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

Authors: Neda Ghadamgahi Sani¹, Malahat Akbarfahimi¹*, Shadi Akbari², Mehdi Alizadeh Zarei³, Ghorban Taghizadeh¹

¹. Department of Occupational therapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.
². Researcher, University of Tabriz, Tabriz, Iran.
³. Corresponding author: Malahat Akbarfahimi, Department of Occupational therapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran. E-mail: akbarfahimi.m@iums.ac.ir

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Abstract

Introduction: Attention deficit hyperactivity disorder (ADHD) is one of the most common childhood psychiatric disorders which is characterized by poor attention and subsequently lower learning capacities comparing with normal children. The purpose of this study was to compare the effectiveness of neurofeedback and perceptual-motor exercises as two common non-pharmacological treatments on visual attention.

Method: 40 combined medicated ADHD children (aged 5-12 years) were allocated randomly in 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 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 two groups was not significant (p>0.05). However, in 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, due to its additional effect on motor proficiency, rich content of purposeful activities and social interactions.

Keywords: Attention deficit hyperactivity disorder, Neurofeedback, Perceptual motor, Attention, Children, Randomized Controlled Trial
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 (Association, 2013). Impairments in sustained attention, executive function, attentional processing and response inhibition domains are indicated as main symptoms of ADHD which can interfere learning and educational achievements of these children (Enriquez-Geppert, Smit, Pimenta, & Arns, 2019). According to the literatures, early and effective intervention at pre-school stage could enhance educational performance of ADHD children (Charach et al., 2013), therefore various pharmacological and non-pharmacological 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). Due to concerns around adverse and short term effect of pharmacological treatments, a variety of non-pharmacological 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 still remain to be addressed or need further research (Enriquez-Geppert et al., 2019). Among the long list of these non-pharmacological interventions, neurofeedback training has received considerable attention and over recent years, it has been used as a combination or alternative treatment for attention deficits. As a well-established and non-pharmacological intervention, neurofeedback training has zero to minimal adverse effects which is a big advantage. It helps the brain to 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 non-pharmacological intervention in children with ADHD is physical exercises (Ng, Ho, Chan, Yong, & Yeo, 2017). Among different types of physical exercises, perceptual-motor exercises has a crucial role in cognitive rehabilitation. The efficacy of physical and perceptual–motor exercises in improving the 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 which facilitate the interaction of human with environment and have crucial role in his development (Sousa & Rueda, 2017; Wang et al., 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 is reported in children with autism (Afshari, 2012) and ADHD (Taft Yazd et al., 2015). However, the evidence that examine 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 important role to modulate the sensory processing and increasing the perceptual sensitivity to discriminate the target (Pessoa, Kastner, & Ungerleider, 2003). However, to our knowledge, there is still 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, the main purpose of this study was to compare the differential efficacies of neurofeedback training and perceptual-motor exercises in the reduction of visual inattention symptom in children with ADHD. The specific objectives were to compare the second outcome, perceptual-motor skills between 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. The written informed consent was obtained from all parents before the pre-test session. The research project was registered as a RCT, no IRCT2015061910806N2 in http://www.irect.ir/.
2.1 Participants

For this study, 80 medical records of 5-12 years old children diagnosed with combined type of ADHD by child-psychiatrist based on Diagnostic and Statistical Manual of Mental Disorders (DSM–5) (Association, 2013). Fifty children who met the inclusion criteria participated in this study (Fig 1).

![ Consort Flow Diagram of Participants ]( Consort Flow Diagram of Participants )

Fig 1: CONSORT trial flow diagram of participants
The inclusion criteria were defined 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 (Bruininks, 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 a background of participation in similar studies.

Before starting the intervention, the blinded assessor evaluated attention and perceptual motor functions randomly by computer-based continuous performance test (CPT) ("Sina, R. www.sinapsycho.co,"), and Bruininks-Oseretsky Test of Motor Proficiency, Second Edition, respectively. 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.

2.2 Intervention

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

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 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 first session for 3 minutes. Treatment session entailed two animation tasks (Biofun and Boat
animations), demanding attention and focusing on the screen. Each session consisted of four 10-minute runs of each task.

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

2.3 Outcome measures
Treatment outcomes for each group were evaluated the day after the 20th treatment session as an assessor-blind post-test. The evaluation process was as follows:

The commission and omission errors and reaction time were measured using Persian version of CPT (P-CPT) ("Sina, R.www.sinapsycho.co.") which includes two phases of training and test. In the training phase the child was trained how 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 the 150 stimuli (30 target and 120 non-target) appeared for 200 milliseconds and 1000 milliseconds intervals between each stimuli. The perceptual-motor skills were assessed using 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), strength (5 items). Completion time is about 45-60 minutes (Bruininks, 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 values of the number of omission errors, commission errors and reaction time were statistically analyzed using repeated measures analysis of variance (ANOVA) comprising these core factors: Time (pre-test and post-test) as a within-group factor and group (perceptual-motor exercises and neurofeedback training groups) as a between-group factor. 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 were 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 randomly assigned to the neurofeedback training group (13 boys/7 girls; age (months): 93.4±15.47; IQ: 100.9 ±10.19) and perceptual-motor exercises group (16 boys/4 girls; age (months): 90.00±16.08; IQ: 98.5±10.7). There was not any significant difference 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 variable was shown in Table 1.
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time</th>
<th>Neurofeedback</th>
<th>Groups</th>
<th>Perceptual Motor</th>
<th>Mean change</th>
<th>Mean change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean change</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CPT Omission error</td>
<td>Pre</td>
<td>7.1</td>
<td>3.62</td>
<td>-4.9</td>
<td>7.7</td>
<td>3.18</td>
</tr>
<tr>
<td></td>
<td>post</td>
<td>2.15</td>
<td>2.16</td>
<td></td>
<td>3.5</td>
<td>1.90</td>
</tr>
<tr>
<td>CPT Commission error</td>
<td>Pre</td>
<td>8.35</td>
<td>3.28</td>
<td>-3.9</td>
<td>9.65</td>
<td>3.85</td>
</tr>
<tr>
<td></td>
<td>post</td>
<td>4.45</td>
<td>2.11</td>
<td></td>
<td>2.9</td>
<td>2.29</td>
</tr>
<tr>
<td>CPT Reaction time</td>
<td>Pre</td>
<td>664.2</td>
<td>68.69</td>
<td>-40.9</td>
<td>701.9</td>
<td>93.01</td>
</tr>
<tr>
<td></td>
<td>post</td>
<td>623.3</td>
<td>83.71</td>
<td></td>
<td>597.3</td>
<td>51.06</td>
</tr>
<tr>
<td>Bruininks-Oseretsky Test scores</td>
<td>Pre</td>
<td>74.5</td>
<td>15.57</td>
<td>4.1</td>
<td>75.6</td>
<td>14.01</td>
</tr>
<tr>
<td></td>
<td>post</td>
<td>78.6</td>
<td>14.26</td>
<td></td>
<td>107.35</td>
<td>17.05</td>
</tr>
</tbody>
</table>

SD=standard deviation
Mean change=post-intervention - pre-intervention
CPT= Continuous Performance Test

3.1 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 group and the interaction effect of time by group was insignificant (Table 2). Precisely, this result indicated that both perceptual-motor exercises and neurofeedback training groups resulted in decreased omission error (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 group was not significant for commission errors (Table 2). The results of multiple comparisons indicated that commission errors was significantly decreased following interventions in both perceptual-motor exercises and neurofeedback training groups (Fig. 2).
**Fig. 2.** Plot of group by time interaction effect on commission error. **** P<0.0001 compared with pre-treatment in the same group.

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

<table>
<thead>
<tr>
<th>Variables</th>
<th>Main effect</th>
<th></th>
<th>Interaction effect</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time</td>
<td>Group</td>
<td>Time × Group</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>P</td>
<td>Partial η²</td>
<td>F</td>
</tr>
<tr>
<td>Omission error (number)</td>
<td>107.42</td>
<td>&lt;0.001</td>
<td>0.74</td>
<td>0.72</td>
</tr>
<tr>
<td>Commission error (number)</td>
<td>209.68</td>
<td>&lt;0.001</td>
<td>0.85</td>
<td>0.021</td>
</tr>
<tr>
<td>Reaction Time (millisecond)</td>
<td>49.4</td>
<td>&lt;0.001</td>
<td>0.57</td>
<td>0.07</td>
</tr>
<tr>
<td>Bruininks-Oseretsky Test scores</td>
<td>129.9</td>
<td>&lt;0.001</td>
<td>0.77</td>
<td>10.68</td>
</tr>
</tbody>
</table>

Fig. 3. Plot of group by time interaction effect on reaction time. * P<0.05 and **** P<0.0001 compared with pre-treatment in the same group.
3.2 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 x 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 (Fig. 4).

Fig. 4. Plot of group by time interaction effect on the Bruininks-Oseretsky Test score. **** P<0.0001 compared with pre-treatment in the same group., ++++ P<0.0001
4. Discussion

This study provides an objective comparison between the efficacy of neurofeedback training and perceptual-motor exercises on visual attention domains in children with ADHD. Although there was no any significant difference between 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 showed to be more effective on decreasing commission errors and reducing the 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 an effective in improving self-regulation and academic performance, reduces inattentive and hyperactive/impulsive symptoms, and inhibition. The number of neurofeedback training sessions reported approximately between 30 to 40 in literature (Enriquez-Geppert et al., 2019). The TBR protocol used in the current study was reducing theta (4-7 Hz) and increasing beta (15-20 Hz) frequency, recorded over C3/C4 point and during 20 sessions training. Although the results revealed decreasing commission error and reaction time in neurofeedback training group, increasing the number of sessions or using another protocol such as SMR may change the current results. Therefore, for a more accurate conclusion of comparing the effect of neurofeedback training with perceptual-motor exercises in ADHD, it is recommended to repeat this study with other neurofeedback protocols.

Significant difference between pre and post-test results suggests improvement in attentional performance following neurofeedback training in all areas of CPT. This finding provides evidence that decreasing slow EEG activity and increasing fast wave activity leads to more normal performance in sustained attention task. This is consistent with previous studies (Butnik, 2005; Enriquez-Geppert et al., 2019).

On the other hand our protocol of perceptual-motor exercises showed to be 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 has also reported similar results(Taft Yazd et al., 2015). According to previous literatures, attention is under neurophysiological support for navigation of eyes and the limbs(Ams & Scerif, 2015; Eimer & van Velzen, 2006). This neurophysiological support helps
to increase the attention by making a close link between attention direction and eyes and limb’s movement. Therefore, improving perceptual-motor skills which causes a better integration of eyes and limbs, will increase attentional capacity. Although both approaches showed to be significantly effective in attentional performance, however in general, no significant difference was observed between 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 exercises interventions. This is consistent with previous studies (Gruzelier, Egner, & Vernon, 2006). An omission error indicates that the subject did not respond to a target stimulus which should have elicited a response. This is a good measure of sustained attention (Goetz et al., 2017). Therefore considering our statistical results, we suggest that omission error was reduced in both groups in the same manner and both of neurofeedback training and perceptual-motor exercises are 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, perceptual-motor exercises group showed to be more effective than neurofeedback training. This is consistent with other researches which confirmed 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 mechanism (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 target stimulus while other stimuli are ignored and therefore motor responses are controlled. The larger number of these errors comparing to omission errors, supports the idea that the key to ADHD is that it is an inhibition problem rather than an attention problem proposed by other researchers too (Fosco et al., 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 it means that our approaches increased brain flexibility to switch between stimuli.

The present study was limited by 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 to compare the treatment results.

The comparative studies on the influence of other neurofeedback training protocols and perceptual-motor exercises is also recommended. Besides, the attention in this study evaluated using P-CPT, which assess attention approximately in 8 minutes duration, another assessment tools that measure attention over a longer period of time is suggested.

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 commissions and reaction times, perceptual-motor exercises was more effective but this higher effect did not cause significant difference between the scores of two groups. Overall, given the similar effectiveness 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 consists of purposeful activities.

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