Research Paper

Neurofeedback Training Versus Perceptual-motor Exercises Interventions in Visual Attention for Children With Attention-Deficit/Hyperactivity Disorder: A Randomized Controlled Trial

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ABSTRACT

Introduction: Attention-deficit/hyperactivity disorder (ADHD) is one of the most common childhood psychiatric disorders characterized by poor attention and subsequently lower learning abilities than normal children. This study aimed to compare the effectiveness of neurofeedback and perceptual-motor exercises as two common nonpharmacological treatments for visual attention.

Methods: A total of 40 combined medicated ADHD children (aged 5-12 years) were randomly allocated into two groups: neurofeedback training and perceptual-motor exercises. Visual attention and motor proficiency were assessed before and after the treatment by continuous performance test (CPT) and Bruininks-Oseretsky Test (BOT), respectively.

Results: According to repeated measures analysis of variance (ANOVA), both groups showed significant improvement in three attention-related areas of CPT, including reaction time, omission, and commission errors ($P<0.001$), while the difference between the two groups was not significant ($P>0.05$). However, in the perceptual-motor exercises group, motor proficiency improved significantly ($P<0.01$).

Conclusion: Neurofeedback training intervention, as well as perceptual-motor exercises, are effective in improving ADHD symptoms, and given the similar effect of both interventions and their lack of side effects, perceptual-motor exercises appear to be the more appropriate option for reducing symptoms of ADHD, because of its additional effect on motor proficiency, rich content of purposeful activities, and social interactions.

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Highlights

● Neurofeedback training intervention promote attention in ADHD;

● Perceptual-motor exercises improve ADHD symptoms;

● Perceptual-motor exercises has an additional effect on motor proficiency.

Plain Language Summary

The effectiveness and cost of interventions is an important issue. The result of this study revealed although neurofeedback training intervention as well as perceptual-motor exercises are effective in improving ADHD symptoms, perceptual-motor exercises seem more appropriate option for reducing symptoms of ADHD, due to its additional effect on motor proficiency.

1. Introduction

As one of the most common childhood psychiatric disorders, attention-deficit/hyperactivity disorder (ADHD) is characterized by a combination of cognitive, motor, behavioral, and affective disorders that cause functional problems at school, home, and other social settings (American Psychiatric Association, 2013). Impairments in sustained attention, executive function, attentional processing, and response inhibition domains are the main symptoms of ADHD which can interfere with the learning and educational achievements of these children (Enriquez-Geppert, Smit, Pimenta, & Arns, 2019). According to the literature, early and effective intervention at the preschool stage could enhance the educational performance of ADHD children (Charach, Carson, Fox, Ali, Beckett, & Lim, 2013); therefore, various pharmacological and nonpharmacological therapeutic approaches have been developed to address their specific needs (Enriquez-Geppert et al., 2019).

Although medication therapy is an effective way to reduce hyperactivity and enhance attentional function in children with ADHD, it has limited effects on their executive control (Gonzalez-Castro, Cueli, Rodriguez, Garcia, & Alvarez, 2016), academic performance, social skills, and quality of life (Charach & Fernandez, 2013). Because of concerns around adverse and short term effects of pharmacological treatments, various nonpharmacological interventions are developed to treat its symptoms (Enriquez-Geppert et al., 2019), such as behavior modifications, neurofeedback training, multimodal psychosocial treatment, school-based programs, working memory training, parent training, self-monitoring, and physical exercises (Hodgson, Hutchinson, & Denson, 2014; Tan, Pooley, & Speelman, 2016). The effectiveness and cost of some of these interventions are recorded in meta-analysis and systematic reviews (Page et al., 2016), while many others remain to be addressed or need further research (Enriquez-Geppert et al., 2019).

Among the long list of these nonpharmacological interventions, neurofeedback training has received considerable attention, and in recent years, it has been used as a combination or alternative treatment for attention deficits. As a well-established and nonpharmacological intervention, neurofeedback training has none or minimal adverse effects, which is a significant advantage. It helps the brain improve self-regulation and attention through brainwave frequency modifications (Nooner, Leaberry, Keith, & Ogle, 2017). The positive effect of neurofeedback training on perceptual-motor skills (Jahani, Pishyareh, Haghgoo. HA, SA, & SN., 2016) of ADHD children is reported. However, there is a lack of comparative studies on the effectiveness of this technology with other available options, in addition to the fact that some studies do not confirm its positive effect on neuro-cognitive skills, and still, more investigation is needed (Okumura et al., 2017).

As mentioned above, another beneficial nonpharmacological intervention in children with ADHD is physical exercise (Ng, Ho, Chan, Yong, & Yeo, 2017). Among different types of physical exercises, perceptual-motor exercises have a crucial role in cognitive rehabilitation. The efficacy of physical and perceptual-motor exercises in improving motor coordination and motor control in ADHD is a proven fact (S, Arumugam, & Parasher, 2019; Taft Yazd, Ayatizadeh, Dehghan, Machado, & Wegner, 2015). Perceptual motor skills are movement-related skills that facilitate the interaction of humans with the environment and have a crucial role in their development (Sousa & Rueda, 2017; Wang, Krasich, Bel-Bahar, Hughes, Mitroff, & Appelbaum, 2015). These skills are essential to enhance sensory information processing and result in coordinated, balanced, and goal-oriented motor responses (Watemberg, Waiserberg, Zuk, & Lerman-Sagie, 2007). The relationship between attention and perceptual-motor skills has been reported in children with autism (Afshari, 2012) and ADHD (Taft Yazd et al., 2015). However, the evidence that examines the perceptual-motor exercises with acceptable methodology in ADHD is still limited (Enriquez-Geppert et al., 2019).

Indeed, while the perceptual-motor skills are essential to enhance sensory information processing for coordinated, balanced, and goal-oriented motor responses (Wang et al., 2015), the attention has an essential role in modulating the sensory processing and increasing the perceptual sensitivity to discriminate the target (Pessoa, Kastner, & Ungerleider, 2003). However, to our knowledge, there is still a lack of evidence comparing the effectiveness of interventions based on perceptual-motor exercise with interventions based on brain waves in children with ADHD. As mentioned above, this study aimed to compare the differential efficacies of neurofeedback training and perceptual-motor exercises in reducing visual inattention symptoms in children with ADHD. The specific objectives were to compare the second outcome and perceptual-motor skills between the two groups.

2. Materials and Methods

This study was designed as a single-blind prospective randomized controlled trial and was approved by the Local Ethics Committee. Written informed consent was obtained from all parents before the pretest session. The research project was registered as a randomized controlled trial (No.: IRCT2015061910806N2).

Study participants

For this study, 80 medical records of 5-12 years old children diagnosed with the combined type of ADHD by a child psychiatrist based on the Diagnostic and Statistical Manual of Mental Disorders (DSM–5) (American Psychiatric Association, 2013) were extracted. Fifty children met the inclusion criteria and participated in this study (Figure 1). The inclusion criteria were as follows: a) an IQ above 70 according to the Wechsler Intelligence Scale (Wechsler, 2003), b) proven motor proficiency problems due to ADHD (scored at least one year below their chronological age according to the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition) (Jankovic, 1978), c) no comorbid neurological deficits and mental disorders confirmed by a psychiatrist and neurologists, d) no comorbid orthopedic conditions confirmed by a pediatrician, and e) normal or corrected to normal visual and auditory acuity confirmed by medical records. The exclusion criteria consisted of a) failing to attend two consecutive intervention sessions, b) unstable medication regimen, c) contracting infectious diseases during the intervention period, d) lack of cooperation during the sessions, e) enrolment in similar services, or background of participation in similar studies.

Before starting the intervention, the blinded assessor evaluated attention and perceptual-motor functions through a computer-based continuous performance test (CPT) (Sina, R.www.sinapsycho.com) and Bruininks-Oseretsky Test of Motor Proficiency, Second Edition, respectively (Jankovic, 1978). The participants were allocated to one of two groups (neurofeedback training or perceptual-motor exercise) by randomization digits table. Randomization was stratified based on commission and omission errors and reaction times and Bruininks-Oseretsky test of motor proficiency scores.

Study intervention

Both groups received 20 treatment sessions, three sessions a week. Each session took 40- 45 minutes plus 10 minutes for break time. The treatment protocol in each group was as follows.

Regarding the neurofeedback training group, we used a classical neurofeedback protocol reducing theta (4-7 Hz) and increasing beta (15-20 Hz) frequency oscillations. Electroencephalogram (EEG) was recorded over C3/C4 point (according to the international 10-20 system) and referenced to ears (Egner & Gruzelier, 2001). The impedance was kept below 5 kΩ during the sessions. This intervention was conducted using the ProComp2™ (Thought Technology Ltd, Canada) (http://thoughttechnology.com/index.php/procomp2-2-channel-biofeedback-neurofeedback-system-w-biograph-infiniti-software.html). Baseline values were recorded from all participants at the first session for 3 minutes. The treatment session entailed two animation tasks (Boifun and Boat animations), demanding attention and focusing on the screen. Each session consisted of four 10-minute runs of each task.

For the perceptual-motor exercises group, the program was derived from the Jack Capon protocol and carried out in five stages: basic motor skills, motor perception, identification of different body parts, and coordinated and complex motor skills. The program follows these levels: 1) basic movements; 2) ball activities, rope activities, hoop activities; 3) balance beam activities, coordination ladder activities, jump box activities; 4) bean bag activities, rhythm stick activities; and level 5) tire activities, parachute activities (Capon, 2013a, 2013b; Capon & Alexander, 2013a, 2013b, 2013c).

Outcome measures

Treatment outcomes for each group were evaluated the day after the 20th treatment session as an assessor-blind posttest. The evaluation process was as follows.

The commission and omission errors and reaction time were measured using the Persian version of CPT (P-CPT) (Sina, R.www.sinapsycho.com), which includes two phases of training and test. In the training phase, the child was trained to click the target stimuli (by pressing the "space" button when a candle appeared), and the results were not recorded. In the test phase of P-CPT, a total of 150 stimuli (30 targets and 120 non-targets) appeared for 200 ms with a 1000-ms interval between each stimulus. The perceptual-motor skills were assessed using the Bruininks-Oseretsky test of motor proficiency (BOTMP-BOT-2). It measures gross and fine motor functions in individuals aged 4-21 years old in complete and short forms. The complete form of BOT-2 used in the present study consists of 53 items in 8 subtests from easy to difficult: fine motor precision (7 items), fine motor integration (8 items), manual dexterity (5 items), bilateral coordination (7 items), balance (9 items), running speed and agility (5 items), upper limb coordination (7 items), and strength (5 items). Completion time is about 45-60 minutes (Jankovic, 1978).

2.4. Statistical Analysis

Statistical analysis was performed using SPSS ver. 17.0. The significance level was set at 0.05. All variables were examined for normal distribution using the Shapiro–Wilk test, and t test was applied to compare the baseline demographic characteristics. The mean number of omission errors, commission errors, and reaction time were statistically analyzed using repeated-measures analysis of variance (ANOVA) comprising these core factors: time (pretest and posttest) as a within-group factor and group (perceptual-motor exercises and neurofeedback training groups) as a between-group factor. The Greenhouse-Geisser correction was used for the degrees of freedom whenever the sphericity assumption was violated. Additional post hoc analyses with Bonferroni adjustment for multiple testing was performed when a significant time, group, or group×time interaction was observed to identify sources of differences between and within groups.

3. Results

Forty medicated children with combined ADHD participated in the current study and were randomly assigned to the neurofeedback training group (13 boys/7 girls;

Table 1. Mean±SD of Bruininks-Oseretsky Test scores and Continuous Performance Test scores at pre and post intervention in neurofeedback training and perceptual motor intervention groups

Variable		Time	Neurofeedback		Perceptual Motor	
			Mean±SD	Mean change	Mean±SD	Mean change
CPT	Omission error	Pre-test	7.1±3.62	-4.9	7.7±3.18	-4.2
		Post-test	2.15±2.16		3.5±1.90	
	Commission error	Pre-test	8.35±3.28	-3.9	9.65±3.85	-6.7
		Post-test	4.45±2.11		2.9±2.29	
	Reaction time	Pre-test	664.2±68.69	-40.9	701.9±93.01	-104.6
		Post-test	623.3±83.71		597.3±51.06	
Bruininks-Oseretsky Test scores		Pre-test	74.5±15.57	4.1	75.6±14.01	31.75
		Post-test	78.6±14.26		07.35±17.05	

SD=standard deviation

Mean change=post-intervention - pre- intervention

CPT= Continuous Performance Test

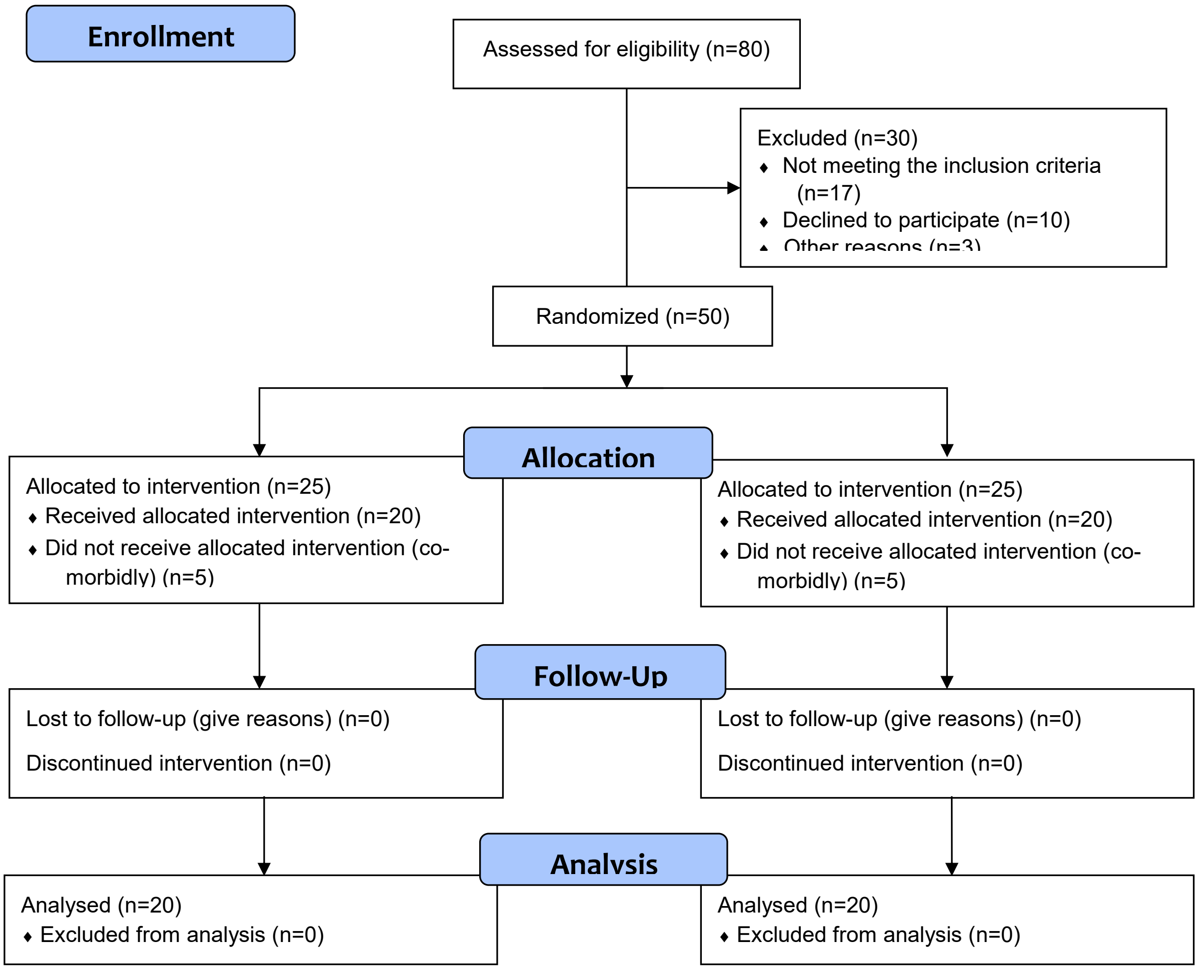

Figure 1. Consort trial flow diagram of the participants

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Mean±SD age: 93.4±15.47 months; IQ: 100.9±10.19) and perceptual-motor exercises group (16 boys/4 girls; Mean±SD age: 90.00±16.08 months; IQ: 98.5±10.7). There were no significant differences between the two groups regarding age (t (38)=0.68, P=0.50) and IQ (t (38)=0.73, P=0.47). The descriptive data of the different variables are presented in Table 1.

Visual attention

Omission errors analysis

The repeated measures ANOVA demonstrated a significant main effect of time on omission errors (F 1, 38 =107.42, P<0.001), while the main effect of the group and the interaction effect of time by the group was insignificant (Table 2). Precisely, this result indicated that both perceptual-motor exercises and neurofeedback training groups resulted in decreased omission errors (Table 1).

Commission Errors Analysis:

In the case of commission errors, the results indicated a significant main effect of time (F 1, 38=209.68, P<0.001) and time × group interaction (F 1, 38=15.02, P<0.001). However, the main effect of the group was not significant for commission errors (Table 2). The results of multiple comparisons indicated that commission errors significantly decreased following interventions in both perceptual-motor exercises and neurofeedback training groups (Figure 2).

Reaction time analysis

Furthermore, a significant main effect of time on reaction time was shown (F 1, 38=49.4, P<0.001), while the main effect of the group was not significant. The time × group interaction was significant in reaction time scores (F 1, 38=9.47, P<0.001) (Table 2). The results of multiple comparisons indicated that, in both perceptual-motor exercises

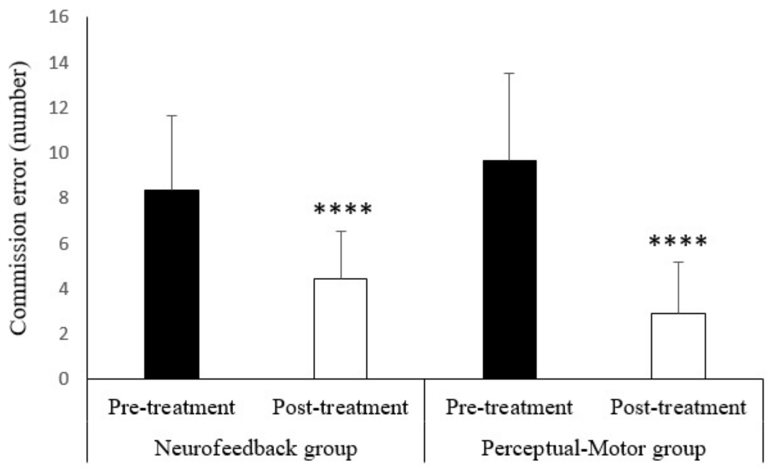

Figure 2. Plot of group by time interaction effect on commission error

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**** P<0.0001 compared with pretreatment in the same group.

and neurofeedback training groups, reaction time was significantly reduced following interventions (Figure 3).

Motor proficiency

As shown in Table 2, the results revealed a significant main effect of time (F 1, 38=129.9, P<0.001) and group (F 1, 38=10.68, P=0.002) on motor proficiency. Similarly, the time×group interaction was significant (F 1, 38=77.27, P<0.001). The results of multiple comparisons showed that motor proficiency was significantly improved in both perceptual-motor exercises and neurofeedback training groups. Moreover, improvement of motor proficiency was significantly greater in the perceptual-motor exercises group compared with the neurofeedback training group (Figure 4).

4. Discussion

This study objectively compared the efficacy of neurofeedback training and perceptual-motor exercises on visual attention domains in children with ADHD. Although there was no significant difference between the two groups in reaction times and the number of commission and omission errors, improvement in these CPT factors was observed following both interventions. However, perceptual-motor exercises were more effective in decreasing commission errors and reducing reaction times.

Obviously, the main focus of neurofeedback training is to select the appropriate protocol and how to implement it. Each protocol has a different effect. The earlier mentioned, well-investigated, and the most accepted protocols in ADHD are theta/beta ratio (TBR), sensory-motor strip (SMR), and slow cortical potential) SCP (as effec-

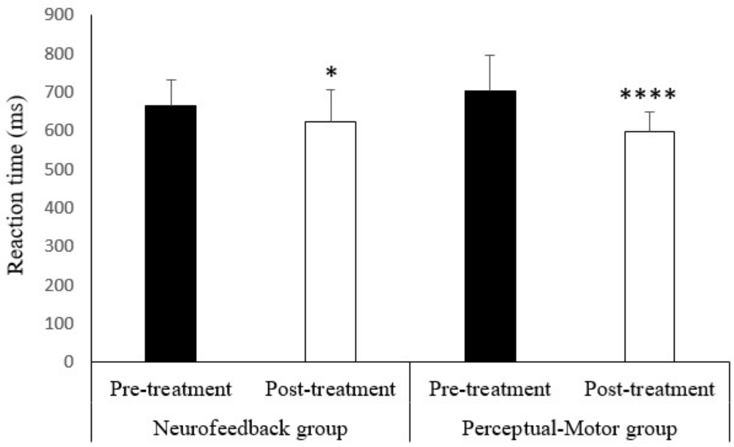

Figure 3. The plot of group by time interaction effect on reaction time

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* P<0.05 and **** P<0.0001 compared with pretreatment in the same group.

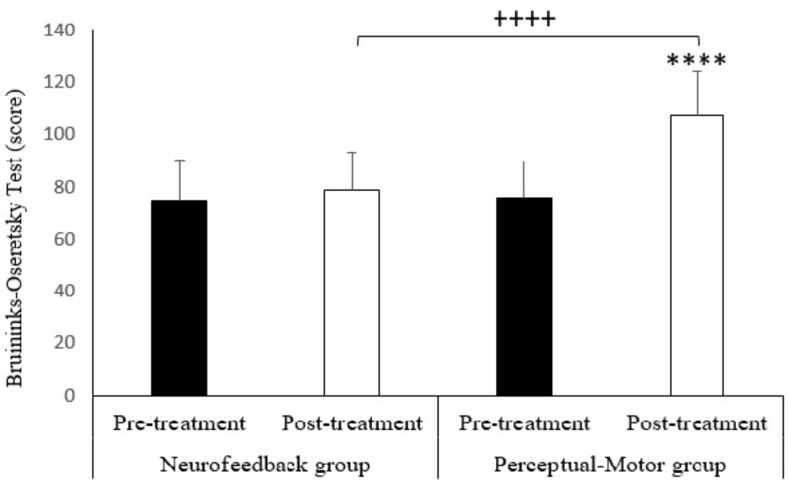

Figure 4. Plot of group by time interaction effect on the Bruininks-Oseretsky test score

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**** P<0.0001 compared with pretreatment in the same group; ++++ P<0.0001.

tive factors in improving self-regulation and academic performance. They reduce inattentiveness, hyperactive/impulsive symptoms, and inhibition. Thirty to 40 neurofeedback training sessions have been reported in the literature (Enriquez-Geppert et al., 2019). The TBR protocol used in the current study reduced theta (4-7 Hz) and increased beta (15-20 Hz) frequency, recorded over C3/C4 point, during 20 sessions of training. Although the results revealed decreasing commission errors and reaction time in the neurofeedback training group, increasing the number of sessions or using another protocol such as SMR may change the current results. Therefore, for more accurate results of comparing the effect of neurofeedback training with perceptual-motor exercises in ADHD, it is recommended to repeat this study with other neurofeedback protocols.

The significant difference between the pretest and posttest results suggests the improvement in attentional performance following neurofeedback training in all areas of CPT. This finding shows that decreasing slow EEG activity and increasing fast wave activity leads to more normal performance in a sustained attention task. This finding is consistent with previous studies (Butnik, 2005; Enriquez-Geppert et al., 2019).

On the other hand, our protocol of perceptual-motor exercises was effective in attention. Therefore, we infer that attention is affected by motor proficiency. Previous investigations about the effectiveness of perceptual-motor exercises on behavioral problems in ADHD children have also reported similar results (Taft Yazd et al., 2015). According to the literature, attention is under neurophysiological support for the navigation of the eyes and the limbs (Amso & Scerif, 2015; Eimer & van Velzen,

Table 2. A summary of the ANOVA results for the sustain attention measures and motor proficiency: F ratios, P values, and effect sizes by variable.

Variables	Main effect						Interaction effect		
	Time			Group			Time×Group		
	F	P	Partial η^2	F	P	Partial η^2	F	P	Partial η^2
Omission error (number)	107.42	<0.001	0.74	0.72	0.40	0.04	1.6	0.21	0.02
Commission error (number)	209.68	<0.001	0.85	0.021	0.88	0.00	15.02	<0.001	0.28
Reaction Time (millisecond)	49.4	<0.001	0.57	0.07	0.78	0.002	9.47	0.004	0.20
Bruininks-Oseretsky Test scores	129.9	<0.001	0.77	10.68	0.002	0.22	77.27	<0.001	0.67

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2006). This neurophysiological support helps increase attention by making a close link between attention direction and eyes and limb movement. Therefore, improving perceptual-motor skills which causes a better integration of eyes and limbs, will increase attentional capacity. Although both approaches are significantly effective in attentional performance, in general, no significant difference was observed between the two groups in terms of their improvement, which can be justified by the short duration of the intervention.

According to our results, omission errors were reduced by both neurofeedback training and perceptual-motor exercise interventions. This finding is consistent with previous studies (Gruzelier, Egner, & Vernon, 2006). An omission error indicates that the subject did not respond to a target stimulus that should have elicited a response. This is a good measure of sustained attention (Goetz et al., 2017). Considering our statistical results, we suggest that omission error was reduced in both groups in the same manner and neurofeedback training and perceptual-motor exercises are both suitable approaches for treating this aspect of attentional performance.

Commission errors were also significantly decreased by both interventions, while the effect of neurofeedback training and perceptual-motor exercises differed between groups. However, the perceptual-motor exercises group was more effective than neurofeedback training. This finding is consistent with other research studies, which confirmed that although neurofeedback training is highly effective in attention-deficit but shows little to moderate effect on treating hyperactivity. The importance of motor control in inhibitory mechanisms (Dahan, Ryder, & Reiner, 2016) is a good explanation for this finding. Commission errors reflect the inhibitory control of executive functioning and impulsivity in children with ADHD (Kaiser, Schoemaker, Albaret, & Geuze, 2015; Tseng, Henderson, Chow, & Yao, 2004). The inhibitory mechanism includes the diagnosis and selection of the target stimulus while other stimuli are ignored, and therefore motor responses are controlled. The larger number of these errors compared to omission errors supports the idea that ADHD is an inhibition problem rather than an attention problem proposed by other researchers too (Fosco, Kofler, Alderson, Tarle, Raiker, & Sarver, 2019).

Our results indicated that reaction times were decreased in both groups of subjects. Decreased reaction time indicates better divided attention (Gualtieri & Johnson, 2006), and our approaches increased brain flexibility to switch between stimuli.

The present study was limited by the subject's uncontrolled diet (which probably affected their symptoms). Further investigations are recommended to study the consistency of treatment effects of neurofeedback training and perceptual-motor exercises and compare the treatment results. Comparative studies on the influence of other neurofeedback training protocols and perceptual-motor exercises are also recommended. Besides, the attention in this study was evaluated using P-CPT, which assesses attention for approximately 8 minutes; another assessment tool that measures attention over a longer period is suggested. We did not assess the motivation of the participations (Dehghanizadeh M, 2020). Besides investigation of the effect of interventions on activities of daily living should be studied (Ghaffari et al, 2021).

To conclude, our findings suggest that neurofeedback training, as well as perceptual-motor exercises, are effective in improving ADHD symptoms, such as decreased omissions. While in the case of commission errors and reaction times, perceptual-motor exercises were more effective, this higher effect did not cause a significant difference between the scores of the two groups. Overall, given the similar effect of both interventions and their lack of side effects, perceptual-motor exercises appear to be the more appropriate option for reducing symptoms of ADHD due to more extensive therapist-child interaction, an active motor function, and purposeful activities.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of the Iran University of Medical Sciences (Code: 3058/105//93D).

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Authors' contributions

Conceptualization and Supervision: Neda Ghadamgahi Sani and Malahat Akbarfahimi; Methodology: Malahat Akbarfahimi; Investigation, Writing – original draft, and Writing – review & editing: All authors; Data collection: Neda Ghadamgahi Sani; Data analysis: Malahat Akbarfahimi and Ghorban Taghizadeh.

Conflict of interest

The authors declared no conflict of interest.

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