Motor Learning in children with ADHD and Normal Children: Comparison of Implicit and Explicit Motor Sequence

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Abstract

Introduction: Children with Attention Deficit Hyperactivity Disorder (ADHD) face many academic and training problems and also impose some problems on their teachers and classmates. Motor learning can be categorized into two main types: implicit and explicit. The main goal of the present study was to investigate the possible differences between implicit and explicit motor sequence learning in children with ADHD and normal children by using serial reaction time task. **Materials and Methods**: The sample consisted of 24 children with ADHD, who were equally assigned to explicit and implicit learning groups, and 24 normal children, also equally assigned to implicit and explicit learning groups. Each group, therefore, consisted of 12 participants. Repetitive Measure ANOVA was run to compare reaction time and error in different blocks, and squared t-test was used to compare regular and irregular blocks. **Results**: Comparison of implicit and explicit learning for accuracy (the number of reaction errors) and speed (response time) revealed the accuracy to be $P=0.012$ and speed $P=0.012$ in ADHD explicit group, and accuracy $P=0.094$ and speed $P=0.954$, in ADHD implicit group. Normal explicit group indicated accuracy of ($P=0.008$) and speed of ($P=0.05$) and normal implicit group indicated accuracy of ($P=0.011$) and speed of ($P=0.442$). **Conclusion**: The results of the present study indicated that explanation and description of the task was more effective in motor sequence learning in ADHD children. It is, therefore, recommended that pre-exercise training be included in the programs provided to these children.

Keywords: Motor Sequence, Explicit Learning, Implicit Learning, ADHD

Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a sustainable pattern of attention deficit or hyperactivity of impulsive behaviours, which is more prevalent in children with similar growth levels. The prevalence of this disorder varies from 2 to 20% of elementary school students, with the more accurate percentage of about 3-7% of elementary school students and pre-maturated children. It is more common in boys (2 to 1 ratio) than in girls (9 to 1 ratio) (1). Although the disorder begins before the age of 3, it cannot be diagnosed generally till the time that the child starts elementary school and academic education and faces organized patterns (1).

ADHD children face many academic and training problems and can cause some problems for their teachers and classmates, as well. Studies have indicated that 20-25% of these students have specific learning disorder, while ADHD children have no mental disorder (2).

Various studies in the field of ADHD indicate the disorder infronto-striatal-cerebellar track (3), which covers some structures such as basal ganglia, cortex, and thalamus (4, 5), which are the involved tracks in motor learning process.

Motor learning refers to relatively stable changes of motor behavior and is different from performance (3). Learning is one of the most complicated cognitive processes that can be divided generally into two groups. The two types of learning are separated from each other both in terms of the involved cerebral zones and performance. These learning types are known as explicit and implicit learning (6).

Explicit learning turns back to learning realities and personal memories and access to such information is possible consciously (7). Motor learning can be considered in this group, when required explanations are provided for learners in regard with the aim and style of doing motor tasks (6). Brain imaging and pathology of brain damages indicate that explicit learning can make several parts

involved such as temporal lobe, frontal lobe, hippocampus, and thalamus (6, 8). Implicit learning refers to all types of unconscious learning processes. Evidences indicate that there are different kinds of implicit learning, which can make every cerebral zones involved. For example, classical conditioning can be referred to include motor responses that can make cerebellum involved and conditioning of emotional responses that can make amygdale involved(7). In motor learning process, if the learner performs a motor task with no knowledge of the action that should be conducted, the learning would be implicit(6). Implicit learning of motor sequence depends on a wide network, including joints among frontal cortex and parietal and cortical areas. Cortical areas include cerebellum and basal ganglia (7, 9, 10).

Implicit learning does not depended on IQ, although explicit learning significantly depends on it. If explicit learning occurs during the process of implicit learning, low IQ can indicate deficit in implicit learning (11).

One of the most common methods for evaluating implicit and explicit learning is using Serial Reaction Time Task introduced by Nissen and Bullemer(12). In this method, target stimulus appears in several spatial areas and contributors should rapidly press relevant button of the place of stimulation. This type of motor task includes two motor and cognitive components and participants should show response to a single cognitive stimulus (such as visual or auditory stimuli).

Studies in the field of implicit motor learning in ADHD children have not indicated similar results (7). In addition, a separated study with regard to explicit motor learning has indicated perfection of this kind of learning in ADHD children.

Moreover, a single study (13) has comparatively investigated both types of implicit and explicit learning.

The present study can be a suitable pattern for rehabilitation caregivers and also teachers of ADHD children based on which motor learning can be followed implicitly or explicitly. A question raised here is whether describing and explaining components of motion can help motor learning in ADHD children or not.

Materials and Methods

Sample

The present study follows a quasi-empirical design. A total of 48 children with ADHD participated in the present study. Participants were 24 children with ADHD disorder in both groups of explicit learning (12 girls) and implicit learning (9 boys and 3 girls), and 24 normal children in two groups of explicit learning (10 boys and 2 girls) and implicit learning (4 boys and 8 girls). Considering standard deviation of the previous studies, sample size was decided to be 12 participants in each group (13). All the participants were selected from a normal elementary schools in Abarkooh.

Inclusion criteria for both groups of ADHD and normal children included right-handedness using Edinburgh test, no auditory and visual disorders, no motor pathology in the upper limb, and the age range of 7-12.

One specific inclusion criteria for ADHD group was sample individuals had to obtain a desired score from both the teacher version and parent version of Connors Test and the final diagnosis had to be conducted by a kid psychiatrist. Exclusion criteria included other diseases and mental disorders like autism and so on, reluctance to cooperate in the study, inability to do motor tasks, absences in the required sessions, and unwillingness for continuing motor tasks.

From among the early pool, 5 children with ADHD disorder were excluded as they were left-handed, 1 was excluded because of lack of parental consent, and 3 other were excluded because of absences in the two test sessions.

Firstly, the authors referred to Yazd Ministry of Education and Abarkooh Ministry of Education to receive required permissions to conduct the study in urban schools in Abarkooh. After referring to the specified school and meeting the school manager, necessary explanations and specifications were provided to the teachers regarding ADHD. Then, teachers were asked to introduce students with aforementioned specifications.

After selecting suspected students, teacher's version of Connors test was filled by the teachers. In this test, children could pass when required score was obtained.

In the next stage, parent version was presented to the parents and students, who were able to gain the required score to go to next stage. In the next stage, children were referred to psychiatrist, and finally, the final diagnosis of ADHD was made by a kid psychiatrist.

After selecting the children with ADHD, informed consent was sent to the parents in which objectives and specifications of the study were explained. It was stated to parents that no physical or mental disorder and problem would be imposed on their children and they could cancel their cooperation at any stage of the research and that all personal and medical information of children would be kept anonymous. When parents accepted and signed the informed consent, two forms of personal and medical information related to children were filled out by parents and children entered the test. Children's functional IQ was measured using Wechsler Intelligence Scale for Children III. Then, samples in both groups of ADHD and normal group were randomly categorized into two groups. Studied groups were the same in terms of functional IQ and handedness inventory. Table 1 presents demographic features of the samples.

Instruments
Serial reaction time task
Data collection was conducted using Persian version of serial time reaction task. Validity and stability of the version was already determined (6).

In the software, a square appeared in 4 points of the monitor (every time in one of these points), which had the ability to change into 4 colors (yellow, green, blue, and red). Every color was

Figure 1.Squares on monitor

embedded on the monitor in the form of a label (button P was for blue; Q for yellow, Z for green, and M for red). After pressing the relevant button, another square would appear and in case the child made a mistake, again the next square could appear as shown in Figure 1. Individuals had to show response to stimuli through pressing the relevant buttons by their index figure. In this software, every serial had 7 squares, and by repeating 10 sequences, 70 squares could be created, named block. Then, calculations and analyses were conducted on these blocks. A total of 7 blocks were applied in this test and, totally, children had to show response to 490 colorful squares.

Repetition of colorful squares in every sequence included two different patterns, which were applied in different parts of the test. One of these patterns was random pattern, which was determined by the software and could appear following no logical formulation. Another form of appearance of the square patterns was regular: the order of appearance followed a predetermined design including blue, yellow, blue, red, yellow, green, and yellow.

In the present study, decrease in errors or increase in correct responses to stimuli was considered as accuracy criteria and also the time of appearing the response was considered as speed of motor learning. Tasks presented to trials had 7 stages: stages 2 and 6 were irregular and other stages were presented in a specific order and sequence.

In this version, in order to decrease the probability of using explicit strategies, during conducting motor task related to implicit motor learning, the time interval from providing the response to a stimulus up to emergence of the next stimulus was set at zero.

The duration of every stage of the test (per ms millennium) and the number of wrong answers to target stimuli were measured using the software. Reaction time was a criterion for learning speed, and the number of wrong answers was considered as a criterion for learning accuracy.

Edinburgh **Handedness Inventory questionnaire**
Edinburgh handedness inventory questionnaire is a questionnaire

with 10 items, which is used for determining handedness through investigating which hand individuals use while doing 10 tasks. Positive scores indicate right-handedness and negative scores indicate left-handedness and 0 score indicates lack of handedness. Reliability and validity of the test was previously confirmed by Alipour *et al.* (14).

Connors Questionnaire
Parent version
Connors scale includes 48 items using a 4-point Likert-type scale (0: not correct at all, never, rarely, 3: completely correct, often, almost always), which should be filled out by parents. The score of 60 and above was considered as ADHD disorder. The reliability and validity of the questionnaire had previously been confirmed by Shahaian*et al.*in a study on 6-11 year old children in Shiraz. Shahaian*et al.* used Cronbach's alpha to determine the reliability. The obtained scores were 0.58, 0.73, and 0.70, respectively for A, B, and C. This indicated that applying the test for the purpose of screening children with ADHD disorder was desirable. Coefficients of correlation between subscales and the total score varied between 0.76 and 0.90 (15, 16).

Teacher version
Teacher version is a 38-item questionnaire using a 4-point Likert scale from 0 (not correct at all, never, rarely) to 3 (completely correct, often, almost always) to be filled out by teachers. Scores 75 and above were considered as ADHD disorder. Normalization and psychometric properties of Connors scale for teacher version were confirmed by Shahim*et al.* The validity of the scale was obtained to be 0.76 using equivalent retest method and 0.86 using Cronbach's alpha, which indicates desirable rate (15).

Procedure
To perform the test, the serial reaction time task software was installed on a personal computer. The participants had to sit on a chair in front of the computer and take the test using their index fingers. The software used was the same for all the groups although the test stage was different due to the type of learning whether to be explicit or implicit. Both normal and ADHD children in implicit group sat on a chair in front of the computer and asked to press the relevant button immediately after observing every square.

In this stage, the test included 7 blocks, which blocks 2 and 6 had random arrangements and blocks 3-5 and blocks 7 and 1 had ordered patterns. Here, no explanation was given to the children about repeating order of the squares and they were just asked to press the relevant button immediately after observing each square. Between both sequential blocks, children were allowed to have a 1-minute break. At the end of block 7, a sign appeared on the monitor indicating that the test finished.

Finally, the children were asked if there were a pattern between repeating squares or not. If there were a repeated pattern, children were asked to express it. If children were able

*Table 1.*Mean (SD) for demographic information of participants

Demographic information	Mean (SD)[ADHD group]		Mean (SD) [Normal group]	
	Explicit	Implicit	Explicit	Implicit
Age	8.50 (1.67)	8.83 (1.46)	8.83 (1.66)	8.83 (1.33)
Functional IQ	96.92 (16.91)	95.50 (18.03)	97 (15.25)	99.33 (15.81)
Gender	12boys/0girls	9boys/3girls	10boys/2girls	4boys/8girls

Table 2: Results of squared t-test in irregular steps and repeated measure analysis of variance in 4 studied groups

Variable		Normal group			ADHD group			Interactional effect of group variable	Group effect
		Mean (SD)		*P*-value	Mean (SD)		*P*-value	*P*-value	*P*-value
		block2	block6		block2	block6			
Implicit learning	Accuracy	66.36 (3.731)	67.85 (2.42)	0.309	68.25 (1.42)	68.33 (1.37)	0.838	0.358	0.457
	Speed	1.82 (0.57)	1.65 (0.53)	0.044	1.560 (0.286)	1.64 (0.384)	0.216	0.017	0.108
Explicit learning	Accuracy	68.33 (1.61)	68.25 (1.21)	0.878	86.67 (1.23)	69.00 (1.47)	0.517	0.572	0.230
	Speed	1.703 (0.543)	1.658 (0.454)	0.604	1.79 (0.491)	1.73 (0.48)	0.147	0.882	0.657

Table 3: Results of repeated measure analysis of variance in regular steps for 4 studied groups

Variable		Normal peers group						ADHD group						Group effect	Interactional effect
		Mean (SD)					*P*-value	Mean (SD)					*P*-value	*P*-value	*P*-value
		1	3	4	5	7		1	3	4	5	7			
Implicit learning	Accuracy	66.92(2.42)	67.67(2.42)	67 (2.23)	67 (2.76)	68.67 (1.73)	0.01	66.17(3.66)	66.25 (2.45)	67.92 (1.83)	68.42 (1.50)	68.25 (2.22)	0.09	0.13	0.845
	Speed	1.72(0 .57)	1.72(0 .53)	1.82(0 .57)	1.56(0. 62)	1.60 (0.50)	0.42	1.61(0 40)	1.57 (031)	1.59 (0.31)	1.58 (0.32)	1.58 (0.36)	0.95	0.544	0.48
Explicit learning	Accuracy	66.92(3.05)	68.5(1 .38)	68.08(2.23)	(0.98)6 9.33	69 (1.34)	0.008	66.25 (3.81)	67.43 (1.642)	68.5 (1.16)	(1.80) 68	69 (1.47)	0.07	0.369	0.38
	Speed	1.92(0 .66)	1.63(0 .68)	1.65(0 .63)	1.59(0. 52)	1.55(0 .50)	0.05	2.005 (0.64)	1.84 (0.70)	1.67 (0.37)	1.55 (0.56)	1.57 (0.60)	0.000	0.783	0.57

to state repetition of squares correctly, they were excluded from implicit group and included in the explicit group instead.

The procedure in explicit group was similar to that in implicit motor teaching group with the difference that repetition pattern of squares and arrangements of sequences and blocks were previously explained to the children. In this case, in the first block, arrangement of the emergence of colors was placed besides them in drawing form and was then removed. Individuals in this group were asked to press the relevant button for every square. They were asked to do this with more speed and accuracy and the drawing could show which colors appeared, respectively.

Data analysis
Data was analyzed using SPSS (v. 18). After comparing distribution of the variables with normal theoretical distribution using Kolmogorov-Smirnov test and making sure about normality of the distribution, to analyze dependent variables in test steps, Repeated Measure Analysis of Variance was run. In irregular steps, squared t-test was run to compare dependent variables. In order to evaluate specific effect of learning, squared t-test was run between relevant data of regular and irregular steps.

Results

The mean value and standard deviation of the data related to participant's demographic information are presented in Table 1. Also, obtained results from squared t-test and repeated measure analysis of variance in 4 studied groups are provided in Tables 2 and 3.

Implicit motor learning in motor sequence for ADHD group
Error reduction: Based on the results from repeated measure analysis of variance in ADHD implicit group, the difference between errors in regular steps was not found to be significant (*P*-value=0.094). Squared t-test in irregular sequences was observed to be insignificant, too (*P*-value=0.838) indicating that ADHD children had the same errors regarding regular sequences of implicit motor learning.

Reducing reaction time: No significant difference was found between reaction times in regular steps in implementing the sequence of ADHD implicit motor learning (*P*-value=0.954). The squared t-test was not observed to be significant for reaction time in irregular sequences either (*P*-value= 0.216).

Explicit motor learning in motor sequence for ADHD group
Error reduction: Based on the obtained results from repeated measure analysis of variance in ADHD implicit group, the difference between the number of errors in regular steps was found to be statistically significant (*P*-value=0.012), but the squared t-test in irregular sequences was not significant (*P*-value=0.510).

Reducing reaction time: The difference between reaction times in regular steps in implementing sequence for this group was not found to be significant (*P*-value=0.012), neither was the squared t-test obtained for reaction time in irregular sequences (*P*-value=0.147).

Comparing explicit and implicit learning of motor sequence
The main effect of the block on accuracy of learning showed no significant difference between the two groups (*P*-value=0.006) although the main effect of the type of learning on accuracy revealed insignificant difference (*P*-value=0.844). In addition, the main effect of the block in learning speed has showed statistically significant difference (*P*-value=0.009), although the main effect of the type of learning on speed was not significant (*P*-value=0.431). Comparing irregular steps (blocks 2 and 6) did not reveal a significant difference with regard to accuracy (*P*-value=0.512) and speed (*P*-value=0.734) either.

Discussion

The results obtained in the present study indicated that, in ADHD group, explicit motor learning was achieved and there was no significant difference between this group and their normal peers. Motor performance of this group was not improved with practice in irregular blocks, which was not significantly different from that for the normal peers. The results have been consistent with studies reported by Watanabe *et al.* with regard to investigating motor visual explicit learning of sequences on 17 children using an instrument named 2*10 (17).

However, due to the inconsistency in samples of Watanabe *et al.* in terms of IQ, their results should be used cautiously. Our results are in consistence with those reported by Karatekin *et al.* too. They investigated implicit and explicit learning for motor sequence in ADHD people with the age range of 8-19 using Serial Time Reaction Task, and explicit learning of motor sequence in ADHD children was observed to be perfect (13).

Involved cerebral areas in learning serial motions include cortex premotor, dorsal prefrontal cortex, and anterior supplementary motor area (17). Cerebral neuroanatomy in explicit learning is also under the effect of several subsets including activation of cerebellum, thalamus, cerebral stem, and bilateral cerebellar vermis. Visual and tongue areas are also activated in this kind of learning, which indicates using strategies in this type of learning purposefully (18). Evidence indicated that brain becomes small in cerebellum areas and cordite core in children with ADHD disorder (19) and that thickness and volume of frontal cerebral cortex reduce (20, 21), and also disorder in parietal cortex and cingulate have been reported (5). In general, it seems, that because of lack of adaptation of involved cerebral areas in ADHD disorder and involved neuroanatomic areas in explicit learning, this kind of learning in these children is a perfect learning method. According to the findings, it can be stated that using clear instructions for task details can be effective in rehabilitation process of children with ADHD and can significantly facilitate their process of motor learning.

Another finding of the present study is that implicit learning cannot occur in ADHD children, which shows shortcoming of this kind of learning in ADHD disorder, although this kind of learning happens in normal peers.

Although there was no significant difference between the two groups, it could be mentioned that such learning is imperfect for them. Motor performance in this group in irregular blocks was not improved by practice and this shows a significant difference with that in their peers. The findings are consistent with those of Barnes *et al.* who compared two types of implicit learning with each other. They studies 15 boys in the age range of 7-12 and with similar IQ and a control group with normal peers. The instruments used in their study were serial time reaction for motor serial measurement and contextual cueing for measuring spatial contextual learning (22). Their findings indicated that because of the damage to fronto-striatal-cerebellar track in ADHD group, motor serial learning is imperfect in this group, although spatial contextual learning was perfect as supported by temporal medial track. This study is significantly similar to the present study and it can be cited with more confidence. Another relevant study is the study by Domuta *et al.* on investigating implicit learning of ADHD group using artificial grammar task. Obtained results from this study have been in line with those of the present study, in that they have also considered overlap of neurologic bases of implicit learning and conducting directions in ADHD disorder as a reason for imperfection in this kind of learning (23). In this regard, the study by Karatekin *et al.* presented different results. They reported that implicit learning was perfect regarding ADHD disorder and claimed that such unexpected result has been induced by different nature of existing cognitive processes in the tasks used in the previous studies with applied processes in serial reaction time (13). In viewpoint of the researcher, involvement of different factors in this type of learning and also its multidimensional nature has been the reason for these findings that are different from those of other studies (2).

Involved cerebral areas in implicit learning include ventral premotor right cortex, right striatum ventral, right thalamus, and bilateral visual association cortex (24). Various studies in the field of ADHD indicate defects in fronto-striatal-cerebellar track (19), which covers some structures such as basal ganglia, cortex, and thalamus (24, 18). According to the present study, in order to explain results of the study in relation with other studies, one can refer to overlap of damaged cerebral areas in ADHD and neurologic base mechanisms involved in an implicit learning process.

Conclusion

In general, based on the obtained results from the present study, it seems that explicit motor learning using handedness inventory is perfect for ADHD children.

Limitations

Due to the prevalence of ADHD disorder in boys, the present study faced the problem of adjusting the number of girls and boys. To avoid extension of the period to carry out the study, we could not investigate different subtypes of ADHD, the effect of cerebral hemispheres, and the role of growth process in every type of explicit and implicit motor learning methods.

Suggestions

1- Finding subtypes of ADHD and examining them using serial time reaction,
2- Investigating the role of cerebral hemispheres in learning process, and

Investigating the role of growth process in every type of explicit and implicit learning methods.

Conflict of interest:
None

Authors' contributions:
All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

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