Original Article

The Effectiveness of a Working Memory Training Regimen for Iranian University Students: Implications for Medical Students

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Abstract

Introduction: Working memory is thought to serve as a part of memory structure where functions like temporary storage and manipulation of information take place. This study investigates the effectiveness of working memory training regimens with Iranian university students, while considering the implications for medical students.

Methods: Thirty university students studying at different universities in Kermanshah took part in the study. They were divided into two groups as the experimental and control groups. Both groups took pre- tests on their working memory capacity. The experimental group then underwent working memory training exercises for ten sessions. Both groups then took post- tests on their working memory capacity. The data collected through the pre- test and post- test were analyzed using SPSS software, version 16. The statistical procedure employed during data analysis included paired t-test and independent samples t-test.

Results: Analysis of the data revealed significant improvements in different measures of working memory in the experimental group in comparison to the control.

Conclusion: It is possible to improve working memory measures through training regimens. Given the similarities of the kinds of tasks medical students deal with in their academic lives to those of the working memory training exercises, further studies are required to investigate the effects of improved working memory capacity on medical students' academic achievements.

Keywords: Working memory, Training, Medical students

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Introduction

Working memory is claimed to play a key role in the performance of various cognitive functions. Its importance becomes paramount once one ponders upon a celebratory metaphor that has been assigned to it: 'the hub of cognition' (1), or postulates the triumphant reign of such a construct in the field of cognitive psychology and neuroscience manifested by such claims as "perhaps the most significant achievement of human mental evolution" (2). Baddeley (3), defines Working Memory as "the temporary storage and manipulation of information that is assumed to be necessary for a wide range of complex cognitive activities". It is a theoretical construct in cognitive psychology that refers to the mechanisms underlying maintenance of information that are related to performing a cognitive task (4), let the task be recalling a seven digit phone number, mentally rearranging the stuff in the garage to find more space for a newly purchased car, or comparing and contrasting the attributes of two products before making a purchase. In order to carry out these and similar tasks, one needs to carry out several cognitive functions such as attention and noticing, processing, evaluating, etc. temporarily. This is where working memory comes into play. Similarly, it is most evident that an endeavor like academic achievement with many intervening cognitive functions and intermediate short term steps and functions cannot spare the influence of working memory. In fact, working memory has been shown to be related to intelligence, information processing, executive function, comprehension, problem solving, education, and learning (5).

The functions and structure of working memory

That fact that many higher level cognitive functions have something to do with working memory in human beings can have practical implications for various domains of education in general and academic practices in particular. For example, teaching materials can be suited to the working memory capacity of the pupils, and assessment and evaluation practices can be adjusted to the learners' working memory conditions. In fact, if a curriculum needs to be compatible to the students' individual cognitive differences, it needs to have working memory at its very crux.

As far as the relationship between working memory and education is concerned, two different approaches can be discussed. On the one hand, we can adjust all our teaching practices to the level of the learner's cognitive functioning such as the working memory capacity and teach to that level. This view toward education is not without precedence (6-8). On the other hand, there is the other approach in favor of training practices to improve working memory in order to help achievement in dealing with related educational tasks (9). This study aims at discovering whether the values provided by the working memory software improve as a result of using a related training regimen.

With such a wide range of functions for the working memory to account for, it is imperative to find out whether or not it is possible to improve university students' working memory through intensive training instruction delivered by the relevant software. If such training proves feasible, the next step will be to investigate the role of such improvement in the working memory on the academic achievement of university student population.

The contemporary investigations into the nature of Working Memory stems from the seminal work of Baddeley and Hitch (10), abandoning the unitary conceptualization of the short term memory and proposing a multicomponent model instead that incorporates 'a central executive' along with its two buffer/slave systems: 'a phonological loop' and 'a visuospatial sketchpad'. The central executive is claimed to be the site where some cognitive functions such as the following are carried out among others: focusing, dividing, and switching attention; activating and inhibiting processing routines; and regulating the information flow from the short-term storage subsystems and from Long Term Memory (3). The phonological loop is supposed to store phonological information temporarily and manipulate verbal and acoustic information to prevent its decay. The other buffer, the visuospatial buffer, stores and processes visual and spatial information, like the information that makes up a visual image or constructs a mental map (11). Another subsystem which was later added to the model by Baddeley (12), is the episodic buffer. This one is held responsible for the integration of visual, spatial, and verbal information from the two other buffers and from the Long Term Memory into unitary episodic representations.

Working memory assessment

As far as measuring the components of working memory is concerned, there are two main measures that assess the capacity of the phonological loop: the forward digit set tasks which involve the repetition of sets of digits in increasing numbers, and the nonword set tasks in which the examinee repeats sets of nonwords of varying lengths. Obviously, these tasks primarily deal with the storage capacity of this buffer. In order to assess the capacity of the main component of working memory, i.e. the central executive, complex working memory tasks such as reading and listening span are used (4,13). These tasks require the participants to read or listen to a series of sentences. Later they try to recall and report the final word of each preceding sentence. In comparison to the tasks that assess the phonological loop, these tasks are far more complex verbal working memory tasks that involve both storage and processing of verbal information, with the possibility of providing information related to the functioning of the central executive (14).

With regard to training regimens in order to improve working memory capacity, several attempts have been reported in the literature, with a very limited number being carried out in Iran. Among the ones related to Iranian subjects, almost none deals with training practices on adults. The training practices have all been carried out with the prospect of improving educational achievements that require working memory. The logic supporting those practices is predicated on the assumption that training of such executive functions as inhibiting irrelevant information, updating working memory, controlling attention favors a boost in the capacity of working memory (15, 16). As examples of studies carried out on the effects of interventions aimed at improving working memory in children, one can refer to Alloway (17), who reported improvements in vocabulary retention and arithmetic gains and Klingberg et al. (18), who discovered improvements in nonverbal intelligence and ADHD symptoms.

Implications for medical students

The benefits gained through such working memory practices mostly apply to those areas of one's academic life which bear similarities to the training materials (called 'near transfer' by Redick, 19). Presumably, improving such aspects of the academic endeavor and modifying desirable behavioral outcomes which are different from the working memory training programs in nature are not among the goals of working memory improvement regimens. As far as medical students are concerned, they routinely deal with large bulks of readings that task the individual's working memory capacity, while many of them basically share similarities with the working memory training tasks. The point is to find out whether improvement in the working memory leads to a corresponding development in those areas of medical education practices that are basically similar to the training materials. Before dealing with this issue, it is imperative to show whether working memory training programs work with the Iranian university student population or not. Therefore, the following research question was proposed: Do working memory training programs lead to developments in Iranian university students' working memory capacity?

Methods

The sample population of this experimental study consisted of 30 male and female university students who were studying English at Zaban Sara Language Institute in Kermanshah, Iran, chosen through the convenient sampling approach. Their age range varied between 19 and 26. After gaining approval of the manager of the English institute to carry out the study, the list of university students studying English there was provided to the researchers. They were then individually referred to and briefed on the purpose of the study. Altogether, 30 of them expressed their agreement to participate by signing the written consents. The subjects were subsequently divided to an experimental group and a control one based on their enrollment list. The design of the study was the pre-test post-test design with an experimental and a control group. There were 8 male and 7 female students with the age mean of 20.2 years (±0.77) in the control group, while there were 7 male and 8 female students with the age mean of 20.4 years (±1.172) in the experimental one. In addition, running a X^2 test on the group members' gender features revealed no significant difference in terms of the distribution of both genders in the groups ($p=0.715$).

In this study, two pieces of software have been used. The first, the Working Memory Software, which assesses individuals on such features of the working memory as the ability to recall both visual and auditory characters in direct and reversed orders, is developed by Sina Institute for Cognitive and Behavioral Studies in Iran. In fact, it is the Persian duplicate of such programs as Cogmed and Jungle Memory Program which are internationally used for the same purpose with English speaking subjects. The second software was used in the intervention phase of the study with the experimental group. This software which is also developed by Sina Institute for Cognitive and Behavioral Studies in Iran provides different visual and auditory practice opportunities to help individuals increase their working memory capacity.

At the beginning of the study, members of both groups were individually assessed on their working memory capacity using the Working Memory Software. The output of the software provided detailed information on different aspects of their working memory such as the ability to recall visual and auditory information in direct and reversed orders, auditory working memory span, and visual working memory span. The output was automatically saved for future referral and comparison. Depending on the subjects' capability to keep up with the stimuli generated by the software, each assessment session lasted between 20 minutes to half an hour.

While the control group met again for the post- test on their working memory capacity after 45 days, the experimental group followed a working memory training regimen for ten sessions. They met the researchers every other two days on the average and exercised their working memory capacity using the second software, i.e. the Working Memory Training Software. They practiced individually for about one hour each session. The stimuli they received got increasingly complicated as they proceeded and covered a range of both auditory and visual working memory exercises dealing with shapes, letters, and numbers. At the end of each session, their performance was saved so that the subsequent session they began where they had previously left. Once all done, the post- test was administered to both groups, and the results were saved and loaded onto SPSS software, version 16, for comparison. In order to compare the performance of each group on the pre- test and post- test, the paired t-test was used. However, to compare the performances of the control group with those of the experimental one on the pre- test and post- test, independent samples t-test was used.

Results

The aim of this study was to find out whether working memory training regimens would prove effective in improving the working memory capacity of Iranian university students. To do so, the performance of the experimental group on the pre- test and post- test needed to be compared with that of the control group. Table 1 provides an account of the results of the performance of each group on the pre- test and post- test.

Table 1. Paired samples statistics for both groups

Paired Samples Statistics						
Group			Mean	N	SD	SD Mean
Experimental	Pair 1	Aural span pre- test	5.87	15	1.125	0.291
		Aural span post- test	8.53	15	0.640	0.165
	Pair 2	Visual span pre- test	7.20	15	1.656	0.428
		Visual span post- test	8.80	15	0.414	0.107
Control	Pair 1	Aural span pre- test	6.20	15	1.082	0.279
		Aural span post- test	6.53	15	1.187	0.307
	Pair 2	Visual span pre- test	7.13	15	1.187	0.307
		Visual span post- test	7.60	15	0.986	0.254

In order to detect any statistically significant differences between the performance of each group on the pre- test and the post- test, the paired t-test analysis was carried out. Table 2 presents the results of such analysis for each group. As indicated in table 2, the differences between the pre- test and post- test in the experimental group are statistically significant ($p<0.05$). The figures for the control group, however, do not show significant improvement on the post- test in comparison to the pre- test ($p>0.05$). To compare the performance of the groups with each other, independent group t-test was run.

Table 2. Paired t-test results for both groups

Paired Samples Test										
Group			Paired Differences					t	df	P
			Mean	SD	SD mean	95% CI of the Difference				
						Lower	Upper			
Experimental	Pair 1	Aural span pre- test aural span post- test	-2.667	1.047	0.270	-3.246	-2.087	-9.869	14	0.000
	Pair 2	Visual span pre- test visual span post- test	-1.600	1.639	0.423	-2.508	-0.692	-3.781	14	0.002
Control	Pair 1	Aural span pre- test aural span post- test	-0.333	0.724	0.187	-0.734	0.067	-1.784	14	0.096
	Pair 2	Visual span pre- test visual span post- test	-0.467	1.302	0.336	-1.188	0.254	-1.388	14	0.187

Table 3 compares such statistics of both groups as the mean, standard deviation, and standard error of measurement, and table 4 provides the p-values for each compared category.

Table 3. Group statistics for both groups

Group statistics					
	Group	**N**	**Mean**	**SD**	**SD Mean**
Aural span pre- test	**Intervention**	15	5.87	1.125	0.291
	control	15	6.20	1.082	0.279
Visual span pre- test	**Intervention**	15	7.20	1.656	0.428
	control	15	7.13	1.187	0.307
Aural span post- test	**Intervention**	15	8.53	0.640	0.165
	control	15	6.53	1.187	0.307
Visual span post- test	**Intervention**	15	8.80	0.414	0.107
	control	15	7.60	0.986	0.254

According to table 4, comparisons of the two group's performances on the pre- test do not yield a statistically significant difference (p>0.05). Comparisons of the post-test results of both groups, however, show a statistically significant difference (p<0.05).

Table 4. P-values for each compared category

		t-test for Equality of Means						
		t	df	P	Mean Difference	SD Error Difference	95% CI of the Difference	
							Lower	Upper
Aural span	**Equal variances assumed**	-0.827	28	0.415	-0.333	0.403	-1.159	0.493
Visual span	**Equal variances assumed**	0.127	28	0.900	0.067	0.526	-1.011	1.144
Aural span post- test	**Equal variances assumed**	5.743	28	0.000**	2.000	0.348	1.287	2.713
Visual span post- test	**Equal variances assumed**	4.347	28	0.000**	1.200	0.276	0.635	1.765

Discussion

The aim of this experimental study expressed through the research question was to find out whether working memory training efforts would lead to improvements of the working memory capacity. The results of the present study support the occurrence of such an improvement in both capacities of the working memory: the auditory capacity and the visual one among adult Iranian university students. While the two groups were almost homogenous in terms of age and gender and the results of their performances on the working memory pre- tests were not significantly different, analyzing the results of the post-tests indicated the effectiveness of the intervention. Such improvements can bear valuable implications for the subjects. For one thing, improvements in the auditory capacity of the participants might indicate a development in the phonological loop, the slave system of the working memory that, according to Baddeley (11), is responsible for the temporary storage and manipulation of verbal and acoustic information. In many academic settings in general and in medical education environments in particular, the teaching materials are delivered through lectures. There is therefore the possibility that improve-ements in this component of the working memory might give the students in those settings the advantage of improvements in their cognitive uptakes. Similarly, the other component, i.e. the visual-spatial sketchpad, takes care of storing and processing different visual and spatial information. A familiar scene in many medical education settings in Iran is the one in which a main portion of the teaching materials is presented using visual media such as overhead projectors and similar facilities. This can be another area in which improvements in the visual capacity of working memory might offer the students a privileged advantage of improved learning opportunities.

The effectiveness of working memory training regimens observed in the present study is in line with the findings of other pieces of research which have been reported in the literature. For example, Cowan, et al. (20) reported the effectiveness of visual working memory training programs in children and adults, and further its effects on the ability to combine items in an array to form a coherent configuration. Such improvements in the working memory capacity have also been pointed out by Alloway et al. (21), Ang et al. (22), Chacko et al. (23), and Karbach et al. (24), to name a few. These studies, however, have mainly focused on children as the target population. Similarly, studies carried out on working memory in Iran have so far been targeted at children, too. They have investigated the effects of working memory training on subject areas like reading skill, dictation, and math in primary school children (for example, 25, 26, 27). They have all reported significant developments in the target areas as the result of improvements in working memory capacity.

Although the importance of improving working memory capacity in children is well established by now among researchers and child education specialists, one might question its relevance to adult lives. The importance of such practices is mainly linked to the functions of working memory and is multifold. The capacity limits of working memory are believed to constrain understandings of concepts by individuals or the ability to solve problems (7). According to Cowan (2014), developments in working memory can provide the best course for improving educational practices. He argues for the roles that working memory plays in concept formation, control processes, and pneumonic strategies. Fenesi et al. (28) believe that working memory is the best predictor of success in academic practices, and that working memory is the basis of classroom learning, because students are supposed to process critical information as they try to retain verbal instructions delivered by the teacher.

Conclusion

It can be concluded that working memory capacity of the participants of the study in the experimental group improved in terms of its auditory and visual spans, and that this development was due to the effectiveness of the training program delivered by the use of the related software. Given the importance of the role of working memory in our lives in general and in learning practices in particular, it is recommended that its effects on medical students' academic achievements be explored in more details in order to increase efficiency and provide help whenever failure is due to deficiencies in working memory. However, as Redick, et al. (19), point out, research in this area has so far produced mixed results mainly due to differences in the design of the studies and the nature of the tasks included in those studies, among some other factors. Any future studies planned to deal with the effects of improvements in the medical students' working memory should lack any such deficiencies in its designs and include assessment tasks which are similar to the ones the students deal with in their real lives.

Limitations

Some limitations might have affected the strength of the claims presented by the researchers and the generalizability of the results of the study. First of all, sample selection for the study was not randomized. Other studies are required to be carried out with true random selection of subjects to allow stronger claims to be made. In addition, the study was done in a limited period of time. Longer observations are required to see if the observed benefits are long-lasting. The last but not the least, improvements in working memory was not linked to possible improvements in other areas of the subjects' academic lives. Future studies exploring such relationships will put us in a better position to understand the real function/benefit of working memory improvement practices.

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