Effect of working memory training on memory performance in young adults of Medical University

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Abstract: Background: One of the indicators of the quality of medical education is good study performance which is very much influenced by the working memory capacity. Recent studies have reported that working memory can be improved after training. In this study, we were looking for association between working memory training and its performance among healthy students of Medical University. In Kazakhstan, a similar study has not been conducted before. **Methods:** design is before and after study. 409 students of Medical University took part in the study: 191 in study group and 218 - in control. The study and control groups were comparatively equal by age and gender. Reading span test was used for working memory training and Dual N-back test was used for results' measuring. Five weeks training in study group were performed. **Results:** in study group the mean of correct answers in pre-test was 62.5 ± 12.3 and after training it increased till 73.6 ± 12.3 (p<0.001). In control group in pre- and post-test were 63.3 ± 11.5 and 63.7 ± 12.4 (p = 0.303) respectively. In comparison between groups the mean of correct answers in study group was higher by 17.8% (p<0.001). **Conclusion:** we have found not only increases of working memory in healthy young adults after 5-weeks training, but also develop other cognitive functions - improving auditory and spatial memory in parallel to visual one.
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1. Introduction

The learning material of Medical Schools basically is not more difficult than courses of other High Educational Institutions but the volume of information per day is much greater. For sophisticated performance in many subjects, such as anatomy, pharmacology etc., students need to memorize a lot of factual data. Memorizing of large amount of written and lecture materials is essential to learning and requires both auditory visual perception and auditory visual working memory (WM).

WM is defined as *"the system for the temporary maintenance and manipulation of information, necessary for the performance of such complex cognitive activities as comprehension, learning, and reasoning..."* (Baddeley, 1992 cited in Collette Mann et.al., 2013).

Growing number of studies suggesting that the working memory can be improved after memory training (Perrig WJ et.al., 2009; Olesen PJ et.al., 2004; Norbert Jaušovec et.al., 2012; Leona Pascoe et.al., 2013; Hikaru Takeuchi et.al., 2012; J. Holmes. et.al., 2009; Yvonne Brehmer et.al., 2012; Rui Nouchi et.al., 2013). For example, improving of WM after training has been shown not only in healthy preschoolers aged 5 to 6 years (Olesen PJ et.al., 2004), young adult (Salminen T.et.al.,2012; Yvonne Brehmer et.al., 2012; Rui Nouchi et.al., 2013) and elderly persons (Yvonne Brehmer et.al., 2012), but also in children with Attention deficit hyperactivity disorder (J. Holmes. et. al., 2009), persons with intellectual deficiencies (Perrig WJ et.al., 2009), in adolescents born at extremely low and low birth weight (Gro C.C. Løhaugen et.al., 2011; Grunewaldt KH et.al., 2013).

There are different ways for WM training such as letter-span task (Klingberg T. et.al., 2002), reading span task (RST) (Daneman M. et.al., 1985; Leona Pascoe et.al., 2013). Some scientists used brain age game, tetris and puzzle (Rui Nouchi et.al., 2013); others used complex of training program (DS, RAPM and PF&C) (Norbert Jaušovec et.al., 2012). The computer programs like a N-back training (Salminen T. et.al., 2012; Buschkuehl M. et.al., 2007; Jaeggi S. M. et.al., 2008), Cogmed program (Olesen PJ et.al., 2004; Gro C.C. Løhaugen et.al., 2011; J. Holmes et. al., 2009; Xin Zhao et.al., 2013) or PS-training program (Hikaru Takeuchi et.al., 2012) can be used for WM training too.

Previous findings have indicated that WM training can improve not only performance on trained tasks but also untrained cognitive tasks (Perrig WJ et.al., 2009; Kawashima R. et.al., 2005; Olesen PJ et. al., 2004; Salminen T. et.al., 2012). For example, Salminen T et al. (2012) studied transfer effects from WM training to different aspects of executive functioning and proved, that the training effects can generalize to various other tasks tapping on executive functions. Also, Olesen PJ et.al. (2004) have demonstrated changes in the front-parietal cortices activity during untrained cognitive tasks after working memory training. Other studies have shown that the capacity of WM predicts performance in several cognitive tasks ranging from simple attention tasks (Kane M.J. et.al., 2001; Bleckley M.K. et.al., 2003; Fukuda K. et.al., 2009) to tasks tapping more complex abilities, such as reading comprehension (Grunewaldt K.H. et.al., 2013), reasoning and problem-solving (Kyllonen P.C. et.al., 1990; Engle R.W. et.al., 1991; Fry A. F. et.al., 1996; Barrouillet P. et.al., 1999; Engle R.W. et.al., 1999), along with executive functioning in everyday life (Kane M. J. et.al., 2007).

In this study, we were looking for association between working memory training and WM performance among healthy students of Medical University.

2. Materials and methods:

Participants

The study was carried out in Kazakh National Medical University from November 5th till December 13th, 2012. Initially 440 students were included into the sample (mean age 19.2 ± 1.8 years old). They were randomly divided into two groups: study group (220 participants) and control group (220 participants). Response rate was 92.9%. During the study period 31 students (7.1% of total; 29 in study group and 2 in control) were lost to follow-up due to illness (13 students) and private issues (18 students), and consequently we excluded them from study. All further calculations in the article are based on the results of these 409 students.

The demographic data such as age, gender, stress level (not shown here) was collected from each participant. Unique code was given to each participant so researcher, who analyzed data was "blinded" to names to avoid biases.

Tests for pre- and post-training evaluation

Jaeggi S.M. and colleagues in 2007-2008 described the Dual N-back test, which was used as a training program (Buschkuehl M. et.al., 2007; Jaeggi S. M. et.al., 2008). The test was composed of sequences of visual-spatial and auditory stimuli that individuals should memorize and indicate whether the current stimulus matched an item that was presented n steps back (Salminen T. et.al., 2011). We used Dual N-back test as a working memory measurement instrument as a pre- and post-test. Number of steps was 24, with a 3 seconds time interval between them.

Before a pre-test all participants have had visual explanation and were given one trial attempt for the acquaintance with the task. After trial attempt results of pre-tests were recorded. Pre-test was carried out one day before the starting of training and the post-test - the next day after finishing training. Ten computers in 2 classrooms (5 computers per room) were used for the pre-test and post-test. Individual testing was performed by N-back on-line program (http://brainscale.ru/n-back/training) in each computer.

Training task

First time a reading span test (RST) were published by M. Daneman and P. Carpenter (1980). It was determined as "a common memory span task widely cited in, and adapted for investigations of working memory, cognitive processing, and reading comprehension".

RST training task was given for the period of 5 weeks only to study group. During that time the control groups' participants were engaged in «paopao» computer game (Chen program study, 2006)

For each RST pre-designed sentences were used. Sentences were adopted from the high school program, i.e. were not difficult to understand and do not include technical phrases. Every single sentence was not logically connected with the following one.

We have used RST with incremented volume of memory load by increasing the number of sentences. Participants have received one additional sentence each 3 days.

On the first 3 days participants were given the combination of three sentences on the following 3-4 sentences and so on. During five weeks there were totally 25 training days (weekends were free of training), so on the final day they have received 11 sentences to memorize.

Participants were asked to read and memorize prepared sentences. Time for memorizing was given 1 minute per each sentence. All sentences were printed on single page. Participants were allowed to write notes on that page. Then participants were asked to put aside task sentences ant to recall and write the words from the specified position (first or last) in the sentence on a separate sheet of paper. The position of the word that needed to be recalled varied each time randomly, and was announced after the RST task just before recalling process. Then participants were allowed to compare recalled words with original ones to see their progress.

Ethics Statement

At the beginning of the experiment each participant signed written consent of participation in this experiment. The study protocol was approved by the Local Ethics Committee of the Kazakh National

Medical University with the number of №3 dated October 25th, 2012.

Statistical Analysis

Statistical Analysis was carried out using the SPSS statistical package, version 20.0 for Windows (IBM Ireland Product Distribution Limited, Ireland). We describe categorical data with the use of absolute frequency and percentage. Quantitative data are represented as mean ± standard deviation. For explanation of differences between the quantitative data in subgroups a paired group t- test was used and between groups the t-test for independent groups was used. The level of significance was set at α< 0.05.

3. Results:

The baseline characteristics of study and control groups are shown in table 1.

Totally, 409 students took part in our study. 46.9% (n=192) of them were men and 53.1% (n=217) were women. Mean age for all students was 19.2±1.8 years old. In study and control groups the mean age was 19.4±1.7 and 19.0±1.8 years respectively. The gender proportion of men/women in study group was 43.5/56.5 and 50/50 – in control group. So the study and control groups were comparatively equal.

Table 1. The baseline characteristics of study and control groups.

Gender, abs (%)						
	Study group		**Control group**		**Total**	
Men	83 (43.5)		109 (50.0)		192 (46.9)	
Women	108 (56.5)		109 (50.0)		217 (53.1)	
Age, years						
	Study group		**Control group**		**Total**	
	M	SD	M	SD	M	SD
Men	19.4	1.8	19.0	1.8	19.1	1.8
Women	19.5	1.7	19.0	1.8	19.3	1.8
Total	19.4	1.7	19.0	1.8	19.2	1.8

The main results of study and control groups are shown in table 2.

Table 2. The pre- and post-test results in study and control groups

	Pre-test		**Post-test**		**p-value**	**p-value**
	M	SD	M	SD	(pre-/post-test)	(study/control groups)
Study group	62.5	12.3	73.6	12.3	<0.001	<0.001
Control group	63.3	11.5	63.7	12.4	0.303	

In control group the mean of correct answers in pre- and post-test were practically unchanged: 63.3 ± 11.5 and 63.7 ± 12.4 (p=0.303) respectively. At the same time, in study group pre-test was 62.5 ± 12.3 and after training it increased till 73.6 ± 12.3, which was statistically significant (p<0.001).

In comparison between groups the mean of correct answers in study group was higher by 9.9 correct answers or 17.8%. Increasing was statistically significant (p<0.001).

4. Discussion

In this research we aimed to determine whether working memory training could improve working memory capacity in healthy young adults of Medical University using for training RST and for effect's controlling N-back test.

Recently, researchers adopted several methods of WM training that have been used with different level of success. Mostly used: letter-span task (Klingberg T. et.al., 2002), brain age game, tetris and puzzle (Rui Nouchi et.al., 2013), computer programs like a N-back training (Salminen T. et.al., 2012; Buschkuehl M. et.al., 2007; Jaeggi S.M. et.al., 2008), Cogmed program (Olesen PJ et.al., 2004; Gro C.C. Løhaugen et.al., 2011; J. Holmes. et.al., 2009; Xin Zhao et.al., 2013) or PS-training program (Hikaru Takeuchi et.al., 2012). Some scientists have also used complex of training program (DS, RAPM and PF&C) (Norbert Jaušovec et.al., 2012).

According to Leona Pascoe et. al. (2013), Reading Span Task "originally was devised as a measure that the processing and storage functions of working memory which is necessary for understanding and memorizing of written material". So we have presumed that RST is also could be effective in WM training, when repeatedly applied for a prolonged period and with incrementing number of sentences. Moreover, this training is closely related to students usual studying pattern. The only difference, that the memorizing load of RST is more higher for a short period of time.

The training outcomes were measured by dual N-back test, which is used as training method in general. Dual N-back training was described by Jaeggi et al. (2008). On each trial, participants were presented simultaneously with a visual (different position of box on screen) and an auditory stimulus (one of letters) (L. Lilienthal et al., 2012). Also N-back training was used by Gro C.C. Løhaugen et.al. (2011) and Buschkuehl, M. et.al. (2007). We have used dual N-back test for post-test because it is simple for using and could test several participants simultaneously.

Similarly to other studies (Olesen PJ et.al., 2004; Salminen T. et.al., 2012; N. Jaušovec et.al., 2012; Leona Pascoe et.al., 2013; Hikaru Takeuchi et.al., 2012; J. Holmes. et.al., 2009; Xin Zhao et.al., 2013; Klingberg T. et.al., 2002), we have indicated increasing of WM in study group (by 17,8%). Our result is slightly higher than N. Jaušovec, K. Jaušovec (2012) who reported increasing of WM in students by different training methods up to 15,3 % (by DS), 12,9 % (by RAPM, the advanced form of Raven's Progressive Matrices, a non-verbal intelligence test), 13,7% (by PF&C, the spatial rotation test was based on the Paper Folding and Cutting). This difference can be attributed to the fact that in our study the tests and training method were different and that in their research control group have had more active involvement compared to ours.

In the work of Y. Brehmer et.al. (2012), where participants' mean age was 20-30 years in comparison with 60–70 years adults, the adaptive training group increased their performance across the 3 and 4 weeks of training. At T. Salminen study (2012) the participants mean age was 24.4 years and their results were similar too. In our study participants' mean age was 19.4 years and we have also found improvement of WM.

Interestingly, although, RST is mainly designed for visual WM training, but by using c N-back test for post-test we have seen the improved of other cognitive functions, such as auditory memory and spatial memory. Similar improvement in association with WM increasing was noted in other studies (T. Salminen et al., 2012; H. Takeuchi et.al., 2011; Perrig et.al., 2009; Kawashima et al., 2005). XinZhao et. al. (2013) have reported that participants in the training group after 20 days of the two-back working memory training task had no significant differences in improving of WM in comparison to control group, but reaction time was reduced significantly. This basically can indicate an improvement of cognitive functions.

5. Conclusion

Thus, the present study examined the relationship of working memory training and increasing of its volume in healthy young adults. Our findings indirectly confirm that training not only increases the amount of WM, but also develop other cognitive functions - improving auditory and spatial memory in parallel to visual one. In Kazakhstan, a similar study has not been conducted before.

Strengths of our study:

1. Large sample of students.
2. Random participants' allocation.

Limitations of our study:

1. Training was conducted by reading span task; pre- and post-test - by N-back test.
2. Didn't discover a dynamic of result during training as well as in the long term (1 - 3 months) as in the other studies.
3. We assessed in testing the total number of correct answers, and not its separate components (visual, auditory and spatial memory).

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