IRSTI 11.25.67 https://doi.org/10.26577/ijbch.2021.v14.i1.07

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How does training of the working memory effect the memory performance in young people?

Abstract. One of the quality indicators of the medical education is a good study performance, which is very much influenced by the capacity of the working memory. Recent studies have reported that working memory can be improved by training. In this study, we were looking for association between the training of the working memory and its performance in healthy students at Kazakh National Medical University. A total of 676 students participated: 346 in study group and 346 – in control. Reading span test (RST) was used for working memory training and Dual N-back test was used for measurement of results. According to the results obtained, one-and-a-half-month RST training of the memory (RAM) statistically significantly increases the amount of the working memory on average by 12.3 %: min on 9.9 %; max on 15.5 % ($p<0.001$). The present study examined the relationship of the working memory training and increase in its level in healthy young adults. Our findings indirectly confirm that training not only increases the level of the working memory, but also stimulates other cognitive functions: improving auditory and spatial memory in parallel to the visual one.

Key words: medical students, working memory training, moving intelligence.

Introduction

Moving intelligence according to the theory applies to all areas of life, but mostly relates to the scientific and technical branches, including mathematics and programming. It includes the ability to learn, inductive and deductive thinking, abstract thinking, recognizing connections and regularities. Moving intelligence uses the working memory and often its level in person is generally closely related to the size of the working memory. The latter in turn, characterizes human ability to manipulate information stored for a short time in his or her memory. Such manipulation underlies the processes of thinking: reasoning, learning, understanding [1].

In this connection, a theory arose concerning the possibility for development of the moving intelligence by developing the working memory, using techniques like N-back [2]. Human moving intelligence grows until about 30-40 years, after which it begins to decline [3]. In particular, it predominates in patients with autism [4]. Developed by Kirchner in 1958 [5], the task of continuous execution – the N-back problem (so called continuous performance task), is used in neurophysiological studies to stimulate the activity of certain brain zones, as well as in psychology for the evaluation and development of the working memory, logical thinking, the ability to concentrate and, in general, moving intelligence (also known as fluid intelligence, Gf; is the ability to think logically, to perceive and remember new things, to solve new unusual problems).

A study conducted in 2008 by Jaeggi et al. showed [6] that the regular training in the performance of this task is able in a short period to significantly develop the moving intelligence, expand the working memory of a person, improve logical thinking and the ability to concentrate. The correctness of the evaluation of the results of the study was criticized by David Moody, who believed that the final measurements were not carried out correctly. But Jaeggi challenged Moody's criticism and in 2010 the study with some changes was carried out again, confirming the initial results [7].

In current study, we looked for association between the working memory training and its

performance in healthy students at Kazakh National Medical University.

Materials and methods

Participants. The study was carried out in Kazakh National Medical University from April 1st to May 10th, 2019. According to the criteria for inclusion and exclusion from the study, a total initial number of 692 students was formed. After randomization, two groups were formed: the main group and the control group, each of 346 students. In the course of the study, 21 students who expressed a desire to train their memory were transferred to the main of the control group. In addition, 16 students were expelled from the control group (9 students – withdrawal, 7 students – failure to appear for a repeat examination). In total, the main group consisted of 367 students, the control group of 309 students. All research was based on the results of 676 students (total final number). The total number of students, as well as the number of students in the main and control groups who took part in our study exceeds the minimum number of sample calculations.

Tests for pre- and post-training evaluation. Jaeggi et al. in 2007, 2008 described the Dual N-back test, which was used as a training program [8; 9]. The test consisted of sequences of visual-spatial and auditory stimuli that individuals should memorize and indicate whether the current stimulus matched an item that was presented a few steps back [10]. We used Dual N-back test as a working memory measurement instrument for pre- and post-examination. Number of steps equaled 24, with a 3 second time interval between them.

Prior to pre-examination all participants had a 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 prior to the initiation of training and the post-test – the next day after the completion of training. Ten computers in 2 classrooms (5 computers per room) were used for the pre-test and post-test. Individual examination was performed by N-back on-line program (http://brainscale.ru/n-back/training) on each computer.

Training task. For the first time RST was mentioned by Daneman and Carpenter (1980) [11]. It was explained as "a common memory span task widely cited in, and adapted for investigations of the working memory, cognitive processing, and reading comprehension."

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

For each RST pre-designed sentences were used. They were adopted from the high school program, which means, they were not too difficult to understand and did not include technical phrases. Every single sentence was not logically connected with the following one.

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

On the first 3 days participants were given the combination of 3 sentences, on the following – 3-4 sentences and etc. For five weeks there were 25 training days in total (weekends were free of training), so on the final day participants received 11 sentences to memorize.

Participants were asked to read and memorize prepared sentences. For memorizing 1 minute was given per each sentence. All sentences were printed on a single page. Participants were allowed to write notes on that page. Then participants were asked to put those sentences aside and 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 just before the recalling process. Then participants were allowed to compare recalled words with original ones to see their progress.

Ethical statement. At the beginning of the experiment each participant signed written consent of participation in this experiment. The study protocol No.3 was approved by the Local Ethics Committee of the University from 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 is presented as mean ± standard deviation. For explanation of differences between the quantitative data in subgroups a paired group Student's t-test was used and between the groups a Student's t-test for independent groups was used. The level of significance was set at $\alpha<0.05$.

Results and discussion

The study involved 676 students. The average age was 19.3 years old (SD=1.9). There were more girls (n=356; 50.7 %), than guys (n=320;

47.3 %). Average age of girls (M=19.4 years old; SD=1.9) and guys (M=19.3 years old; SD=1.8) was not statistically different (Student's t-test=0.598; df=674; p=0.550).

All students (n=676) were determined the basic (i.e., initial, prior to training) amount of RAM. It averaged 49.8 (SD=19.2), its distribution was consistent with the law of normal distribution of the quantitative data (Figure 1).

The memory parameters in the main group at the end of the training were as follows: average – 59.2, standard deviation – 19.1. The distribution of the post-test values corresponds to the law of the normal distribution (Figure 2).

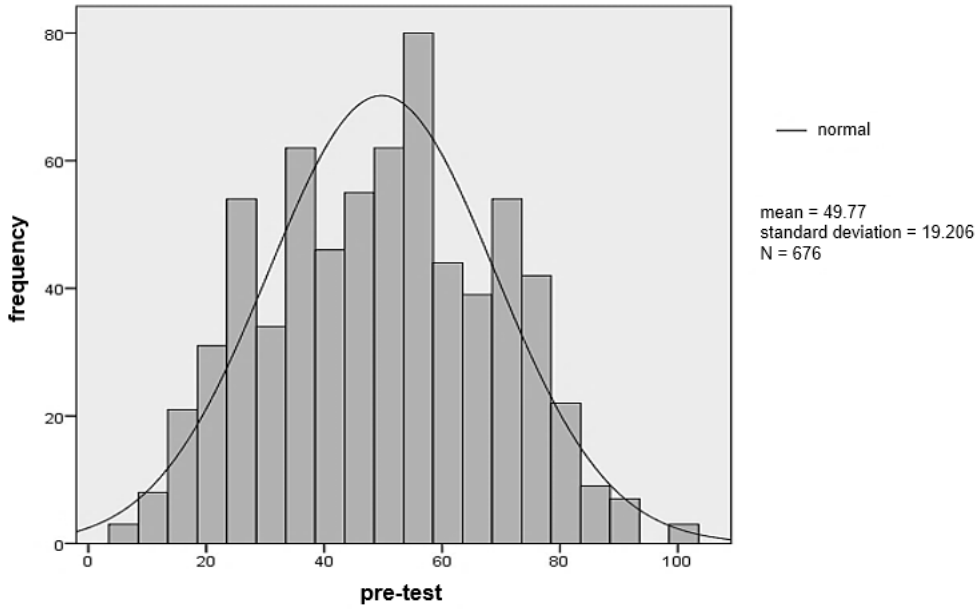

Figure 1 – Results of the determination of working memory (pre-test)

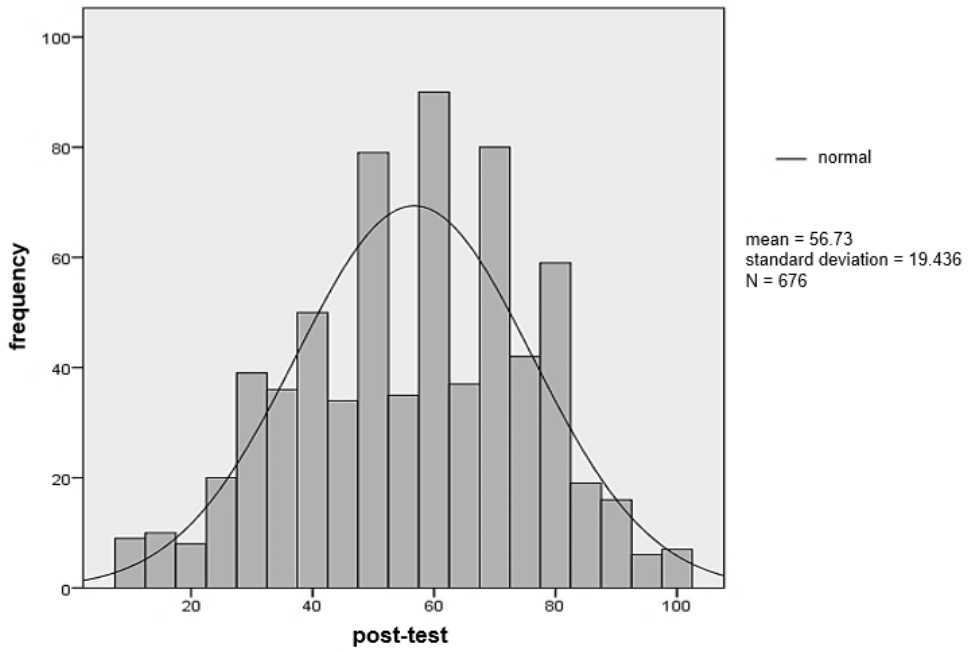

Figure 2 – Results of determining the working memory after training (post-test)

The indicators of the post-test among the students of the control group were as follows: average – 53.8, standard deviation – 19.4. At the same time, the difference between the post-test and pre-test results in control group averaged 0.7 (SD=6.5) (p=0.066).

The indicators of the post-test among the students of the main group were as follows: average – 59.2, standard deviation – 19.1. At the same time, the difference between the results of the post-test and the pre-test averaged 12.3 (SD=7.3) ($p<0.001$).

In this research we aimed to determine whether training of the working memory could improve the working memory capacity in healthy students using N-back test for control of the effect and RST for training.

Recently, researchers adopted several methods of the working memory training that have been used with different level of success. Brain age game, tetris and puzzle [12], letter-span task [13], computer trainings like a N-back training [8-10], Cogmed program [14-16] or PS-training program [17]. Some scientists also used a complex of training programs (DS, RAPM and PF&C) [18].

In our study, training outcomes were measured by dual N-back test, described by Jaeggi et al. [9], which was used as a training method in general. On each trial, participants encountered simultaneous visual (different position of box on a screen) and auditory stimulus (one of the letters) [19]. We have used this test as a post-test because it is simple to use and allows to test several participants simultaneously. Same was used by Løhaugen et al. [15], and Buschkuehl et al. [8].

RST was originally developed as a measure for analysis of processing and storage functions of the working memory, required for understanding and memorizing the written material. So, we have presumed that RST could also be effective in training of the working memory, when repeatedly applied for a prolonged period of time and with incrementing amount of information in the form of sentences. Moreover, this training is closely related to the usual studying pattern of students. The only difference is that the memorizing load of RST is larger for a short period of time.

In the work by Brehmer et al. [20], the mean age of participants was 25 in comparison with 65 years old adults; the adaptive training group increased their performance across the 3 and 4 weeks of training. In Salminen study [21], participants with the mean age of 24.4 showed similar results. In our study, the mean age of participants was 19.4, and we have also witnessed the improvement of the working memory.

Also, RST is mainly designed for visual training of the working memory, by using the N-back test as post-test we have seen the improvement of other cognitive functions. Similar improvements in association with the working memory increase was noted in other studies [10; 16; 17; 22-25], which have reported that participants in the training group after 18 days of the two-back working memory training showed no significant differences in improvement of the working memory in comparison with the control group, but reaction time was reduced significantly. This basically can indicate an improvement of the cognitive functions.

Strengths of our study:

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

Limitations of our study:

1. Training was conducted by RST; pre- and post-test by N-back test.
2. No dynamics in results has been found during the training period as well as in the long term (1-3 months) as in the other studies.

Conclusion

The study conducted using the N-back program showed that the difference between the results of the post-test 1 and pre-test in the control group averaged 0.7, in the main group – 12.3.

One-and-a-half-month training of memory (RAM) with reading span task (RST) statistically significantly increases the amount of working memory on average 12.3 %: min – 9.9 %; max – 15.5 % ($p<0.001$).

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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