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The Effect of Implicit and Explicit Learning of Bimanual Coordination on Debilitating Behaviours in Autism

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Original Article

Abstract

Introduction: Disabling behaviors of autism are a prominent factor in differences with normal individuals. Therefore, the purpose of this study was to investigate the effect of implicit and explicit learning of bimanual coordination on disabling social, communicative, and motor behaviors in autism.

Materials and Methods: This was semi-experimental research. 24 patients with autism and with an average age of 10 ± 3 years were divided into three equal groups of implicit learning, explicit learning, and control, with the help of pretest Autism Spectrum Screening Questionnaire (SSRQ). The training groups performed bimanual coordination exercises for six days; the implicit learning group performed low-error learning and the explicit learning group performed full-error learning. Then, all of the subjects were re-measured using SSRQ. On the sixth day, the test was taken into account. The data were analyzed using one-way analysis of variance (ANOVA).

Results: One-way ANOVA showed a significant difference between the implicit learning group with the explicit learning and control groups (P = 0.014). This was significant for social interaction index (P = 0.019) and behavioral disorders (P = 0.002), too. However, there was no significant difference in speech disorder index (P = 0.910).

Conclusion: It is suggested that error-less learning be used to educate people with high-performance autism. In addition to benefiting from implicit learning features, we can improve behavioral and social performance.

Keywords: Autism, Explicit learning, Implicit learning, Bimanual coordination

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Introduction

Autism is a syndrome that emerges in the first three years of life in the form of abnormal quality patterns in social interactions, communication, and repetitive behaviors (autism indices) (1). The observation of different variations in sensory-motor domains, stereotypical and obsessive behaviors, social problems, and language problems, reveals a wide range of psychiatric and medical disorders in these children and its negative impact on social interactions with the peripheral world has attracted the attention of researchers to this disorder. These factors have made medical diagnosis and intervention very important (2). The present study was performed on individuals with high functioning autism (HFA) disorder. All of the disorders in these patients originated from the central nervous system (CNS) (3). In subjects with autism, the function, weight, and interaction of various parts of CNS differ with those in normal people, and the more severe these disorders, the more severe the symptoms of autism (4). One of these disorders is associated with the performance of the functional memory (5). This part of the brain is responsible for cognitive analysis in the learning process based on the Fitts learning model. That is, the person looks for an answer to the question of what to do at the beginning of the learning process and consciously examines the execution process. The Fitts learning model actually describes explicit learning (6).

Numerous studies have shown the presence of explicit and implicit learning in normal individuals. Explicit learning is referred to as acquiring or retrieving information along with the knowledge of the

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information learned so that the individual can explain it (7), however in implicit learning, information acquisition is taken place based on a rule in the environment without paying attention to learning or awareness of this rule, or without remembering how this information is acquired (6). Implicit learning has many different forms, but all of them are characterized by a decrease in the degree of CNS involvement in cognitive processes during the learning process (6).

Numerous studies have indicated the tendency of individuals with autism to solving problems and learning skills through explicit learning, however most of these studies have addressed the social and linguistic domain, and very few of them have been conducted in the motor domain, with most of which using only an implicit learning method of laboratory motor task type (using the sequence of motions) whose results cannot be generalized to other skills (4). The study conducted by Dawson et al. is one of these studies (8). By examining learning in patients with autism, they found that if they were trained using the explicit learning method, they would not be able to generalize their learning in everyday life. In contrast, they found the implicit learning to be very important in subjects with autism, albeit with some limitations (8).

Despite the knowledge of different types of implicit learning, most studies on motor learning in individuals with autism are related to the chain sequence of motions that may be due to the simplicity of this design. Therefore, using other methods to assess motor and communication learning ability seems necessary. Low-error learning refers to learning a skill with the least error; this is a new strategy in implicit motor learning programs leading to acquiring motor skills (9). As such, the execution or goal is designed very simply to be very successful in execution, so that the person pursues the least amount of mental involvement to perform the task and, as the execution progresses, gets closer to performing the original and difficult task. On the contrary, there is high-error learning that is the opposite of the pervious case. The low error-high error learning method was chosen because of the characteristics of individuals with autism and the ability to apply these two methods in daily life (10).

Motor impairments and delay in learning motor skills are common in individuals with autism. Less skill in motor activities results in less participation of these individuals (11). In fact, the emotional development of the children with autism explains how they deal with communication situations and how they interact with peers and other people, in addition to adjusting the way they control their extremist behaviors and ideals. Executional success is one of the determinants of emotional behavior, as the more successful a person is in execution, the more willing they are to engage and interact (12), demonstrating the importance of motor skills. On the other hand, coordination is very important in performing motor skills (13).

Motion coordination is defined as the "access plan of the body and organs in relation to objects and environmental events" (14). This definition consists of two parts and indicates that coordination leads to the collaboration of the body's patterns of movement or organs. Certain patterns of organ movements enable the individuals to achieve their goal (14). The second part of the definition states that the characteristics of the environmental conditions limit the body and organs in a certain way to achieve the goal. For example, the person has to adjust the patterns of movement of his body and organs with the characteristics of the path for walking along a path. This part is of importance because it specifies the need to examine and study the motor skill coordination about the situation in which the skill is performed (14).

Coordination plays a key role in communication behaviors. A communication should be proper in all aspects including speech to the use of hands, body, and head and face movements. All these factors must be in harmony with each other (13). Neurophysiology and brain imaging studies have also shown a link between motor and communication skills (4).

Problems in learning basic motor skills, which are the main cause of motor disorders in individuals with autism, may be due to the impaired coordination skills (15). Given the importance of success in motor performance for the willingness to participate in subjects with autism, the present study was conducted to explore more efficient ways to learn motor performance. To this end, taking into account the involvement of different learning strategies in both explicit and implicit learning methods, the study examines whether different learning styles are effective in improving the behaviors of people with autism, and in case of its importance, to determine which approach has the most impact on autism indicators. Moreover, the study aims to provide coaches and occupational therapists who are associated with this segment of the community with the most effective way to improve maladaptive behaviors and to avoid wasting time and costs.

Materials and Methods

This study was a non-randomized controlled clinical trial in which the participants included all children with HFA disorder who referred to Autism Center in Gonbad Kavous, Iran in 2017 for treatment.

24 children who scored 50 to 100 on the Autism Spectrum Screening Questionnaire (ASSQ) were referred by the center instructor. The study inclusion criteria were age 8 to 12 years and ASSQ score of 50 to 100. Based on similar studies (16,17) and according to Cochran's formula, 24 children aged 8 to 12 years with a significance level of 0.05 (Z = 1.96), P = 90%, and acceptable error level of 0.12, were selected as available samples. The subjects who were not willing to continue the exercise protocol or did not participate in the exercise regularly after the start of the training program were excluded, who were 2 in the present study.

Initially, the project was approved in the research council with code of ethics IR.SBU.ICBS.97/1004 from Life Sciences Research Center, Tehran Shahid Beheshti University, Tehran, Iran and registered with code IRCT20171231038156N1 on the Iranian Registry of Clinical Trials (IRCT). Then, the study objectives were explained to parents of children with HFA disorder. The parents and managers were assured that their identities would be kept confidential and their consent to participate in the study was obtained.

ASSQ was employed to identify and diagnose the severity of the autism symptoms. This questionnaire includes 27 items to assess the problems of patients with autism in three areas of "social interaction, speech delay and behavioral problems, and abnormal symbolic games", which were completed by the parents or child caregivers (17). The internal validity of the ASSQ for first to fifth grade children was 0.77, 0.65, 0.81, and 0.70 in the groups of parents of normal children, parents of children with autism spectrum, teachers of normal children, and teachers of children with autism, respectively. The test-retest reliability coefficient for the children with autism spectrum in the parent group and in the teachers group was respectively r = 0.467 and r = 0.614 (17).

At first, the severity of autism was determined for all individuals using ASSQ. The subjects with autism were divided into three groups of explicit, implicit, and control that were homogeneous in terms of severity of complication. Then, the explicit and implicit groups performed the bimanual coordination task for 6 days, each day for 30 minutes using a bimanual coordination measurement device (Padidar-OmidFarda Institute, Development and Technology Center, Shahid Beheshti University, Tehran, Iran) including two software and hardware parts. The validity and reliability of the device were reported 0.81 and 0.90, respectively (18). The subject had to use the two levers to move the red circle observed on the screen to reach point A and as soon as point A was reached, the direction of movement appeared. Using the two levers of which the right lever was moving only in the upper and lower directions and the left lever only in the right and left directions, the individual had to reach point B without colliding with the walls of the route. As soon as the red circle hit the walls, a buzzing sound was heard. The subjects had to try to cross the path in the least possible time with the least number of errors, such that the explicit group practiced the task from the difficult level (high-risk learning) and the difficulty of the task gradually reduced by completing each exercise effort (increasing range of error), while the subjects of the implicit group practiced the task from the easy level and the task difficulty increased gradually. After completing the exercise protocol, the ASSQ scale was again performed for all groups and evaluated as the study variables. One of the problems with working with subjects with autism was their motivation to perform. For this purpose, similar to the study by Pascualvaca et al. (19), chocolate and pastry bonuses were used after each successful performance, such that the sum of total bonuses was given after the protocol exercise ended.

Descriptive statistics were utilized to classify and adjust the data and calculate measures of central tendency, as well as for dispersion and group separation. The Shapiro-Wilk test to check the normality of data distribution, Levene test for homogeneity of variances, and one-way analysis of variance (ANOVA) test for differences among the groups in the pre-test and post-test stages. Finally, the data were analyzed in SPSS software (version 18.0, SPSS Inc., Chicago, IL, USA). P < 0.05 was considered as the level of significance.

Results

The demographics of the participants are presented in table 1.

Table 1. Demographic characteristics of the subjects

Variable	Group	High-error	Low-error	Control
Age (year) (mean ± SD)		10 ± 3	10 ± 3	10 ± 3
Weight (kg)		39	40	37
Height (cm)		135	140	138
Gender	Male	6	7	7
	Female	-	1	1
Dominant hand	Right	6	8	8
	Left	-	-	-

After ensuring the data distribution with the help of the Shapiro-Wilk test (P < 0.05) and homogeneity of variances with Levene statistic (P > 0.05), parametric inferential statistical methods were used for further investigation. The one-way ANOVA results showed

that there was no significant difference among the groups in the pre-test stage ($P \leq 0.991$, $F = 0.09$).

The differences among the groups at the post-test stage are presented in table 2. Given the one-way ANOVA test results, the difference among the groups was significant.

Table 2. One-way analysis of variance (ANOVA) test results to investigate differences among the groups in the post-test stage

	Sum of squares	df	Mean squares	F	P value
Intergroup	568.189	2	284.095	5.403	0.014*
Intragroup	999.083	19	52.583		
Total	1567.273	21	-		

df: Degree of freedom
*P < 0.050 intergroup differences

The Bonferroni post-hoc test was exploited to investigate these differences. Accordingly, there was a significant difference between the explicit and implicit groups ($P \leq 0.030$). Moreover, the difference between the implicit and control groups at $P < 0.05$ level was significant ($P \leq 0.080$). One-way ANOVA test was utilized to examine the subscales of the autism indices, with the results presented in table 3.

The findings revealed significant differences among the groups in the two subscales of social interactions and behavioral disorders. The Bonferroni post-hoc test was used to determine the location of these differences (Table 4). Based on the results of table 4, there was a significant difference in both subscales of social interactions and behavioral disorders between the implicit group and the explicit group ($P < 0.050$), and the implicit group indicated a significant difference with the control group only in the behavioral disorders ($P < 0.050$).

Discussion

The current study was conducted with the objective of investigating the effect of the two methods of explicit and explicit learning on autism maladaptive indexes.

For this purpose, learning the coordination skills, which is one of the problems of these subjects in the execution process, was used.

The results indicated that the subjects who practiced in the implicit learning method showed improvement in some of the maladaptive autism indices, however the results were different in the explicit group, as the maladaptive autism indices appeared to be more severe; even two of this group withdrew from the study. The findings of the present study supported the implicit learning by the low-error learning method to train the individuals with autism, indicating the effectiveness of this method in learning as well as reducing the indices of autism. The findings of the study by Dawson et al. suggested that people with autism are able to learn motor skills (8). Furthermore, Boss concluded in a study that participation in this type of activity, in addition to learning skills, leads to a decrease in maladaptive behaviors that is consistent with the findings of the current study.

Motivation and attention of children with autism is one of the most important factors in communication and education. In previous studies, using various tools and methods, such as horse riding, swimming, and other training programs, higher attention and motivation were provided for continued activity and greater communication.

One of the studies that investigated the impact of the research variable on the autism indices was the study by Boss, which examined the effect of horse riding on autism symptoms. The results of this study showed improvement in some of the symptoms of autism, including sensory sensitivity, social sensitivity, attention problems, and rhythmic behaviors. Additionally, Pan in his study addressed the effect of hydrotherapy on children with autism, and his findings, with the help of 18 occupational therapist reports, showed a significant increase in attention, muscle strength, balance, touch tolerance, initiation and maintenance of eye contact, and social participation. Moreover, children with autism and their parents became familiar with water play and the pleasure of swimming (11).

Table 3. One-way analysis of variance (ANOVA) of the subscales of social interaction, speech skills, and behavioral disorders

Subscale		Sum of squares	df	Mean squares	F	P value
Social interaction	Intergroup	45.383	2	22.691	4.944	0.019*
	Intragroup	87.208	19	4.590		
	Total	132.591	21	-		
Speech skills	Intergroup	1.008	2	0.504	0.094	0.910
	Intragroup	101.583	19	5.346		
	Total	102.591	21	-		
Behavioral disorders	Intergroup	313.443	2	156.772	8.647	0.002#
	Intragroup	344.375	19	18.125		
	Total	657.818	21	-		

df: Degree of freedom
*P < 0.050 intergroup differences in social interactions, #P < 0.050 intergroup differences in behavioral disorders

Table 4. Bonferroni post-hoc test of the subscales of social interaction and behavioral disorders

Subscale	Groups	Explicit	Implicit	Control
Social interaction	Explicit	-	-	-
	Implicit	0.029*	-	-
	Control	1.000	0.072	-
Behavioral disorders	Explicit	-	-	-
	Implicit	0.005*	-	-
	Control	1.000	0.008#	-

*P < 0.050 difference between implicit and explicit groups in social interactions, *P < 0.050 difference between implicit and explicit groups in behavioral disorders, #P < 0.050 difference between implicit and control groups in behavioral disorders

Furthermore, in an investigation, Vang investigated the effectiveness of intervention programs in improving social relationships, with the results suggesting an improvement in the relationships and consistency with the results of the present study. The common point in these studies is to draw children's attention to different ways and success of these individuals as a result of exercise and its effect on the improvement of behavior in individuals with autism which was in line with the results of the present study.

In the present study, the use of the computer and the similarity of the training protocol to the computer game were intrinsically enjoyable for these individuals, and the combination of the game with successful efforts in the low-error learning group provided more motivation for these individuals, as noted in the study by Boss and Pan (11). According to Abbasi et al., the main factor in children's close communication is an emotional tool in a supportive atmosphere that is not pursued by guilt, which, together with increased communicational, social, and interactive skills, enables the children to organize broad relationships in positive ways and consequently, a significant increase in social acceptance during and after the treatment sessions will not be unexpected (21).

In the high-error group, because of the low level of success in initial efforts, there was a poor initial impact on these individuals and less motivation to continue their activity. Motivation and passion were the same factors that were emphasized in the study by Lara et al. exploring the therapeutic modalities of movement in inndividuals with autism (27). Dance and music are a very enjoyable process that everyone loves and sooner or later everybody communicates in this way verbally and non-verbally. Even children with low-functioning autism (LFA) start communicating because music and dance are inherently enjoyable and provide high motivation to participate in motor activity and communication.

The findings of the study by Piek et al. indicated that children with high social and communication skills and abilities are likely able to cooperate and play with peers and that the communication of children with poor motor skills is not as good as that of more skilled children and they have higher levels of anxiety and lower self-esteem. The positive relationship between the motor skill and social skill can be explained by the multi-factor approach that creates a cyclic nature in the perception-action-cognition evolution. A child needs a complete set of functional activities to engage in social interactions, and poor coordination and specific movements of the child with autism have a negative impact on their social participation (22). An example of a child with autism spectrum disorder is that uncoordinated and slow head movements can influence the actions of timely head rotation, reaching, pointing, giving and pointing to an object, which are important issues in response to social interactions with others (12).

Another important point in the present study was that in order to perform the coordination skill, the subject had to first direct the indicator to the starting point using the two levers then reach the end point by moving on the route. This beginning-continuing-ending process is very important because children with autism are unable to understand this factor, which cause problems such as rhythmic and hyperactive movements in them. This principle was in line with the study by Lara et al. (27), in that individuals had to start and end dance from the predicted locations (27). Explaining the above findings, it can be stated that when a child with autism faces many challenges at the beginning of the learning process and is unable to control them, his emotions are not organized in accordance with his level of emotional and functional development. Moreover, in this process, the child faces difficulties in experiencing pleasure, happiness, and curiosity, in addition to encountering challenges in the expression of a range of emotions and ideation about them, as well as impulse control, and then the level of inhibition reaches its lowest level, resulting in repetitive rhythmic patterns.

One of the three indices of autism is behavioral problems and abnormal rhythmic motions that are measured in SSRQ. Rhythmic movement is one of the major problems in these individuals, as it can lead to disapproval of children from the community and exclusion from the classroom; this is one of the most prominent symptoms of autism (5). In their study, Lara et al. stated that emphasizing the beginning-continuing-ending process in each session and exercise challenges

the brain of children with autism and leads their brains to wake up (27). The training protocol used in the present study also benefited from the same factor, so that the mark had to be directed to a specific location in order to begin each attempt. It then received the start permission and followed a specified route and reached the end point, which indicated the end of the attempt (the starting and ending points as well as the route were fixed and predetermined). One of the most important principles in social relations is that people should know that relationships must start somewhere (start of the conversation with a subject) and end somewhere (end of the speech) and avoid repetitive and vain speech that is one of the types of rhythmic movements in these people. In this regard, the results of the present study are in agreement with and support the findings of the study by Lara et al (27).

Given the results of the present study, there was a significant difference between the implicit group and the explicit and control groups in rhythmic movements. The individuals who practiced in the low-error learning method showed an improvement in the behavioral index as a result of the exercise variable, whereas these symptoms intensified in the high-error group, consistent with the findings of the studies by Harvey et al. (23), Lang et al. (24), and Liu et al. (5). As stated previously, motivation is very important for the performance and participation of children with autism, but the high-error group was less motivated to continue the activity because of failure in the early efforts, what that Lara et al. believed to be the advantage of music (27). In fact, the severity of symptoms in subjects with autism as a result of explicit learning may be due to less motivation and desire to continue the activity. Duffy et al. in a study reported no improvement in rhythmic motions due to physical activity (25), which was consistent with the findings of the explicit group in the present study.

Relationship is another subscale examined in SSRQ. In general, human communication with each other is a dynamic, reciprocal, and social relationship, and social communication is the basis of social life, besides without social interaction, the foundations of collective life do not form. Human, as a social being, manifests social tendencies since birth. The need for security through caretakers (parents) may be the first indication of one's need for external factors. One of the prominent features that distinguishes human beings from animals is not only the ability of humans to think, but the ability to know how to think and what to think, and even though there are some commonalities between humans and some animal species, socialization is more important. By combining these two characteristics together, a concept known as "social cognition" can be constructed which plays an integral role in establishing social relationships and successful and productive interactions with others.

Social interaction is another indicator examined in autism and is defined as social behaviors acquired that enable one to interact with others in a way that evokes their positive reactions and prevents their negative reactions (26). The scores of this index showed a decrease in maladaptive behaviors in the implicit group and an increase in the disorders of this index in the explicit group. The findings of this study indicated a significant difference between the implicit group and the two groups of explicit and control. Additionally, the results of the low-error learning group were in line with the findings of the study by Lara et al., which discussed the importance of the starting point. They suggested that this point in life indicate the starting point for other work (27). Every relationship has a starting point and an ending point. The actual or unrealistic point can be an order to awakening the brain to take steps, for instance, questions like where is your place? Or where can we start to solve this problem? The starting point factor is generalizable to daily life and is very helpful in solving social and communication problems. With this knowledge, children can initiate a relationship themselves (27).

Language skills are among the skills that are widely developed by implicit learning processes and so individuals learn their mother tongue (6); speech problems in subjects with autism are other well-known indicators. If the implicit learning path is assumed to be intact, this defect cannot be explained, and given the assumption of different paths in implicit learning, this disorder may be related to other implicit learning paths that may require further investigations in this area or it may be due to the effect of another skill, such as speech coordination. Despite the high importance of coordination in speech and communication with the outside world in individuals with autism (28), this index has not been affected by the study variables in any group, indicating that speech is independent of and not influenced by bimanual coordination motor learning methods. This finding is in agreement with the results of the studies by Lang et al. (24) and Mortimer et al. (20) and did not coincide with the findings of the studies by Duffy et al. (25) and Lara et al. (27) who reported an improvement in speech. Furthermore, this cannot be justified by the intact implicit learning path, which is

probably due to the overlap of brain processes in implicit and explicit learning. Problems with language learning in individuals with autism may not be related to the implicit learning ability, but rather to their ability to apply this process in everyday life and they may not be able to use whatever they learn (29).

Limitations

The number of samples in the present study matched that of many previous studies with an acceptable error level of 0.12, but more samples are suggested to be used in future studies to compare the results.

Other limitations of this study include lack of control over medication and its time of use by the subjects with autism, as it was not possible to prevent medication during the study period. Moreover, drug use times throughout the day varied in patients with autism, depending on the physician's diagnosis, and there was no control over this. Lack of control over the subjects' nocturnal sleep was another limitation of the study, as the nocturnal sleep is of great importance due to its effect on the learning process (30).

Recommendations

The findings in this study showed that low-error learning style is more useful in education because it is more compatible with the characteristics of people with autism. Therefore, it is suggested that further studies be carried out with different tasks to speak more confidently in this regard. Since there are many different types of implicit learning, it is better to use other types of implicit learning to examine the usefulness of this learning in other ways.

Conclusion

The results indicated that individuals with autism are more likely to benefit from the low-error implicit learning method. These people, while learning the skills using the low-error learning method, showed improvement in the two maladaptive autism indices (socio-communication and motor problems), but the speech index was not improved. However, in the subjects who used the high-error explicit learning method, there were no improvements in the autism indices. As a result, it is better to use the low-error learning to train subjects with autism.

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Authors' Contribution

Benyamin Ghelichpoor: Study design and ideation, manuscript arrangement, sample collection, data collection, expert manuscript assessment in scientific concepts, support and execution services, final approval of the study to submit to the journal, responsibility to maintain the study integrity from beginning to end, and responding to referees' comments; Behrouz Abdoli: Study design and ideation, expert manuscript assessment in scientific concepts, final approval of the study to submit to the journal; Alireza Farsi: Analysis and interpretation of results, expert manuscript assessment in scientific terms, providing study equipment; Rzieh Jorjani: sample collection, support and execution services, data collection.

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Conflict of Interest

The authors declare no conflict of interest. Benyamin Ghelichpoor has been a PhD student at the School of Physical Education, Shahid Beheshti University of Tehran since 2018. Behrouz Abdoli and Alireza Farsi are faculty members of Shahid Beheshti University of Tehran and Rzieh Jorjani is a physician at Gonbad Kavous Health Center.

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