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Research Article

COMPARING THE EFFECTIVENESS OF COMPUTER AND MOTOR CONTROL-BASED COGNITIVE REHABILITATION ON IMPROVING EXECUTIVE FUNCTIONS IN STUDENTS WITH ADHD

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ABSTRACT

Attention Deficit/Hyperactivity Disorder is thought to be a neuro-developmental disorder whose main symptom is executive dysfunction. The aim of this study was to compare the effectiveness of computer and motor control-based cognitive rehabilitation on improving executive functions in students with attention deficit/ hyperactivity disorder. The number of 30 children aged 6 to 12 years with attention deficit/hyperactivity disorder were randomly placed in two experimental groups in the form of quasi-experimental research and clinical trial design with pre-test and post-test. To measure the variables, continuous performance test, Wisconsin cards, previous multi-stimulus test, modified Stroop test and simple reaction time test were applied. Data analysis using repeated measures analysis of covariance indicated that motor control and computer-based cognitive rehabilitation was effective in improving executive functions; however, the effect of motor control-based cognitive rehabilitation was higher on sustained attention, while computer-based cognitive rehabilitation produced greater effects on the working memory, cognitive flexibility and reaction time. On the other hand, the impacts of both types of intervention on response inhibition was the same. Therefore, it can be concluded that computer and motor control-based cognitive rehabilitation improves the executive functions of children suffering from attention deficit/hyperactivity disorder.

Keywords: cognitive rehabilitation, motor control, computer, cognitive flexibility, working memory, reaction time, response inhibition, sustained attention.

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INTRODUCTION

Attention Deficit/Hyperactivity Disorder (ADHD) is a behavioral neuro-developmental disorder in childhood that affects 3 to 7% of school-age children (Mohammadi, Kazemi, Rezaei and Fesharaki, 2015; Hosseinzadeh, Mashhadi, Soltanifar, Moharrari & Ghanaie, 2013). According to the DSM-5, the disorder is considered to be a chronic disorder characterized by impulsive behavior, inattention, hyperactivity/ impulsivity, and inappropriate restlessness, and is associated with emotional, behavioral, and academic problems (Tajik-Parvinchi, Wright BAHons & Schachar, 2014). To diagnose this, some symptoms must appear before the age of 11. The disorder must exist in at least two areas and the individual's performance be impaired according to the degree of development in the social, academic or occupational areas (Kaplan and Sadok, 2001; Mick and Faraone, 2008; Kieling, Goncalves, Tannock & Castellanous, 2008). On the other hand, the symptoms of this disorder are reported to be more severe and common than those commonly seen in children with similar developmental levels. The ADHD trend is variable with 50% of cases continuing until adolescence or adulthood (Parvaresh, Erfani and Shokouhi, 2014). The prevalence of this disorder is reportedly 2 to 9 times higher in boys than in girls (Mohammadi, Kazemi, Rezaei and Fesharaki, 2015; Parvaresh, Erfani and Shokouhi, 2014; Sadok & Sadok, 2007).

On the other hand, this disorder is viewed as a neuro-psychological disorder in which the main role of attention as one of the executive function components is reiterated (Seidman, 2006, Alipour, Baradaran & Imanifar, 2015). Executive functions refer to excellent cognitive and metacognitive functions which perform a set of excellent abilities, inhibition, self-initiation, strategic planning, cognitive flexibility and impulse control (Abedi, Kazemi and Shoushtari, 2014, Ghamari Givi, Narimani & Mahmoudi, 2012). In reality, such functions as organization, decision making, working memory, maintenance and shift, motor control, time sensation and perception, future prediction, reconstruction, language internalization and problem solving can be considered as the most important neurological executive functions in life as doing learning tasks and intelligence actions helps human beings (Barkley, 1988; Narimani and Soleimani, 2013).

Based on available sources, functions impaired in this disorder include: sustained attention, cognitive flexibility, working memory, response inhibition, and reaction time.

Accordingly, one of the areas disrupted during the impairments related to executive functions is attention processes in such a way that the dysfunction in these processes affects other cognitive processes, especially learning. In this regard, Bandura (1988) states that the initial stage of any learning begins with attention, and if there is no sufficient attention, the individual's learning is impaired.

To further explain that, attention denotes mental and psychological focus on mental or sensory events, and in general terms, a complex and unknown construct, referring to various components including taking the initiative or becoming focused, directing sustained attention or care and vigilance, response inhibition to irrelevant stimuli or selective attention and attention transfer (Hassani & Hadianfard, 2007). The process of selection, the intensity of attention (focus) and the duration of attention aimed at a specific stimulus (maintenance of attention) are among the attention components that influence human "consciousness" at all times (Glass & Holyoak, 1986). Meanwhile, sustained attention is viewed as maintaining controlled processing in doing a task, and therefore the lack of sustained attention in children removes the opportunity to process, store and retrieve information (Kasaiyan, Kiamanesh & Bahrami, 2013).

It should be noted that sustained attention is the ability to maintain purposeful behavior during a continuous activity and is activated when there is a salient stimulus in the field of perception and when the right hemisphere of the brain, especially the right prefrontal area is also activated. Pasner and Swanson (2008) emphasized damage to the attentive vigilance-sustained attention networks in attention deficit/ hyperactivity disorder. Also, research findings by Barkley and Nazifi et al. (2011) suggested that the most important attention problem in these children was sustained attention disorder. Thus, the most important cognitive hypothesis for these children was that when a stimulus would be presented for a long time, sustained attention would become more difficult for them (Glass & Holyoak, 1986).

Another component viewed as one of the largest neurological impairments associated with ADHD is working memory failure as a central working memory, which is probably present in 80% of children with ADHD (Kasper, Alderson, & Hudec, 2015). Information processing begins steadily from the moment our senses receive a stimulus from the outside world. These emotions are briefly retained and recognized in sensory recording, with the identified emotions being transferred to short-term or working memory (Baddeley, 1986). Working memory is a kind of cognitive system of temporary information storage. This system is able to manipulate important information for such activities as excusing, language comprehension and learning (Baddeley, 1992). The content of working memory is the active information that a person envisages about at the moment. This active information may be new information (visual and auditory data) the person has faced with. For this, some psychologists consider working memory the same as consciousness (Anderson, 1990). Attention is closely related to memory. Children with attention deficit/hyperactivity disorder do not process much information because of the attention deficit; thus, they lose the opportunity to store and retrieve information, thereby, experiencing deficits in the memory (Goldstein, 1998). There have been many researches on the memory of children with ADHD that confirm a deficit in working memory. Research findings show that children with ADHD grapple with the most short-term memory problems. They perform poorly in processing information and do not receive much of the auditory information (Kataria et al., 1992).

Also, the way visual, auditory and semantic stimuli is coded in children with ADHD compared to that in normal children showed that ADHD children had no significant difference in coding different stimuli. This is while these children had more deficits in coding similar stimuli (Holing, 1998).

In addition, research on vocabulary homework suggested that children with ADHD had shown obvious deficits in retaining words that needed to be organized and reviewed. Also, ADHD children, compared to normal children, produce significant deficits in performing visual memory tasks (block classification, geometric shape classification, and visual and spatial calling) (Douglas, 1988, 1972). Also, children with ADHD suffer from obvious deficits in behavioral inhibition, working memory, motivational and emotional self-regulation, and internal speech compared to normal children, and these disorders appear in behavioral manifestations such as impulsivity, hyperactivity, and poor academic performance (Stevens & Koitner, 2002). These children suffer from impaired functioning of the working memory due to cognitive inhibition problems (Ingelhart et al., 2008).

Another neurological problem in children with ADHD is cognitive inflexibility. This function is one of the main executive functions and refers to the ability to choose a practical answer from among the available and appropriate options and use of creativity. This is an important prerequisite for adapting to environmental changes and generating new and innovative ideas. Flexibility was at the focal point of recent theories on the neuro-psychology of children at risk of disability, especially children with attention deficit/hyperactivity disorder; this is because it is an important factor in social interactions and is defined as a dynamic process responsible for creating some positive adaptation of the individual to the environment, so that the flexible individual becomes able to adapt to changing environmental stimuli despite the existence of opposite or traumatic experiences (Dennis et al., 2010; Farhoudian, 2003). In this regard, three dimensions of cognitive flexibility include: The tendency to perceive difficult situations as controllable conditions, the ability to provide multiple explanations for life events and human behavior, and the ability to create multiple solutions for difficult situations (Dennis, Vander, Wal & Jillon, 2010).

Many results have shown that children with ADHD have weak performance in executive functions, including cognitive flexibility. Also, one of the most important problems of this group of children is the lack of cognitive flexibility (Baddeley & Nanda, 2016).

As stated, children with ADHD suffer from some impairments in most executive functions, especially in response inhibition. Response inhibition is a neurological component that refers to the ability to cease thoughts, actions, and emotions, and helps children respond without delay. The neurological status of this function is in the basal nodes of the prefrontal cortex of the brain and involves three interconnected processes including: response inhibition or the dominant event, cessation of current behavior, and control-interference (Barkley, 1997). To date, numerous researchers have reported that damage in response inhibition leads to attention deficit/hyperactivity disorder symptoms (Brown, 2005; Schachar, Mota, Logan, & Tannock, 2000; Houghton et al., 1999; & Nig, 2000). In the meantime, Barkley (1997) has proposed a model called "behavioral inhibition" based on which, weakness in response inhibition is considered the main cause of this disorder. According to this model, response inhibition, which is inherently associated with the other four executive functions of this model, including working memory, speech internalization, emotion-motivation-arousal, and reconstruction, causes a delay before responding to an event; thereby allowing them to occur. This relationship is so important that these components depend on response inhibition to be effectively implemented. It should be mentioned that these functions have a direct and effective effect on mental structure and motor control, and in case they have a deficit, the child will have difficulty in mental structure and motor control, and as a result, a set of symptoms appears, which is called attention deficit/hyperactivity disorder (Barkley, 1997).

In addition, it was suggested that impairment in response inhibition, in addition to the occurrence of impulsive behaviors, also leads to dysfunctions in cognitive, developmental, educational, and social areas and increases the likelihood of such disorders as anxiety, depression, moods, poor social relationships, and low education performance (Barkley, 2006). Due to impairment in response inhibition, the child faces impaired self-regulation and is not able to target behaviors and pursue behavioral goals. Besides, the child cannot refrain from creating thoughts or behaviors at an appropriate time and place. For this reason, s/he answers questions abruptly or untimely or interrupts the conversations of others (Mikami, Huang-Pollack, McBurnett, & Hangai, 2007). Barkley (1997) also considers response inhibition to be critical for all behavioral settings and maintains that its weakness causes a wide range of impulses and motor activities being performed improperly, as this explains the impulsivity of children with ADHD.

Another executive function in children with ADHD disabilities is reaction time. The human body responds to external stimuli at a pace of a millionth of a second. The speed of response to these stimuli hinges on the nervous system. This time varies from person to person depending on the age and health of the nervous system. Reaction time refers to the time it takes for a person to respond voluntarily or involuntarily to a more or less complex visual or auditory stimulus. Reaction time depends on such various factors as stimulation of nervous system receptors, transmission time of stimulus effect to central nervous system, decision time of the central nervous system and response command, time of the command transmission from the central nervous system to responding members and response time by responding members. Dysfunction in any of these areas increases reaction time. Besides, reaction time is thought of an information processing indicator, so slow reaction time is often interpreted as slow processing or cognitive degradation (Holler, 2005).

Although various treatments have been suggested for ADHD children in accordance with neurological etiologies, special attention has been paid in recent years to drug therapies, particularly stimulant (activating) drugs. These drugs can improve the cognitive functions of these children (Overtoon, Verbaten, Kemner et al., 2003; Schweitzer, Lee, Hanford et al., 2004), such that these changes occur by increased catecholamines such as dopamine and norepinephrine outside of the cells involved in this dysfunction (Hawi & Lowe, 2007; Barkley, 2006; Nig, 2006) as no sustained structural changes are made to the neurons themselves. Therefore, the impact of drugs is short-term, and as soon as taking the drug is ceased, disorder symptoms appear with the same intensity as before (Lubar, 1995). Moreover, all prescribed drugs have significant side effects such as anorexia, sleep disturbance, physical contractions, uncontrollable verbal expression and temporary growth retardation (Halgin and Whitburn, 2003) as many parents are discouraged to use this (Monastra, 2003).

Thus, in recent years, experts have been looking to design complementary and ultimately alternative therapies for this disorder which do not have the above-mentioned side effects and rather create sustained improvements, including a computer-based cognitive rehabilitation treatment approach that is directly focused on improving executive functions indicators. According to the principle of brain plasticity and self-restoration, computer-based cognitive rehabilitation can produce sustained synaptic changes in the brain by sequentially arousing fewer active areas in attention deficit/hyperactivity disorder (O'Connell, Bellgrove, & Robertson, 2007). Research in this emerging field is scant as they encountered many psychological problems though they were able to hypothesize the effect of computer-based rehabilitation in reducing the symptoms arising from attention deficit/ hyperactivity disorder (Shaffer, Jacokes, Cassily & et al., 2003; Klingberg, Forssberg & Westerberg, 2002; Westerberg et al., 2007; Bidwell, Mcclernon, Kollins, 2011).

In a study on 53 children with attention deficit/hyperactivity disorder (26 comparison groups and 27 treatment groups) it was shown that subjects' performance in working memory tasks can be improved through working memory training, thus slowing down their amount of motor activity. In addition, the effect of this training extends to tasks for which one is not directly trained about but is related to the function of the prefrontal cortex (executive functions) (Klingberg, Fernell, Olesen, Johnson, et al., 2005).

Also, in a study on 34 children aged 7-12 years, it was indicated that computer-based cognitive rehabilitation was in a better condition compared to drug therapy in promoting complex executive functions such as working memory and nonverbal reasoning (Nazifi, 2013).

Other non-pharmacological treatment approaches which have received the attention of many experts include the motor-based cognitive rehabilitation approach (Wendt, 2000; Nogel, 2005; Gapin, 2009; Bailey, 2009; Piepmeier et al., 2015; Ziereis & Janson, 2015). Motor-based cognitive rehabilitation is performed in several consecutive steps. In the first step, cognitive impairment is measured or identified. In the second step, in line with the identified deficits of each individual, cognitive-motor exercises are designed and provided, which based on the brain plasticity principle, it is assumed that by constantly stimulating the areas involved in this disorder (Urban et al., 2014), some chemicals changes similar to the taking of stimulant drugs (increased levels of dopamine and norepinephrine) will be produced in the brain (Gapin, Labban & Etnier, 2011; Lenz, 2012; Wigal, Emmerson, Gehricke & Galassetti, 2013). Motor-based cognitive rehabilitation approach tailored with the Sono Gabarck's Dual Passage Model (2003; 2005) is based on the bottom-up sub-cortical control systems dysfunction and bottom-up cortical regulatory systems in children with attention deficit/hyperactivity disorder, as it provides cognitive-motor exercises which directly target cognitive skills such as attention, concentration, working memory (verbal and spatial visual), reasoning, abstraction, and logical analysis (Oreiz Bicher, 2004).

In this vein, research evidence suggests that motor activities are especially effective in improving children's cognitive functions (Etnir et al., 1997; Sibley, Etnier, 2003; Schaffer et al., 2000; Bailey, 2009; Best, 2010; Vysniauske, Verburgh, Oosterlaan & Molendijk, 2016). Piepmeier Mir et al. (2015) in an article, trying to investigate and compare the effect of intense physical activity on cognitive function in children with/without ADHD, reported that physical activity was effective in improving processing speed and inhibiting the response of children with/without ADHD, while it produced no such beneficial effects on improving the ability to plan or displace the field.

On the other hand, although research evidence has managed to hypothesize the effectiveness of various cognitive rehabilitation approaches on cognitive functions (Chang, Laban, Gapin and Etneir, 2012) especially on executive functions (Bast, 2010; Chang, Chu, Chen and Wang, 2011; Chang, Liu, Yu & Lee, 2012; Chang, Tissai et al., 2011; Verburgh, Konigs, Scherder & Oosterlaan, 2014), research done in this area was scant in quantity, as according to a systematic review by Grassmann, Alves, Santos-Galduroz & Galduroz (2014) on research conducted between 1980 and 2013, only three articles had investigated the effectiveness of conducting a motor activity session on the cognitive functions of ADHD children, of which only two had reported the effectiveness of participation in 30-minute motor activity program to improve cognitive function (Medina et al., 2010; Chang, Tissai et al., 2011). Besides, these studies face numerous methodological problems in terms of quality, such as lack of control group, low sample size and low motor intervention time (less than 20 minutes). In a study, it was suggested that the application of the cognitive rehabilitation program in improving the inhibition of response of people with obsessive-compulsive disorder did not produce a positive effect (Ghamari Givi, Nader and Dehghani (2013). In some studies, cognitive rehabilitation has not been shown to be effective to improve attention (McMillan et al., 2002; Novak et al., 1996). Moreover, in a study on people with moderate traumatic brain injury (TBI), it was indicated that audiovisual mindfulness sessions could not be effective in improving symptoms (Milan et al., 2002). As well, in a study on the effectiveness of a training approach called memory retrieval (spaced retrieval), it was indicated that this approach was not effective on memory function (Bergquist et al., 2007). In another study on the effectiveness of a computer training program based on retraining of four different memory strategies, it was suggested that not all 4 procedures of memory training produced significant positive outcomes, whereas in all 4 procedures, clinical improvement was observed and the experimental group saw a significant increase in self-efficacy compared to the other group (Ruff et al. , 2004). Moreover, some other research did not find the effectiveness of cognitive rehabilitation significant for executive functions (Fasotti et al., 2000; Manly,Hawkins, Evans, Woldt & Robertson, 2002; Roth, Simon, Longenbohn, Sher & Diller, 2003; Constantinidou, Thomas & Robinson, 2008; Fong, K .N., & Howie, D.R., 2009). In this connection, in a study, the effectiveness of an intervention (providing auditory stimulus, creating distraction, giving clues to the patient to consider the overall goal) for planning and problem solving disorders was investigated and the result showed that the intervention group did not change significantly compared to the control group who received another type of cognitive rehabilitation (Manley et al., 2002).

Overall, cognitive rehabilitation appears to be an effective intervention to improve patients' cognitive functions, so that in a review of 47 experimental studies, the effectiveness of cognitive rehabilitation in 37 studies was estimated to be 78.7%, while no such effectiveness was observed for other interventions (Cicerone et al., 2005). Therefore, due to the contradictory research results in the field of cognitive rehabilitation effectiveness, the need for further study in this field is felt.

According to the above, this article aimed to determine the difference of effectiveness of computer-based and motor control-based cognitive rehabilitation treatment approaches in improving executive functions (sustained attention, cognitive flexibility, memory function, response inhibition, reaction time) in students with ADHD and moderate IQ.

RESEARCH METHODOLOGY:

In this study, a quasi-experimental research procedure with a pretest-posttest design was applied, the independent variables of which were motor-based cognitive rehabilitation and computer-based cognitive rehabilitation while the dependent variables were sustained attention, working memory, response inhibition, cognitive flexibility and reaction time. Consistent with the research project, a CSI-4 screening questionnaire was given out to the community of children aged 6-12 years in districts 1 and 4 of Tabriz based on the subscale of attention deficit/hyperactivity disorder. In the meantime, the opinion of a psychiatrist and the results of a clinical interview with one of the children's parents as well as observation and clinical judgment were received. Thus, thirty children diagnosed with ADHD were selected and randomly assigned to two groups of 15 subjects each as the groups involved in computer-based cognitive rehabilitation and motor-based cognitive rehabilitation. The criteria for inclusion in this screening included: a diagnosis of ADHD based on a psychiatric interview and behavioral scoring scales and observing the child and the psychiatrist's opinion, not taking medication, having an IQ above 80, commitment and cooperation by parents, not having any motor or perceptual disability that interferes with computer work and not having severe comorbid disorders, such as coping disorder, autism spectrum disorders and depression, while exclusion criteria included: more than 2 sessions of absence and dis-continuity in performing cognitive rehabilitation exercises.

Instruments:

Child Symptom Inventory-4 (CSI-4):

In the present study, a clinical interview by a psychologist or psychiatrist and a subscale of attention deficit/hyperactivity disorder in the Child Symptom Inventory-4 (CSI-4) were used to diagnose mental disorders. The inventory was developed based on the DSM-4 diagnostic criteria by Gadav and Sprafkin at Stony Brook University in 1994. The inventory has two forms for parents and teachers. In the present study, the parent form was applied. The parent form measures 17 disorders with 97 items. Cronbach's alpha for this questionnaire was reported to be 0.93.

Clinical Interview:

In this study, the subjects who had scored higher than the cut-off line in the CSI-4 inventory were chosen for a structured clinical interview based on the ADHD diagnostic criteria in line with the DSM-5.

Raven's Colored Progressive Matrices Test:

The Raven's test consists of a series of abstract images that produce a logical sequence and are arranged with an increasing difficulty rate. The subject must choose an image from 6 to 8 options to complete the higher matrix. In Iran, validation and standardization studies on this test showed that this test had sufficient validity and reliability and was appropriate for assessing general intelligence in Iranian children.

Continuous Performance Test:

In this study, by sustained attention, it is meant the score one obtains in the computer test of continuous performance. This test is used to measure attention retention and is designed by the Sina Institute. The test in question was developed by Razvold in 1956 and used by Hadianfar and Hassani (2007) to measure attention. Introduced in the 1990s as a test to assess children with ADHD, it is now recognized as the most common laboratory instrument in the diagnosis of sustained attention.

Wisconsin Card Sorting Test:

The initial version of the Wisconsin Card Sorting Test was developed by Berg et al. (1948; quoted by Mitroshina et al. 2005). This test is considered to be one of the main and most widely used instruments of neuropsychology, through which the function and ability to form concepts, abstract thinking, cognitive flexibility and the ability to change the cognitive system are assessed. Several studies (Greaves, 2001; citing Purdon and Valdie, 2001) have supported the validity and reliability of the Wisconsin card sorting test.

Working Memory Test:

In this study, working memory is referred to the score one obtains in the N-back working memory test. This test was first introduced by Kirchner in 1958. In this task, a sequence of stimuli (usually visual stimuli) is presented to the subject in a step-by-step manner, and the subject must investigate whether the current stimulus provided is consistent with the N stimulus of the previous step or not. Bush et al. (2008) reported the reliability of this test to be 0.78. In Iran, Taghizadeh, Nejati, Mohammadzadeh and Akbarzadeh (2014) used this test in a study and confirmed its reliability.

Stroop's Dual Homework Test:

This test was invented in 1935 by Stroop to assess specific attention and cognitive flexibility. Various forms of Stroop task have been developed for research work, of which one can refer to a simple, complex, semantic, and modified Stroop version. In the modified version of this assignment, only inconsistent stimuli of the words in red, blue, green, and yellow with colors different from their meanings are displayed on the screen. The subject must respond to the color of the stimuli and do not heed its meaning, but if the words are displayed in red, s/he must choose the meaning of the word as the correct answer, regardless of its color (red).

Reaction Time Test:

This test should be run in a very conducive place and on time and the test conditions should be observed in terms of psychometrics. The objective is for the subject to use his/her maximum ability and to have the best performance at the same time. The test is such that whenever a red circle appears on the screen, the subject must press the space bar at a maximum speed.

Computer-based Cognitive Rehabilitation:

In this study, with regards to the computer_based cognitive rehabilitation, cognitive games made by Lumosity Company, 10 cognitive games software package and a training software package as well as "improve your working memory" (audio-visual-stabilization) packages produced by Sina Institute were used.

Motor-based Cognitive Rehabilitation:

In this study, by motor-based cognitive rehabilitation, it is meant a set of activities and procedures the researcher applies based on cognitive rehabilitation techniques to improve the executive functions in children with ADHD using software and pencil tests depending on cognitive rehabilitation through cortex movement. The package was designed at the Behavioral Neuroscience Research Center. The target group of this package is comprised of children with autism spectrum disorder, ADHD and learning disabilities as effectiveness studies revealed.

Research Administration Process:

To collect data, with the help of parents, all primary school students in districts 1 and 4 of Tabriz filled out the CSI-4 screening questionnaire. According to the inclusion and exclusion criteria and using diagnostic interviews, the samples were selected. In the next step, the way the work was going to be administered was explained to the parents of each sample and written consent was received from them; then the selected sample was randomly divided into two experimental groups.

After this stage, each member of the experimental and control groups was assessed using continuous performance test, N-back working memory, cognitive flexibility test, response inhibition and reaction time in the executive functions profile (pre-test) and later, the interventions relevant to the experimental groups were presented and in every two sessions, continuous performance test, N-back memory, cognitive flexibility, response inhibition and reaction time were performed on the experimental groups to determine the differences. (post-test).

The computer-based Cognitive Rehabilitation Group intervention included 12 sessions of cognitive training (3 sessions per week). During each of these one-hour sessions, subjects completed an average 12 Lumosity's cognitive games and memory promotion software exercises as well as 10 Sina Institute-developed cognitive software games. The motor-based cognitive rehabilitation group intervention also included 12 sessions (45 to 60 minutes each session) of cortical rehabilitation package cognitive training.

Table 1: Summary of motor-based cognitive rehabilitation sessions

Sessions	Tasks
Tasks from session one to session four	Selective jump of the color
	Sustained jump
	Walking by calculation
	Walking on the pattern
	Pattern-based walking
	Proportional hand movements
	Impact control
Tasks from session four to session eight	Selective jump of numbers
	Continuous jump (the subject is asked to jump on the corresponding number in the banner when s/he sees two similar number on the screen)
	Sequential movement on patterns
	Continuous jump (the subject is asked to jump on the corresponding color in the banner when s/he sees two similar colors on the screen)
	Walking on the pattern
	Walking by calculation
	Impact control
	Opposite hand movement
Tasks from session eight to session twelve	Selective jump of directions
	Jumping on colored houses
	Walking slowly
	Coordinated movements of the limbs

Table 2: Summary of computer-based cognitive rehabilitation sessions

Sessions	Tasks
Tasks from session one to session four	Attention: assist ants, skyrise, train of thought
	Memory: memory nerves, tidal treasures, pinball recall
	Reaction time: highway hazards, penguin pursuit, river ranger
	Flexibility: space trace, disillusion, brain shift
	Response inhibition: color match, robot factory
	Memory training and improvement software: first to fourth level memory training
	Ten brain games: Two cognitive exercises in each session
Tasks from session four to session eight	Attention: star search, lost in migration, playing koi
	Memory: rotation matrix, follow that frog, memory match
	Reaction time: speed pack, penguin pursuit, spatial speed match
	Flexibility: brain shift overdrive, ebb and flow, brain shift
	Response inhibition: color match, robot factory
	Memory training and improvement software: fourth to eighth level memory training
	Ten brain games: Two cognitive exercises in each session
Tasks from session eight to session twelve	Attention: eagle eye, trouble brewing, train of thought
	Memory: familiar faces, memory matrixes, pinball recall
	Reaction time: highway hazards, penguin pursuit, splitting seeds
	Flexibility: space trace, disillusion, brain shift
	Response inhibition: color match, robot factory
	Memory training and improvement software: eighth to twelfth level memory training
	Ten brain games: Two cognitive exercises in each session

In this study, descriptive statistical methods, especially mean and standard deviation as described in Table (3) were used to describe the studied variables.

Table 3: Central indicators and dispersion of variables

Group	Variable	Pretest		Posttest 1		Posttest2		Posttest3		Posttest4		Posttest5	
	Index	M	S	M	S	M	S	M	S	M	S	M	S
Motor-based Cognitive rehabilitation	Simple reaction time	99/12	2/051	34/7	1/822	27/01	1.472	25/76	1.761	19/22	8/97	15/16	6/76
	Sustained attention	81/6	1/666	12/330	1/565	13/135	1.323	141/6	8.16	14/936	7/86	15/076	8/57
	Cognitive flexibility	21/4	4/32	26/27	5/71	33/53	6.08	36/6	4.43	40/47	3/75	44/07	2/46
	active memory	10/63	3/39	8/68	2/64	8/05	2.12	6/59	1.39	6/23	1/66	5/29	1/45
	Response inhibition	35/33	3/340	51/87	35/9	68/13	4.181	80/13	50/3	93/6	5/643	10/136	5/252

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Computer-based Cognitive rehabilitation	Simple reaction time	54/18	1/343	47/21	1/531	35/91	8.56	17/39	3/63	11/34	2/7	8/42	2/24
	Sustained attention	13/670	9/86	134/4	1/053	13/338	9.75	13/677	9/75	14/132	7/4	14/738	7/9
	Cognitive flexibility	27/13	5/99	29/47	6/08	32/33	6.66	34/13	5/59	38/4	5/19	41/4	5/32
	active memory	10/64	3/38	7/12	1/64	5/69	0.76	5/04	0/86	4/48	0/72	3/99	0/45
	Response inhibition	56/93	2/484	73/47	2/961	77/8	2.817	92/14	2/285	10/071	2/456	110	2/89

Descriptive findings suggest that in the reaction time variable in both groups studied, the reaction speed and accuracy of responses saw an increase after the rehabilitation interventions were applied; however, this increase in the computer-based cognitive rehabilitation group was more than that in the motor-based rehabilitation group. As well, in the sustained attention variable in both groups, the accuracy of the answers saw an increase after the rehabilitation interventions were applied; however, this increase was greater in the control-based cognitive rehabilitation group than in the computer-based cognitive rehabilitation group. In the cognitive flexibility variable in both groups, the accuracy of the answers increased after the rehabilitation interventions were applied; however, this increase was greater in the computer-based cognitive rehabilitation group than in the motor-based cognitive rehabilitation group. Also, in the working memory variable in both groups, the reaction speed and accuracy of the responses increased after the rehabilitation interventions were applied, however, this increase was higher in the computer-based cognitive rehabilitation group than that in the motor-based cognitive rehabilitation group. In the response inhibition variable in both groups studied, the accuracy of the responses increased after the rehabilitation interventions were applied; however, this increase occurred almost equally in both groups.

FINDINGS:

To test the hypotheses, repeated measures analysis of covariance was used. Data analysis results related to this question are presented in Table (4):

Table 4: Summary of repeated measures analysis of covariance pertaining to the differences in the effects of training-therapeutic procedures on executive functions

Source of change	Dependent variable	F	P	Mean motor -based cognitive rehabilitation group	Mean computer -based cognitive rehabilitation group
Procedure	Reaction time	0/034	0/005	28/5	30/08
	Sustained attention	8/22	0/008	152/27	130/65
	Cognitive flexibility	0/003	0/01	33/72	45/7
	active memory	5/79	0/01	6/58	8/16
	Response inhibition	1/03	0/31	72/53	85/27

Findings show that the two training-therapeutic procedures have a different and significant effect on improving the reaction time because the calculated F (F=0/034) is significant at the level of P≤0.01 and according to the mean of the two groups, It can be inferred that computer-based cognitive rehabilitation is more effective in improving reaction time. Also, the two training-therapeutic procedures have a different and significant effect on improving sustained attention because the calculated F (F=8/22) is significant at the level of P≤0.01 and it can be inferred from the mean of the two groups that the motor-based cognitive rehabilitation is more effective in improving sustained attention. Moreover, the two training-therapeutic procedures have a different and significant effect on improving cognitive flexibility because the calculated F (F= 0/003) is significant at the level of P≤0.01 and it can be inferred from the mean of the two groups that computer-based cognitive rehabilitation is more effective in improving cognitive flexibility. As well, the two training-therapeutic procedures have a significant effect on improving working memory because the calculated F (F = 5/79) is significant at the level of P≤ 0.01 and according to the mean of the two groups, it can be inferred that motor-based cognitive rehabilitation is more effective in improving working memory. Finally, according to the research findings, the two training-therapeutic methods do not have a significant effect on improving response inhibition because the calculated F (F= 1/03) is not significant at the level of P≤0.01. Therefore, the two training-therapeutic procedures are equally effective in improving response inhibition.

DISCUSSION:

Data analysis showed that computer-based cognitive rehabilitation leads to shortened children's reaction time and working with them and improved information analysis skills (Yuji, 1996). Sensory and motor training in children with ADHD improves sensory and motor coordination, reduces hyperactivity symptoms, and reduces aggressive behaviors (Banashowski, Bessmanz, Zieger, & Rattenberger, 1996). Reaction time required to identify the stimulus is to select the response and initiate the appropriate response. On the other hand, the reaction time consists of two parts, i.e., the pre-motor time and the motor time. During the pre-motor time, some perceptual or cognitive processing of stimulus information takes place and at the motor time, the motor output of the response begins. Research has indicated that changes in reaction time result from increased response complexity, leading to an increase in pre-motor time (Christina and Rose, 2001). Therefore, it is probable that reduced reaction time due to playing computer games is due to a reduction in pre-motor time or an increase in perceptual or cognitive processing speed. Researchers have also reported improvements in perceptual and cognitive processes through computer games. Research has indicated a reduction in reaction time as a result of playing computer games (Drew & Waters, 1986; Clark et al., 1987; Orsay-Fields & Allen, 1989; Greenfield & Subrameniam, 1994; & Yogi, 1996). The results also suggested that motor-based cognitive exercises to focus attention on an object can stimulate the growth of dendrites in nerve cells, allowing the cell to connect with other brain cells. In this developmental perspective, this process helps to form strong neural pathways, enabling the child to have more control over his or her voluntary functions.

Thus, it is necessary to have these exercises that can strengthen the attention of these children. In sum, the results of this study stated that motor-based cognitive rehabilitation increases the attention and concentration of children with ADHD. This achievement is in line with the research of Medina et al., Hillman et al., Kipton, Green, and Boehler. Motor exercises and cognitive training increase norepinephrine and dopamine in the brain, as these neurotransmitters play a key role in the attention and thinking system. Therefore, by combining motor exercises and tasks based on strengthening sustained attention with focus on cognitive tasks, this intervention can have a significant effect on norepinephrine and dopamine in the brains of these children and reduce distraction while improving sustained attention in them. This result is consistent with the research of Reef (2013), Poon, Li-Tsang, Weiss and Rosenbaum (2010), Ghaffarian (2014) and Griffiths (2005), Narimani et al. (2015) on the effectiveness of cognitive therapy on improving sustained attention in children with ADHD. Also, a study showed the impacts of computer program training on improving working memory and cognitive flexibility in children with ADHD and learning disabilities (Milton, 2010). The findings of the present study were consistent with those of Tajik Parvinchi et al. (2014). In another study, training cognitive computer games could improve working memory, attention and cognitive flexibility in children with ADHD (Abdi et al., 2014). Also, in a study, computer-based cognitive rehabilitation program significantly increased processing speed, cognitive flexibility, verbal predictive memory scores and vision, thereby playing an important role in increasing the activity of the forehead cortex (Kessler and Lacayo, 2011). Numerous researchers investigated the impacts of video and computer game training on the cognitive flexibility of children with ADHD, the results of which indicated that executive functions and flexibility had improved as a result of video and computer game training (Barkley, Fisher, Smalish & Eidelbrook, 2008; Abdi, Arabani Dana, Hatami & Parand, 2016). What happens to children with ADHD after computer-based cognitive rehabilitation training sessions is that their mental flexibility, processing speed, anatomical memory, and forehead cortex activity would increase.

After physical exercises, a considerable rise in the volume of gray and white matter in the brain is reported in the anterior and temporal cortex, causing nerve flexibility in the brain. This is because physical activity can also stimulate processes that facilitate neural flexibility, thereby increasing an individual's ability to respond to new desires and behavioral adaptations. To explain this finding, one can say that computer-based cognitive rehabilitation helps the children to better figure out information about themselves and acquire more ability to understand their surroundings. Increasing the ability to understand the environment and the relationships between events allows the child to view the issues and events from different angles and to fill the gaps some of the received data with a more conclusive view, thus increasing his/her mental organization. An increase in the ability of the child with attention deficit/ hyperactivity disorder in adapting to the environment increases the child's cognitive flexibility and affects the child's personality and behavioral dimensions. Computer-based cognitive rehabilitation can reduce hyperactivity symptoms in the child and hence s/he can respond more calmly, more systematically and more flexibly to the world around him/her.

As research evidence has shown, ADHD impairment in children reduces executive function and working memory (Nejati et al., 2013). Neurological studies have shown that people with ADHD suffer from deficits in the hippocampus (Sterley, Howells, & Russell, 2013), and since the hippocampus plays an important role in working memory, working memory deficits in these people can be explained (Malbi and Holm, 2013). Moreover, researchers have referred to the significance of the parietal and frontal lobe in the area of working memory function, such that the supra-marginal gyrus of the parietal and the frontal area play a role in storing information in working memory tasks (Krauss et al., 2014). These areas get activated while performing tasks related to working memory and are abnormal in people with attention deficit /hyperactivity disorder, as deficits in these areas of the brain can explain the problems related to concentration and inhibition in these people (McVee and Kahn, 2009). Based to these studies and the present study findings, one can say that cognitive rehabilitation improves working memory in children with attention deficit /hyperactivity disorder. In yet another study, a review of neuro-psychological studies of frontal lobe function in children with ADHD suggested that most of these tests would measure the ability to inhibit responses, which appears to be through the frontal lobes, especially the orbito-frontal area, frontal medial as well as their many connections with the striatum occur (Barkley, Grodzinski, & Dupal, 1992). In fact, children with ADHD are unable to control their responses and present them thoughtlessly, which is why these children produce such deficits in tasks that require attention and concentration. According to this hypothesis, if the inability of these children to control their responses is corrected, their concentration and attention will also improve. Because children with ADHD respond quickly, the number of mistakes they make increases, but on the other hand, the number of deletions decreases; i.e., the signs that are considered as a goal are also considered, but not out of attention and accuracy, rather on the basis that the child strives to quickly identify the items considered as a goal.

In sum, the findings of this study confirm that children with ADHD, compared to normal children, have disorders in various executive functions such as planning, inhibition, self-regulation, monitoring and problem solving, and cognitive rehabilitation is a useful guideline in this vein as it improves the executive functions of these children.

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