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Neuroscience-Based Visual-Spatial Working Memory Training and its Transfer Effects on the Attention of Dyslexic Children

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Abstract

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 certain plasticity in the neural system that underlies working memory (WM) and that 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 neuroscience-based working memory training. The intervention, BrainWare® Safari by LEC, was conducted with 15 students 8 to 12-year-old with reading problems, comparing them 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 Matrices 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.

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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, Sustain Attention;

1. 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, & Dunning, 2009). But those who suffers from poor WM has difficulty in both of these important aspects of life routines (Gathercole, Lamont, & Alloway, 2006), and in the school, they generally possess poor results academically (Alloway, Gathercole, Kirkwood & Elliott, 2009). For example, those who have neuropsychiatric conditions, such as traumatic brain injury, stroke, mental retardation, schizophrenia, attention-deficit hyperactivity disorder (ADHD) and learning disorders (LD), obviously have impairments in the function of WM (Martinussen et al., 2005). Therefore, it seems that poor reading comprehension and reading problems are virtually correlated with working memory problems.

The relationship between visual attention and working memory has been examined by looking at whether working memory is important for attention tasks. In the recent studies of Awh and his colleagues (Awh & Jonides, 2001; Awh, Jonides, & Reuter-Lorenz, 1998), a close relation between WM and visual attention has been demonstrated.

A body of research have supplied positive results from WM training for both children (Loosli et al., 2011) and adults (von Bastian, Langer, Jäncke & Oberauer, 2012; Brehmer, Westerberg, and Bäckman, 2012). According to a number of research, capacity of WM anticipates its performance in a range of cognitive tasks from simple attention tasks (Kane et al., 2001; Bleckley et al., 2003; Fukuda and Vogel, 2009) to tasks require more complicated capabilities, such as reasoning and problem-solving (Engle et al., 1999), or executive functioning (Salminen et al., 2012). Furthermore, research reports show that WM training is successful (Klingberg et al., 2002; 2005; 2010; Söderqvist et al., 2012; Holmes et al., 2009; 2010, Chein & Morrison, 2010; Jaeggi et al., 2008).

The goal of the present study is to determine whether WM training for Iranian children with reading problems will lead to improved visual spatial working memory (VSWM) or not. Consequently, we hypothesized that working memory ability will be increased by training, having positive effects on children's important cognitive domains and will transfer the effects to attention performance.

2.Methods

2.1. Design. The present study was a 2 × 2 with pre-test – post-test. Before the start of training, all participants were assessed on reading, visual spatial working memory and attention. Following the assessment, participants were randomly assigned to either training or control group. Approximately 7 to 8 weeks after the pre-training assessment, the participants were again assessed on the same test.

2.2. 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 disability 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 two standard deviations below the mean in NAMA Scale (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 or missing data in the post-test session due to time constraints. Of these children, 15 formed the experimental group and 20 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) [IQ = 94.06 ± 10.19 for the experimental group and IQ= 96 ± 11.97 for the control]. All subjects were Persian native speakers, right-handed, displayed normal vision in both eyes, and were screened for normal hearing. None of the participants had a history of neurological or emotional disorders. 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, and no additional training. Those in the experimental group received training in working memory, explained below.

3. Procedure

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

3.1. General ability

Raven's Coloured Progressive Matrices (Raven, 1977). This test examines analogous deduction and the ability to create perceptual connections independent of language and formal learning.

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

3.2. Cognitive Abilities

Visual 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 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 the 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. 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 & 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 minutes. 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.

3.3 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. 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 in similar questions in the future (Helms and Sawtelle, 2007). Considering VSMW ability, we used 6 out of 20 exercises, which are designed to improve VSWM in coordination with other cognitive skills. They titled: Jungle Labyrinth, Memory Mountain, Parroting Colors, Tree Tic Tac Toe, Volcanic Patterns, Web Weaving and Jumping Jaguar Flash.

3.4. Training Procedure

Training was carried out under the supervision of 4 therapists in the clinic. 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 were trained on four (out of six) different versions of the VSWM exercises.

Training performance was monitored by researchers across sessions in the clinic via an internet server for the experimental group. As mentioned above, feedback was provided to the experimental group individually according to the token economy system throughout the sessions.

4.Results

All tests were scored according to standardized procedures and the data were entered into an SPSS 18.0 file for analysis. *T*-tests revealed no significant differences in the baseline performance or age between the two groups (all *p*-values >0.1). Similarly, Chi Square tests showed no significant differences in the distribution for gender and the number of comorbid diagnoses between the two groups (both *p*-values >0.1). Multivariate analysis of variance was conducted to evaluate training effects on the cognitive measures being administered. The effect of training was tested by comparing the outcome scores of the experimental group and the control group at the post-test.

The performance on visual spatial working memory measures [forward block recall, $F(1,288) = 28.6$, $p<001$, backward block recall $F(1,142) = 13.1$, $p<001$, mazes memory $F(1,127) = 12$, $p<001$], Attention performance [full scale attention $F(1,2918) = 8.8$, $p<01$], visual vigilance [$F(1,3303) = 7.4$, $p<01$], and visual speed [$F(1,1657) = 5.1$, $p<05$] was improved at post test, except the visual focus subtest [$F(1,2111) = 2.9$, $p>05$].

5.Discussion

The aim of this study was to investigate whether working memory training could affect WM-measures and improves children's attention performance for Iranian students with reading problems.

The comparison between the experimental and control groups showed that the training, indeed, enhanced children's visual spatial working memory. 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, confirming the results of previous research (Dahlin, 2011; Awh & Jonides, 2001; Awh, Jonides, & Reuter-Lorenz, 1998).

Results of the current study suggest that working memory training may be a potential efficient method to improve cognitive performance in persons with reading problems, although the effects may be domain-specific (Barnes et al., 2009). 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. The results of the study confirm the central role of attention performance in the central executive and the visual-spatial working memory as well (Dahlin, 2011).

In sum, the present study indicates that training of working memory by Brainware Safari may be useful for children with reading 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 for 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 attention.

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