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Original Article

The Durability of the Effects of Analogy-Based Training on Learning Sports Skills in Individuals with Autism Spectrum Disorder Under Conditions of Fatigue and Stress

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ABSTRACT: Analogies help learners grasp new concepts by relating them to familiar, similar concepts. The aim of this study was to investigate the effects of analogy learning and explicit learning on javelin-throwing performance in individuals with ASD and compare the effectiveness of both methods. This quasi-experimental study employed a pretest-post-test design with one control group. Ethical approval was obtained from the Research Ethics Committee of the relevant University and the Iran Autism Center. Written consent was provided by the participant's parents. Thirty-six individuals with ASD from the Iranian Autism Association were selected via convenience sampling. After meeting the study's inclusion criteria, participants were assigned to one of three groups: analogy learning (n=12), explicit learning (n=12), and control (n=12). The inclusion criteria included participants aged 15-30 years, a diagnosis of ASD based on the Diagnostic and Statistical Manual of Mental Disorders, 5th edition, IQ above 50, and the ability to follow instructions. The study was conducted in an indoor gymnasium. Participants in the experimental groups attended five training sessions, each consisting of three blocks of 15 trials with 2-minute rest intervals. The control group only participated in the measurement phases. Participants in the analogy learning group watched a video of swordsmanship movements and were instructed to throw a spear. Those in the explicit learning group watched a video of javelin throwing and followed the video instructions. The control group received no instruction and threw the spear using their own methods. Throwing distance was recorded as the dependent variable, and data were analyzed using mixed analysis of variance with repeated measurements and one-way ANOVA in SPSS, with a significance level of 0.05. One-way ANOVA results showed that both the main effect of time and the interaction of time and group were significant. A significant improvement in performance was observed in the experimental groups, indicating that analogy learning is a feasible method for individuals with ASD to acquire new motor skills. The analogy learning group outperformed the explicit learning group. Analogy learning proved more effective in motor learning for children with ASD compared to explicit learning. This finding holds significant implications for teachers and coaches working with individuals with ASD, especially given the participants' tendency toward visual learning. It suggests the value of using videos and applications that incorporate analogy instruction to help individuals with ASD acquire new motor skills. Further research is needed to explore different types of video modeling and the long-term effects of analogy learning.

KEYWORDS: Analogy learning, Explicit learning, autism spectrum disorder.

1 Introduction

Autism Spectrum Disorder (ASD) is considered a behavioral and neurological disorder of unknown origin, typically appearing before the age of three. It is characterized by three primary challenges: qualitative impairment in social relationships, difficulties in communication and language, and repetitive or stereotypical movements. However, the challenges faced by individuals with ASD are not necessarily limited to these aspects (1,3). ASD has the highest rate of developmental disorders in the United States. According to published statistics, one in eighty-eight children has ASD, reflecting a 23% increase compared to 2009 (4,7). Nevertheless, varying statistics have been reported (7), and there are no precise and documented statistics available for Iran. Although the core diagnostic criteria for ASD are based on deficits in social communication skills (5,8,9), motor impairments are also common among individuals with this condition (10,11). While motor development deficits are not part of the diagnostic criteria for ASD, they can serve as early indicators of abnormal development (10,13). Motor challenges include delayed motor skills, abnormalities in gait, difficulties in gross and fine motor coordination, problems with postural control, balance, and imitation (14,17). In other words, individuals with ASD, especially compared to typically developing individuals, are more likely to experience difficulties in motor skill development and movement execution speed (18).

In recent years, extensive efforts have been made to improve the functioning of individuals with ASD. Due to the negative consequences associated with pharmacological and behavioral interventions, increasing emphasis has been placed on cognitive-behavioral interventions. Various studies have reported different outcomes regarding the effectiveness of such interventions. As a result, recent research efforts have focused on addressing methodological weaknesses and overcoming temporal limitations in implementing cognitive-behavioral interventions to demonstrate their efficacy in controlling ASD-related symptoms and improving the quality of life, motor performance, and behavior of children with ASD (8,9,22). Consequently, recent research in the field of motor behavior has explored different sports, motor, and physical education approaches to enhance the physical, emotional, and behavioral status of children with ASD. These studies have examined different methods of motor, sports, and behavioral training. For instance, Ghayour Najafabadi (2017) found that selected SPARK exercises improved balance and bilateral coordination in children with ASD (22). Amel et al. (2018) showed that a six-month sensory-motor integration program improved both gross and fine motor skills in children with ASD. Similarly, Lee and Porta (2013) demonstrated that water-based exercises could enhance the fundamental motor skills of children with ASD (23). Al-Shami et al. (2018) examined the impact of movement interventions incorporating auditory rhythms on individuals with ASD and found that such interventions improved motor proficiency (20). Rafiei et al. (2017) also confirmed the effectiveness of sports interventions in enhancing gross motor skills in individuals with ASD (21). Based on existing research, it appears necessary to focus more on sports and motor skills that can contribute to improved social interactions and motor skills in individuals with ASD. For example, teaching a sport can enhance self-esteem and social development in children with ASD, thereby achieving both the goal of improving perceptual-motor abilities and enhancing their psychological and social competence (9,24,25). Therefore, this study aims to focus on teaching a sports skill to enable individuals with ASD to expand their psychosocial capacity through participation in physical and motor activities.

Considering the various interventions studied to enhance the perceptual-motor abilities of children with ASD, an important aspect in teaching sports skills to these individuals is ensuring they can apply the learned skills under challenging physical and psychological conditions such as fatigue and stress. The durability of learned skills in individuals with ASD has been largely overlooked. A recent study on typically developing individuals suggested that one method for maintaining learning in challenging conditions was implicit learning while avoiding explicit instruction (26,27,31). The Reinvestment Theory explains that performance decline under stress or other challenging conditions occurs when explicit knowledge related to the skill or task is consciously processed, disrupting automatic movement control (28). Therefore, adopting methods that steer learners away from conscious and explicit processing may help sustain skill execution under difficult physical and psychological conditions.

One such teaching method is analogy learning, where instead of providing explicit instructional guidelines, the coach compares the new skill to a simple and familiar one that the learner can easily understand and apply. Analogy learning is recommended by motor learning scientists to facilitate the acquisition of new skills. In general, analogy learning is a less prescriptive approach where information transfer is not explicit (30,32). Analogies are typically used to help learners grasp new concepts without explicit instruction by linking them to a fundamentally similar concept (33). In a study comparing analogy learning with explicit learning, Andy and Masters (2019) concluded that analogy learning (especially through observation) was more effective for children with ASD (34). While some studies have observed benefits in both explicit and analogy learning, others have found no significant effectiveness. For example, Lia and Masters (2001) showed that learners who acquired a table tennis forehand topspin shot using an analogy demonstrated more stable performance under stress compared to those who learned through explicit instructions (30). Given the advantages of analogy learning and the fact that individuals with ASD generally experience higher levels of stress and fatigue (35,36), this method may help maintain the effects of sports skill training for these individuals under challenging physical and mental conditions such as fatigue and stress.

Thus, the present study aims to answer the question of whether analogy learning can prevent the decline of motor performance under physically and mentally demanding conditions in individuals with ASD.

2 Methods

2.1 Participants

This study employed a pre-test and post-test design with two experimental groups and one control group. The participants consisted of 36 individuals (7 females and 29 males) aged 15 to 30 years with autism spectrum disorder (ASD) who were members of the Autism Association of Iran at the time of the study. To confirm their ASD diagnosis, all participants had undergone prior interviews. The diagnostic criteria for ASD were based on the DSM-5 (American Psychiatric Association, 2000), and the final confirmation of ASD diagnosis was validated by a neurologist's report approved by the Autism Association of Iran.

The inclusion criteria for participation in the study were having ASD, an average or above-average intelligence quotient (IQ), and good physical health and posture. The exclusion criteria included having a comorbid disease, cognitive disorder, learning disability, severe sensory problems, visual impairments, mobility restrictions, and prior experience in targeting and throwing sports such as javelin throw and discus throw.

2.1 Measurement and Tools

The tests were conducted in an indoor sports hall. For the javelin-throwing task, a one-meter-wide and 20-meter-long path was designated on the floor to guide participants in executing their throws. A 30-second instructional video demonstrating javelin throwing was prepared and shown at the beginning of each session to the explicit learning group. Similarly, a 30-second fencing video was shown at the beginning of each session for the analogy learning group. The javelin used in this study was a plastic model weighing 500 grams for males and 300 grams for females, with a length of 120 cm and a diameter of 2.5 cm. A toy sword, weighing 100 grams with a length of 70 cm and a diameter of 3 cm, was used for the analogy learning group to simulate the skill.

To assess and analyze participants' qualitative performance, their javelin-throwing executions were recorded using a Samsung S6 smartphone, and evaluations were conducted based on predetermined criteria. The quantitative measurement of the javelin's travel distance was performed using a measuring tape.

A measuring tape with an accuracy of 0.5 cm was used to measure the throwing distance. The quality of javelin-throwing performance was assessed using a checklist evaluation form. Each item on the form was rated from 1 to 10 by an expert coach, and the total score was considered the final skill execution quality score.

Before the training sessions, participants' parents signed consent forms, ensuring that they could withdraw from the study at any time without consequences. Participants were assured that no harm or injury would occur during the study. Confidentiality of all information, videos, and data was guaranteed, and the potential benefits of the study were explained.

2.3 Implementation Method

2.3.1 Training Period (Pre-Test, Training Sessions, and Post-Test)

In the first session, a pre-test was conducted to ensure group matching. Participants were instructed to throw the javelin for three rounds (15 attempts per round, totaling 45 attempts). The rest interval between each round was two minutes. The average javelin throw distance in the third round was recorded as the final pre-test score for each participant. Based on these pre-test scores, participants were randomly assigned to three groups: analogy learning (n=12), explicit learning (n=12), and control (n=12).

Participants in the analogy learning group observed a fencing model. According to Liao and Masters, an analogy model should be a simple biomechanical metaphor encompassing all rules and dimensions of the primary skill (8). This analogy should also align with the learners' culture and language; otherwise, an inappropriate analogy could lead to poor learning and performance. Therefore, the fencing model was designed as a simple and concise representation of the javelin-throwing skill, rooted in the participants' cultural background, as they had practiced fencing in childhood (8). The analogy learning group attempted to execute the javelin-throwing skill similarly to the fencing video.

Participants in the explicit learning group watched a video of a professional performing a javelin throw and were instructed to replicate the technique precisely as shown. The control group received no instructions (neither analogy nor explicit) and participated only in the pre-test, post-test, transfer, and retention tests. They were instructed to throw the javelin as far as possible using their preferred movement pattern.

2.3.2 Acquisition Phase

Participants trained for four sessions. During these sessions, they completed three rounds of 15 javelin throws each (totaling 45 attempts). The rest interval between each round was two minutes. At the end of the fourth session, the average score from the third round was recorded as the post-test score.

Retention Test: To eliminate temporary training effects, a retention test was conducted 48 hours after the post-test. Participants were required to perform 15 javelin throws. The average throwing distance was recorded as the final score for each participant. Their javelin-throwing performances were also recorded for qualitative assessment.

2.3.3 Transfer Test

To examine the sustainability of skill changes under fatigue and stress conditions, a transfer test was conducted. No instructions were given in this session; participants were simply asked to perform 15 javelin throws under fatigue and stress conditions. To induce fatigue, participants performed 20 minutes of aerobic exercises, including slow running, jumping, and dribbling (soccer for boys and basketball for girls). To introduce controlled stress, parents, who had been present during training sessions, were asked to leave the sports hall for a few minutes during the transfer test. Additionally, financial incentives, such as cash prizes, were offered to top performers based on accurate throws. The final quantitative score was the average javelin-throwing distance, and qualitative execution was assessed through recorded footage.

The present study was approved by the Ethics Committee of the Institute of Physical Education and Sports Science. Parents of participants signed written consent forms. Due to COVID-19 conditions, all health protocols were strictly followed during the study. Researchers and participants wore masks during all procedures and tests. Regular disinfection of equipment and study materials was performed. At the conclusion of the study, all participants were rewarded with gifts in appreciation of their participation.

2.4 Statistical Analysis

The collected data on javelin throw distance across measurement phases (pre-test, acquisition sessions, and post-test) were analyzed using a mixed-design ANOVA: 3 (experimental groups: analogy-explicit-control) × 5 (acquisition blocks: pre-test to post-test) with repeated measures on the latter factor. Additionally, data on the quality of skill execution during the pre-test and post-test were analyzed using a mixed-design ANOVA: 3 (experimental groups: analogy-explicit-control) × 2 (pre-test-post-test) with repeated measures on the pre-test-post-test factor. Group comparisons in the transfer test under stress conditions were conducted using one-way ANOVA and Tukey's post hoc test in SPSS version 21, with a significance level set at $p<0.05$.

The dependent variable data were analyzed in two categories: quantitative and qualitative. The quantitative data included the recorded distances of javelin throws, with descriptive statistics presented in Table 1. Additionally, the qualitative performance analysis of javelin throws during the pre-test, post-test, and transfer phase under fatigue and stress conditions is also provided in Table 1.

Table 1. Javelin Throw Distance Across Different Measurement Phases from Pre-Test to Transfer Test Under Fatigue and Stress Conditions

Measurement Phase	*Pre-Test*	*Day 2*	*Day 3*	*Day 4*	*Post-Test*	*Transfer Test*
Analogy Learning Group	4.58±1.11	4.81±0.85	5.26±0.92	5.70±0.89	6.63±1.20	5.87±0.82
Explicit Learning Group	4.62±0.86	4.90±0.85	5.30±0.68	5.55±0.88	6.12±1.15	3.93±0.59
Control Group	4.56±0.91	4.18±0.75	3.86±0.37	3.99±0.40	4.15±1.02	2.62±0.86

The results of a 3 (experimental groups) × 5 (acquisition phases) mixed ANOVA with repeated measures on the latter factor indicated that the main effect of acquisition blocks was significant [$F(4,132) = 24.006$, $p < 0.001$, $\eta^2p = 0.42$]. Additionally, the main effect of the group was significant [$F(3,33) = 13.543$, $p < 0.001$, $\eta^2p = 0.45$], indicating differences in performance among groups. This was further confirmed by the significant interaction effect between group and acquisition blocks [$F(8,132) = 16.040$, $p < 0.001$, $\eta^2p = 0.49$], suggesting that the groups followed different trajectories of improvement (Table 2).

Table 2. Performance Quality of Groups Across Different Measurement Phases from Pre-Test to Transfer Test Under Fatigue and Stress Conditions

Measurement Phase	*Pre-Test*	*Post-Test*	*Transfer Test*
Analogy Learning Group	4.58±1.11	6.63±1.20	5.87±0.82
Explicit Learning Group	4.62±0.86	6.12±1.15	3.93±0.59
Control Group	4.56±0.91	4.15±1.02	2.62±0.86

3 Results

The results of the mixed 3 (experimental groups) × 2 (pre-test–post-test) ANOVA with repeated measures on the within-group factor showed that the main effect of time was significant [$F(1,33) = 456.006$, $p < 0.001$, $\eta^2p = 0.93$]. Additionally, the main effect of the group was also significant [$F(2,33) = 594.431$, $p < 0.001$, $\eta^2p = 0.86$], indicating a notable difference between the groups regardless of the measurement phase. Moreover, the interaction effect between the group and the measurement phase was significant, reflecting the different patterns of change from the pre-test to the post-test across **groups** [$F(2,33) = 7.618$, $p = 0.002$, $\eta^2p = 0.31$].

The comparison of group performance in the transfer test under physically and mentally demanding conditions revealed significant differences between the groups in both the throwing distance variable [$F(2,33) = 63.461$, $p < 0.001$] and the throwing quality variable [$F(2,33) = 56.97$, $p < 0.001$]. The results of Tukey's post-hoc test showed that in both variables, the analogy learning group outperformed the explicit learning group, and the explicit learning group performed better than the control group (Table 3).

Table 3. Comparison of Quantitative (Throwing Distance) and Qualitative (Throwing Quality) Performance of Groups in the Transfer Test Under Fatigue and Stress Conditions

		Throwing Distance			*Throwing Quality*		
	Group J	*95% Confidence Interval*			*95% Confidence Interval*		
Group I		*p*	*Upper Bound*	*Lower Bound*	*p*	*Upper Bound*	*Lower Bound*
Analogy Learning Group	***Explicit Learning***	0.001	2.407	0.928	0.001	8.510	17.330
	Control Group	0.001	2.657	4.137	0.001	14.340	23.360

Explicit Learning Group	***Control Group***	0.001	2.469-	0.989-	0.007	1.420	10.240

5. Discussion and Conclusion

This study aimed to examine the impact of the analogy learning method on the retention of motor learning under fatigue and stress conditions in individuals with autism spectrum disorder (ASD). The findings showed that the analogy learning method significantly outperformed explicit instruction in terms of the quality and outcome of the javelin throwing skill. A comparison of the performance of the analogy and explicit groups under challenging physical and psychological conditions revealed that individuals with ASD who had learned the skill using the analogy method were able to maintain their performance improvements more easily under these difficult conditions. Their performance remained stable and consistent under stress. The relative superiority of the analogy learning group during the acquisition phase confirmed previous findings (34, 37). The reliance of individuals with ASD on observational learning (38, 39) could be one potential reason for this outcome. The literature in this field consistently shows that individuals with ASD perform better in non-verbal problem-solving tasks than in verbal reasoning, and they have a relative advantage in visual-spatial encoding over auditory processing (20, 40). Individuals with ASD appear to learn motor skills more effectively through comparison, using visual information and perception rather than explicit instructions.

The stability of the learned skill performance in the analogy group under difficult conditions was noteworthy, as the explicit learning group was unable to maintain their performance under such conditions. This suggests that the analogy method offers resistance to fatigue and stress conditions for individuals with ASD. The robustness and consistency observed in the quantity and quality of performance under challenging physical and mental conditions support the tangible and lasting effectiveness of the analogy-based approach to teaching motor skills to individuals with ASD. Although this superiority was somewhat evident during the acquisition phase, it became more prominent during the transfer phase, meaning that the differences between the analogy and explicit groups were more pronounced in the transfer phase compared to earlier stages. A comparison of effect sizes in the inter-group changes suggested that this finding significantly differed from the results of Tess and Masters (2019), who found no clear differences between groups in the acquisition phase (34). Based on these findings, it could be argued that the consolidation of retention (i.e., the period of inactivity after acquisition) in the analogy group was more firmly established, with performance scores showing less decline compared to the explicit learning group. In contrast, declines in performance under fatigue and stress conditions have been observed in regular individuals when learning sports skills based on vision (41). Nevertheless, the differences, as well as the larger effect size observed in the current study between groups in the transfer and retention phases, suggest that analogy learning can effectively induce motor learning benefits (e.g., robust performance in retention and transfer) for individuals with ASD, particularly considering the visual nature of the task. Although it is believed that verbal analogy learning may stimulate implicit motor learning, which requires less conscious processing (30, 42), it appears that through implicit learning, individuals can gain benefits from motor skill training (31, 43, 44). However, verbal processing still demands phonological resources from working memory (28, 37, 42). Previous studies have shown that verbal working memory capacity in children with autism is generally limited in retaining and monitoring goal-related information, while the present task was visual, and learning occurred through visual analogy, making this advantage more pronounced.

The study had some limitations, the first of which was the limited number of participants, all of whom were individuals with ASD from both genders. Given the cultural characteristics in Iran, it might have been better to include only male participants in the analogy group, considering that boys likely have more experience with the sword fighting game compared to girls. Furthermore, it is suggested to use slow-motion instructional videos, allowing learners to choose the speed at which they wish to view the motor skill (slow or normal). Additionally, instructional videos should display the skill from various angles, and the learner should have the option to choose the angle at which they wish to view the motor skill. It is also recommended to compare observational analogy learning using both video models and live models.

Based on the findings of this study, it can be concluded that teaching motor skills to individuals with ASD using the analogy learning method may be a viable approach. Physical activity, under normal circumstances, is associated with some stress, so a method that helps maintain the changes made is necessary. Furthermore, individuals with ASD tend to experience fatigue sooner than typical individuals due to muscular weakness. Therefore, methods that help strengthen performance against fatigue are valuable, and the analogy learning method appears to be somewhat effective in this regard according to the present study.

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