Full Length Research Paper

Neuroscience-based visual-spatial working memory training and its effects on the attention of dyslexic children

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Accepted 08 May, 2013

A body of research indicates that impairment of working memory (WM) may be one of the factors that impede the ability to attend a task correctly and accurately. Emerging evidence suggests that WM might be improved by intensive computerized training, however, it remains unclear whether this intervention would be effective for children with severe reading problems. Although the capacity of working memory is traditionally considered to be constant, recent data shows a certain plasticity in the neural system that underlies working memory (WM), can be improved by training and may increase sustain attention. In this study, we examined whether attention components of dyslexic readers can be increased by a neuroscience-based working memory training or not. The intervention (BrainWare Safari by LEC) was conducted with 15 students 8 to 12-year-old with reading problems compared with 20 students in the control group. All the subjects in the experimental group were trained over a six week period (30 sessions). All subjects in the experimental and control groups were tested by Computerized Raven’s Colored Progressive Matrix for children, WMTB-C and IVA-CPT. The students in the experimental group considerably improved their performance in the trained visual spatial working memory tasks. Additionally, compared to a matched control group, the experimental group showed training effects on non-trained tests as well as transfer effects to visual/auditory sustain attention, visual/auditory vigilance/speed and hyperactivity after training; providing further evidence for shared processes between working memory, attention and reading.

Keywords: Cognitive Remediation, Neuropsychological Training, Reading Problems and Sustain Attention.

INTRODUCTION

Working Memory (WM), as a cognitive system, has a vital role in order to provide a capacity for storing information temporarily when we do some complicated cognitive activities. It supports learning and keeps our behavior concentrated in real situations (Holmes, Gathercole, and Dunning, 2009). But those who suffers from poor WM has difficulty in both of these important aspects of life routine (Gathercole, Lamont, and Alloway, 2006) and in the school, they generally possess poor results academically (Alloway, Gathercole, Kirkwood and Elliott, 2009). For example, those who has neuropsychiatric conditions, such as traumatic brain injury, stroke, mental retardation, schizophrenia, attention-deficit hyperactivity disorder (ADHD) and learning disorders (LD), obviously has impairment in the function of WM (Martinussen et al., 2005). Therefore, it seems that poor reading comprehension and reading problems is virtually concerned with working memory problems.
The relationship between visual attention and working memory has been examined by looking at whether working memory is important for attentional tasks. In the recent studies of Awh and his colleagues (Awh and Jonides, 2001; Awh, Jonides, and Reuter-Lorenz, 1998), a close relation between WM and visual attention has been demonstrated in any case for Visual-Spatial Working Memory (VSWM). According to the above fact, WM as a limited capacity was conventionally unwilling for improvement (e.g., Niazi and Logie, 1993). Though, current researches have supplied positive results from WM training for both children (Loosli et al., 2011) and adults (von Bastian, Langer, Jäncke and Oberauer, 2012; Brehmer, Westerberg, and Bäckman, 2012). According to researches, the capacity of WM anticipates its performance in various other cognitive tasks which has a range of simple attentional tasks (Kane et al., 2001; Bleckley et al., 2003; Fukuda and Vogel, 2009) to a range of tasks require more complicated capabilities, such as reasoning and problem-solving (Engle et al., 1999), as well as executive functioning in everyday life (Salminen et al., 2012). As a matter of fact, Furthermore to reports that show WM training is successful (Klingberg et al., 2002, 2005, 2010; Söderqvist et al., 2012; Holmes et al., 2009, 2010), recently, it is proved that WM training can perfect a person's accomplishment extensively rather than other cognitive measurements, i.e. cognitive control (Klingberg et al., 2002, 2005; Chein and Morrison, 2010), and fluid intelligence (Gf) (Olesen et al., 2004; Jaeggi et al., 2008).

So, the goal of present study is to determine whether WM training for Iranian children with reading problems will lead to improved VSWM of them or not. Consequently, we hypothesized that working memory ability would be increases through the training with a positive effect on children's important cognitive domains and transfer its effects to attention performance.

METHODS

Design

The present study was a 2 (Group: training vs. control) × 2 (Session: pre-test vs. post-test) mixed-design with testing occasions as the within variable. Before the start of training, all participants were assessed on a battery of tests regarding reading, visuo-spatial working memory and attention. Following the assessment, participants were randomly assigned to either the training or the control group. Approximately 7 to 8 weeks after the pre-training assessment, the participants were again assessed on the cognitive battery.

Participants

A total of 41 children aged 7 to 12 (M = 8.2 years, SD = 1.4), 11 girls and 30 boys with reading problems in grades 1–5, from the 3 official learning disabilities centers and some schools in Tehran, participated in the study. The parents gave written consent for their children to participate in the study. All students scored -2 STD in NAMA Scale for children reading disabilities (Kormi Nouri and Moradi, 2008) in reading words and reading pseudoword subtests. After data collection, 6 children were excluded from data analyses because of diagnosed neurological, psychiatric, or developmental disorders as assessed by the evaluator and because of missing data in the post-test session due to time constraints, thus the data of 6 children were not used for data analyses (2 girls and 4 boys). Of these children, 15 formed the experimental group and 20 children in the control group. Both groups were matched for chronological age (experimental X = 8.26 ± 1.43 years, and control X = 8.15 ± 1.42 years) and were within normal non-verbal IQ range as measured by the Raven Colored Progressive Matrices (Raven, 1977) [T (2, 33) = -0.5, P = 0.61 for the Raven matrix test: X = 94.06 ± 10.19 for the experimental group and X = 96 ± 11.97 for the control]. All subjects were Persian native speakers, right-handed, displayed normal or corrected-to-normal vision in both eyes, and were screened for normal hearing. None of the participants had a history of neurological or emotional disorders. No payment was offered for participation but the students in the experimental group were given rewards (i.e. every session 10-20 points to access to dolls, toys and childish games at the end of the experiment) for their attempts during the treatment procedure. Those in the control group received their ordinary academic education in school but no additional training. Those in the experimental group received training in working memory, detailed below.

PROCEDURE

Assessments included reading ability, visuo-spatial WM tasks, non-verbal reasoning and attention performance. All tests were administered before training and directly after the training period. Each child was tested individually in a quiet area of the clinic for six sessions lasting up to 60 minutes per session across eight weeks. The following tests were administered by psychometrics in a fixed sequence designed to vary task demands across the testing session.

General ability

This test examines analogous deduction and the ability to create perceptual connections independent of language and formal learning.

**Verbal**

Reading Words and Reading Pseudoword subtests of NAMA Scale (Kormi Nouri and Moradi, 2008) for measure children reading problems.

**Cognitive Abilities**

**Visuo-Spatial Working Memory**

During the block recall test, the child views nine cubes located randomly on a board. The test administrator taps a sequence of blocks, and the child’s task is to repeat the sequence in the same order. Testing begins with a single block tap, and increases by one additional block following the span procedure outlined above. The mean test-retest reliability coefficient for this measure is 0.53. In the mazes memory test, the child views on each trial a two-dimensional line maze with a path drawn through the maze. The test administrator traces the line with her/his finger in view of the child. The same maze is then shown to the child without the path, and the child is asked to recall the path by drawing it on the maze. Maze complexity is increased by adding additional walls to the maze, following the span procedure outline above. The mean test-retest reliability coefficient for this measure is 0.62 (Pickering and Gathercole, 2004).

**Integrated Visual Auditory Continuous Performance Test**

The IVA-CPT (Sandford and Turner, 2000) is a computerized assessment requiring the examinee to press a button when he/she sees or hears a ‘1’ (target) and not to press when he/she sees or hears a ‘2’ (foil). The task starts with a 1.5 min warm-up, followed by 32 practice items. The test has 500 trials and lasts for approximately 13 min. An equal number of auditory and visual stimuli are presented in a pseudo-random order. Prudence scores indicate errors of commission, with low prudence scores indicate carelessness or over-reactivity, and high scores indicate cautious, careful responding. As a measure of attention vigilance scores indicate errors of omission. IVA-CPT scores are calculated as both raw scores and quotient scores that have a mean of 100 and a standard deviation of 15. The labels mildly, moderately, severely, and extremely impaired are reflected in IVA quotient scores that are less than 90, 80, 70, and 60, respectively.

**Intervention program**

**WM Training Program**

We selected a software program (BrainWare Safari; Learning Enhancement Corporation©, IL, USA), a computerized program designed to train broad cognitive functions. BrainWare Safari (BWS) is a computer-based cognitive skills development program in a video-game format for individuals aged 6 to 12. It is designed to comprehensively develop 41 cognitive skills covering the major areas of visual processing, auditory processing, working memory, attention, sensory integration and thinking. Set in a South American jungle, it consists of 20 exercises designed to develop various cognitive skills. Each exercise builds multiple skills at the same time in the specific area; this enables the player to use their strengths to build their weaknesses. The highly integrated skill development drives them to a subconscious level of processing so they become automatic. Eighteen of the exercises have seven levels which become progressively more difficult. Once a player passes a level they cannot go back to easier levels, forcing the player to continue where they left off. The two logic and reasoning exercises operate slightly differently due to the nature of the logic questions. Multiple attempts at the same question could end up just a guessing game, so after two incorrect answers, the player is shown the correct answer so they can see how to work out the correct answer to similar questions in the future (Helms and Sawtelle, 2007). By considering VSMW ability, we used 6 out of 20 exercises which are designed to improve VSMW that called: Jungle Labyrinth, Memory Mountain, Parroting Colors, Tree Tic Tac Toe, Volcanic Patterns, Web Weaving and Jumping Jaguar Flash.

**Training Procedure**

Training was carried out with the supervision of 4 therapists in the clinic (for all participants). Training was performed for approximately 50-60 min a day, 5 days a week for 6 weeks. A minimum of 30 training sessions was required for inclusion in the analyses. At each training session, the participants trained on four (out of six) different versions of the VSWM exercises. Training performance was monitored by researchers across sessions in clinic via an internet server for the experimental group to ensure that training was being performed and that each session lasted approximately 50-60 min. As mentioned above, feedback was provided to the experimental group individually according to the token economy system throughout the sessions.
RESULTS

All tests were scored according to standardized procedures and the data were entered into an SPSS 18.0 file for analysis. An alpha level of 0.001 to 0.05 was used to determine statistical significance.

T-tests revealed no significant differences in baseline performance or age between the two groups (all $p$-values >0.1). Similarly, Chi Square tests showed no significant differences in the distribution of gender and number of comorbid diagnoses between the two training groups (both $p$-values >0.1).

The outcome of the working memory training in the experimental group was investigated. Multivariate analysis of variance was conducted to evaluate training effects from the cognitive measures being administered. The effect of training was tested by comparing the outcome score of the experimental group and the control group at post-test.

The performance on three out of three visual spatial working memory measures (forward block recall ($F(1,288) = 28.6, p<0.001$), backward block recall ($F(1,142) = 13.1, p<0.001$) and mazes memory ($F(1,127) = 12, p<0.001$)), and Attention performance (full scale attention ($F(1,2918) = 8.8, p<0.01$), visual vigilance ($F(1,3303) = 7.4, p<0.01$), visual speed ($F(1,1657) = 5.1, p<0.05$) was improved at post test, except the visual focus subtest ($F(1,2111) = 2.9, p>0.05$).

DISCUSSION

The aim of this study was to investigate whether working memory training could affect WM-measures and improve children’s attention performance in Iranian student with reading problem. It was found that comparison of the experimental group with an additional control group showed that the training indeed enhanced children’s visual spatial working memory. The results from the pre- and post-tests of the experimental group were also compared to a group which did not receive any additional training. Also we found a transfer effect to the attention performance tasks, such as full scale attention, visual vigilance and visual speed that were improved after training confirm the results of previous researches (Dahlin, 2011; Awh and Jonides, 2001; Awh, Jonides, and Reuter-Lorenz, 1998).

Current results suggest that working memory training may be a potential efficient method to improve cognitive performance in persons with reading problems. Some functional domains also benefit from the intervention, although the effects may be domain-specific (Barnes et al., 2009). Students with reading problems improve significantly in functional abilities, indicating the transfer effect of the attention performance. Moreover, It has been suggested that executive function is more strongly related to visual-spatial memory than to verbal memory (Gathercole et al., 2006) and that visual-spatial memory may require more attention ability than verbal memory does (Dahlin, 2011). These results confirm the central role of attention performance in working memory, not only in the phonological loop but in the central executive and the visual-spatial working memory as well.

In sum, the present study indicates that training of working memory by Brainware Safari may be useful for children with reading problems, and attention problems. Thus the study has important practical implications as mentioned by Dahlin (2011). First, working memory capacity may be valuable in identifying children at risk poor scholastic progress. It is important to screen working memory ability in the lower grades, as Alloway, Gathercole, Kirkwood and Elliot (2009) suggest. Likewise, such screening may be an alternative to clinical diagnosis for identifying those children who might benefit from working memory training. Another practical implication is that working memory training may improve reading skills in children with problems in literacy and in attention.

REFERENCES


