials in monolinguals and bilinguals. Based on the results, a wider range of responses, i.e. auditory brainstem response to complex sounds (cABR) and middle latency response (MLR), was reported in bilinguals, compared to monolinguals. This could be attributed to the positive role of bilingualism in the development of concentration networks and selective attention through constant control during speech production [29,30].

Moreover, in some MRI and fMRI imaging studies of the brain, the auditory cortex was shown to be larger in bilinguals, compared to monolinguals. Since learning a second language requires the activation of the right hemisphere of the brain, more parts of the brain are involved in language learning and processing in bilinguals, compared to monolinguals [31,32,33]. Researchers have also attributed the better performance of auditory memory in bilinguals to the increased activity of the frontal and prefrontal lobes of the brain in early bilinguals. It has been shown that these parts of the brain are involved in auditory memory [34-36]. In this regard, Parsaie et al. [24] conducted a study on 89 male monolingual and bilingual (Turkish-Persian) fifth-grade students. According to the results, bilinguals showed a better performance on Cornoldi's memory test, compared to monolinguals [24]. Therefore, this advantage could be observed in bilinguals coming from different cultural backgrounds and is not exclusive to Arabic-Persian speaking bilinguals, as shown in the present study.

Nevertheless, the current research is not in congruence with the results reported by Cockcroft [19] and Khashawi [20], in which AWMA was used to assess the participants. In the study by Cockcroft, 120 monolingual and bilingual students with the mean age of 6.37 years were evaluated in South Africa. Meanwhile, Khashawi conducted a study on 396 monolingual and bilingual children with the mean age of 7.99 years in Kuwait. In addition, Cohen and Stewart compared the recall abilities of both monolingual and bilingual groups of different ages, and the results were indicative of an association between the increased mean age and improved scores on the tests. According to these findings, bilingualism could lead to the improvement of memory, which was closely related to the age of the speaker; in other words, higher age was associated with the greater improvement of memory skills [23]. Since the mean age of the subjects in the present study was 11.98 years and higher than the mentioned studies, the discrepancy between the results could be justified by the age difference (in the two mentioned studies, the mean age of the participants was low). Considering the speculation suggesting the effect of age on the benefits of bilingualism, it is possible that the positive impact of bilingualism on cognitive abilities (especially memory) was not expanded yet in the evaluated age range in previous studies. Moreover, bilingual children with any level of proficiency in a foreign language might show a weaker performance on language and vocabulary skills in early years of primary school, compared to monolinguals;

the discrepancy between the reported findings might be due to this factor, as well [22]. In conclusion, since a large part of language learning is accomplished through hearing, bilingualism could have a major positive influence on auditory abilities, such as auditory memory [18]. It is suggested that future studies evaluate students from different age groups (and higher grades), using other neuropsychological tests.

Conclusion

According to the results of the present study, the bilingual group showed a better auditory-verbal working memory performance, compared to monolinguals, based on the RAVLT results. Given the influential role of auditory-verbal working memory in the development of language, speech, and learning skills and the possible occurrence of speech and language problems in early years of primary school in bilingual children, it is recommended that the auditory working memory be enhanced in order to promote the students' language learning abilities and decrease the possible problems.

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