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The Effect of Internal and External Attention on Gaze Behavior and Skill Learning During Observational Learning in Children with Autism Spectrum Disorder: An Eye-Tracking Study

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Abstract

Background: Autism is one of the most common disorders in children. Children with autism have difficulty with many motor skills. This study aimed to investigate the effect of internal and external attention on gaze behavior and skill learning in children with autism spectrum disorder.

Methods: A total of 40 children with autism spectrum disorder were selected to participate in this study. The subjects were randomly divided into two groups: external attention and internal attention. Motor function and gaze control (quiet eye duration) were evaluated before and after observation exercises. Observation exercises included ten viewings of observation clips manipulated in the form of gaze behavior in each attention group (internal/external signs) during observation. To ensure the adherence of the participants' visual attention to the given instructions, the gaze behavior of these subjects while watching the video clips was examined using eye tracking.

Results: The results showed that the external attention group had better performance and longer quiet-eye duration than the internal attention group ($P \leq 0.05$).

Conclusion: Providing educational instructions to promote external attention in the form of gaze facilitates the effects of observational learning for the cognitive-motor improvement of autistic children.

Keywords: Modeling, Internal and external attention, Gaze behavior, Autism, Children

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Introduction

Autism spectrum disorder is a behavioral and neurological disorder of unknown origin that usually appears before the age of three. The three main indicators of this disorder include qualitative defects in socialization, defects in communication and language, and repetitive and stereotyped movements. However, the defects and problems of people with autism are not necessarily limited to the mentioned items (1). Various efforts, including traditional interventions, have been made to improve the lives of children and adults with autism. Traditional interventions include speech therapy, occupational therapy, and treatments based on sensory integration alongside regular education, which is common for other children (2). Many researchers have tried to introduce the most optimal method for addressing these disorders. These researchers have investigated various methods, including behavioral therapy, cognitive-behavioral therapy, and stimulant drugs. In addition, other treatment methods, including play therapy, relaxation, and non-stimulant drugs, have also been investigated (3,4). Nowadays, it is well known that the side effects of drugs and medical interventions can have negative consequences for the people undergoing these interventions. Additionally, due to the negative consequences of pharmacological-behavioral interventions, a growing emphasis has been placed on cognitive-behavioral interventions, one of the most important of which is modeling.

One of the problems of children with autism spectrum disorder is the difficulty in imitating the behavior of others (5). However, in the research literature on autistic children, it has been emphasized that these children can learn a new skill through observational learning as a cognitive-behavioral method (6). Through observation, the general rules of behavior are formed, and this information will be coded and will become a pattern of behavior in the future (7). Therefore, observing a model teaches subjects what to do before doing anything. This enables them to save time and effort (8). Research on individuals without disorders has shown that observational learning can be suitable for teaching motor skills (9). While limited, existing research on observational learning of motor and non-motor skills in children with autism spectrum disorder has shown the effectiveness of this method (10-17).

Integrating attentional cues is very effective in observational learning. A learner can easily become overwhelmed, not knowing which information to focus on. Attention to the most critical aspect of the skill has been found to increase the use of observational learning (18). Several studies have investigated different cue paradigms to facilitate observational learning (18-20). For example, Janelle et al found that learning a soccer pass was facilitated when video modeling was used in addition to verbal and visual instructions rather than video modeling alone (20). Singer et al investigated the prediction accuracy and reaction time of a simulated tennis shot after rapid mental and physical training. Both groups watched videos on the tennis serve technique. Verbal cues about aspects related to anticipation were provided to the mental speed group, whereas no verbal cues were provided to the physical speed training group. The results showed that verbal cues improved both reaction time and prediction in average tennis players (21). Finally, in two consecutive studies, Asadi et al showed that verbally providing external attention instructions during modeling led to better gaze and movement performance in children with normal development and autism spectrum disorders (10,19).

In addition to verbal cues in observational research, visual cues can direct the learner's attention to relevant aspects of the skill. Eye movement patterning was investigated in an experiment by Jarodzka et al, in which the gaze behavior of an expert model was examined on videos that learners watched (22). The subjects who watched these films on gaze behavior showed better search behaviors in a novel task than a control group who only watched films without eye movements (22). Therefore, presenting gaze behavior allows subjects to learn strategies highlighting critical movement areas (20).

Recent research has emphasized the relationship between gaze behavior and motor performance in two main areas of research. The first area examines the differences related to the gaze behavior of skilled and novice performers. Most of these studies have shown that skilled performers exhibit a more optimal visual search pattern than novice performers (23). The research has also shown that the optimal gaze pattern is more likely to be used compared to suboptimal patterns (24). Mann et al.'s research showed that fewer fixations with longer durations have been considered optimal gaze patterns, leading to better motor performance (23,25). A second area of research has examined the "quiet eye," defined as the final fixation point of gaze before the critical phase of movement begins. The quiet eye period must last at least 100 ms and remain within 3 degrees of visual angle from the intended target. Research has consistently shown that longer quiet eye durations are associated with better performance (26). In addition, skilled performers have been found to show a longer dwell period than novice performers (23,26,27).

Although researchers have used visual guidance to increase the use of hidden knowledge to increase the cognitive abilities of learners (10,18-20), the use of these methods for acceleration of observational learning of motor skills, especially through the use of gaze patterns on internal and external signs during observational learning, has been largely ignored. Despite existing research in observational learning and autistic children, no research has investigated the type of focus of attention (internal/external) for directing the gaze during gaze behavior modeling and motor learning of autistic children. Therefore, the present study aimed to investigate the effects of the focus of attention in the form of gaze behavior during the observational learning of autistic children. It is predicted that external attention instruction for directing gaze behavior while watching a video model (e.g., seeing the eye movement patterns of an expert on the ball and the video model's throwing path) is more effective than internal attention instruction for directing gaze (e.g., seeing the eye movement patterns of an expert on the video model's body), resulting in better overarm throwing performance and a longer quiet eye.

Methods

Participants

In this cross-sectional study, 40 children with autism spectrum disorder were selected and were randomly divided into two groups: external attention and internal attention. The criteria for entering the study included having a level 1 disorder of the autism spectrum (based on the Diagnostic and Statistical Manual of Mental Disorders, 2013), the age range of seven to ten years, being right-handed (Edinburgh Scale), and not having problems with vision, hearing, etc. (1). The exclusion criteria included not completing training sessions and assessments, severe autism spectrum disorder (level 2 and 3), and a lack of a clear dominant hand.

Task and research tools

The above shoulder throw accuracy test was used to measure movement performance. This test was conducted by throwing a clay tennis ball from a distance of 3 meters to a circular target on the wall, which consisted of ten concentric circles (10, 20, 30 ..., 100 cm). The center of the circle had the highest score (100 points), and the circle with a radius of 100 cm had the lowest score (10 points). Zero points were considered for throws outside the target. The plane's height from the ground was adjusted according to the height of each subject to ensure that the center of the target was in line with the eyes of the subjects.

Video clips

First, a children's movement skill instructor was invited and asked to carefully watch a video of an expert performer throwing from over the shoulder ten times from a sagittal (side) view while simultaneously recording gaze information. He was being recorded while observing. In the first half of the clips, the coach or the observer was asked to pay attention to the hand and body movements of the model (internal attention), and in the other half, they were asked to pay attention to the ball and the trajectory of the model ball (external attention) towards the target. Videos with high glare quality (more fixation and less jump) were selected and saved in two forms of video with glare using People Player software. Therefore, the clips prepared for the interventions of the experimental groups directed external attention in the form of gaze instructions or directed internal attention in the form of gaze instructions.

Eye tracking

The Pupil Labs Core model eye tracking device, which recorded the gaze points at every moment with a frequency of 60 Hz, was used. This system included glasses equipped with a camera to record eye movements and a camera to capture the environment. The collected data were sent to a computer via a video cable. The device was calibrated using the five-point natural feature method on the target in the same position as overarm throwing by the subject and the examiner. A laser pointer was used to draw the subjects' visual attention to the desired calibration points. In addition, a Xiaomi side video camera with a speed of 60 frames per second was located on the right side of the participants, which recorded the throwing hand movements of the subjects at the sagittal level. Before each trial, a laser pointer was presented and recorded by the side and vision tracker cameras. This light was used as a reference to synchronize the two videos for further analysis. Pupil Capture software was used to record eye movements and changes, and Pupil Player software was used to analyze the recorded data.

The video information obtained from the vision tracker was identified frame by frame using Pupil Player software, and the duration of fixation before overarm throwing was identified and recorded using Excel software. Both videos from the vision tracker and the side camera were synchronized using optical events through Kinovea software. This method allowed for precise synchronization of gaze information and motion data. To extract the quiet eye duration, according to the information from both side and eye tracking cameras, the last visual fixation before the release of the dart was manually identified as the quiet eye, and its duration was extracted from the Excel file of the eye tracker output.

Recording and analyzing eye-tracking

The overarm throwing video was played on a 1.5 x 2 m screen using a CP-EX251N projector (Hitachi, Japan) to measure the visual search behavior. The subject was seated in a comfortable chair at a distance of two meters from the screen. To investigate the vision search behavior during task observation (in the sagittal plane), the pupil capture feature of the vision tracker device was used to record gaze points at any moment in the desired places: internal signs, including the head, shoulder, elbow, hand, and lower body, external signs, including the ball and the throwing path, and irrelevant signs, such as grass and the sky. The device was calibrated using the five-point natural feature method on the film screen using a laser pointer to attract the attention of the subjects.

Similar to recording the quiet eye data, the video information obtained from the vision tracker while observing the overarm throwing was analyzed frame by frame using the People Player software, and the number of visual frames in the desired places of the internal signs (head, hand, trunk, and legs), external signs (ball and ball throwing path), and irrelevant signs (sky, grass, etc.) were identified and recorded in an Excel output.

Procedure

First, the necessary arrangements were made to obtain ethical approval for the research and to secure access to subjects and research facilities from the Kerman Autism School. After subject selection, group assignment, and obtaining consent from the subjects' parents, the coach instructed each subject on the correct overarm throwing technique before conducting the movement measurement. In the pre-test stage, to ensure the acquisition of the basic movement pattern, the subjects performed the desired skill five times without being scored. Then, all the subjects performed the overarm throwing ten times while the gaze behavior was being recorded, with a rest interval of one minute between attempts, and their score and the duration of their quiet eye were recorded as the pre-test score. A skilled model performed the overarm throwing, and then, the subjects performed observational exercises ten times. During observation, the internal attention group was instructed to focus their gaze on the gaze points on the body of the observational model. The external attention group was instructed to focus their gaze on the gaze points on the ball and the trajectory of the ball thrown toward the target. Immediately after the last observation, the post-test was performed. Like the pre-test, all the subjects performed overarm throwing ten times while their gaze was being recorded without receiving feedback or instructions from the trainer. At the end of the study, the children and their families were thanked for their cooperation.

Statistical analysis

Mean and standard deviation were used as descriptive statistics in charts and tables. The Shapiro-Wilk and Levene tests were used to investigate normality and homogeny. In addition, ANCOVA was used to analyze the research hypotheses. All data were analyzed using SPSS version 26 statistical software at a significance level of 0.05. Tables and graphs were drawn using Excel software version 2019.

Results

The results of the Shapiro-Wilk and Levene tests showed that the variables had normal distribution and homogenous inter-group variances ($P > 0.05$). The interaction between pre-tests and groups was tested to check the homogeneity of regression slopes (the linear relationship between variables). The results showed that the interaction between the test conditions and the covariate variable (pre-test) was not significant ($P > 0.05$). ANCOVA was used to investigate the effect of visual attention instructions on gaze behavior and learning during overarm throwing in children with autism spectrum disorder. The ANCOVA results are shown in Table 1.

The ANCOVA results for the score of overarm throwing and duration of the quiet eye showed significant differences between the two groups, and the external attention instructions were more effective than the internal attention instructions (Table 1).

The independent *t*-test results to compare the visual attention of groups during overarm throwing showed that the external attention group had a significantly higher percentage of looking at external signs than the internal attention group ($P < 0.05$). In addition, the internal attention group had a significantly higher percentage of looking at internal signs than the external attention group ($P < 0.05$). There was no significant difference between the percentage of looking at irrelevant signs ($P > 0.05$) (Figure 1).

Discussion

This study aimed to investigate the effect of visual attention instructions on gaze behavior and the score of overarm throwing in children with autism spectrum disorder. The results of the study indicated the effectiveness of external attention direction in children with autism spectrum disorder. In addition, the results indicated the high adherence of visual attention in children with autism spectrum disorder to the provided instructions during observation.

The result of the implementation indicated a significant improvement of the research groups from pre-test to post-test, in the sense that modeling the observational model, regardless of attention manipulations, significantly improved overarm throwing in children with autism spectrum disorder. The results of this research were consistent with the research of Javadian et al (13), Moradi Farsani et al (14), Taheri-Torbati and Sotoodeh (12), Foti et al (28), and Asadi et al (10, 19), which indicate the effectiveness of observational learning on motor learning in children, especially children with autism spectrum disorder.

According to Bandura, observational learning is an information-processing process carried out through four sub-processes: attention, memorization, production, and motivation (8). Observational learning will be ineffective if the observer goes through all the sub-processes before the motivation stage but lacks the motivation to perform the skill (7). Bandura and Walters believed that motivation plays two basic roles and can be used as an incentive to motivate the learner (7). Motivation is an incentive to transform observations into motor performance and an incentive to use what has been learned (29). In addition, research evidence shows that watching movies is one of the favorite activities of children with autism spectrum disorder. This activity increases their motivation and

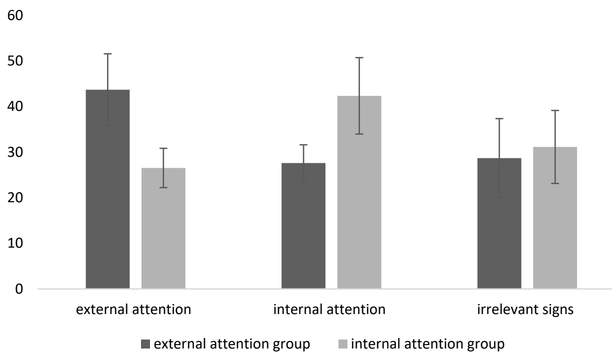

Figure 1. The mean and standard deviation of the percentage of looking at external, internal, and irrelevant signs during overarm throwing in children with autism spectrum disorder

Table 1. Results of ANCOVA for investigating the effect of visual attention instructions on variables during the overarm throwing

Variable	Group	Pre-test Mean ± SD	Post-test Mean ± SD	Mean square	F	*P*	Effect size
Score of overarm throwing	External attention	25.75 ± 6.91	43.80 ± 9.37	1447.67	17.847	0.0001*	0.325
	Internal attention	26.25 ± 6.22	31.80 ± 8.40				
Duration of the quiet eye	External attention	246.40 ± 52.28	672.10 ± 105.58	604357.18	33.872	0.0001*	0.478
	Internal attention	244.70 ± 53.27	427.25 ± 160.01				

* Shows a significant difference ($P < 0.05$).

attention to the skill depicted in the video and, as a result, facilitates motor learning (30).

Another finding of the study indicated the greater effectiveness of paying attention to the external signs of the observation model compared to the internal signs during observation in learning overarm throwing in children with autism spectrum disorder, which is consistent with the results of Asadi and colleagues' study (10). In addition, these results were consistent with the research of Ziv and Emanuel et al. Children with autism spectrum disorder often have difficulty imitating others or are less accurate in their imitations (31-33). This is problematic because observational learning is a common intervention for teaching new motor skills (34). Understanding how attention can shift during observational learning may allow children to benefit from manipulations (directing attention during observation) that do not normally occur during observational learning.

Our results showed that both groups trained with gaze guidance were significantly more focused on the relevant aspects of the skill task than on the irrelevant aspects. Guiding visual attention by gaze instructions may optimize attentional processes during observational learning, which helps learners acquire relevant information. This finding is consistent with the prediction of the zoom lens theory (35). This theory suggests that pre-cueing critical locations during observational learning increases the salience of task-relevant aspects. It also speeds up focusing on relevant specific point information by reducing processing density in the field of view. This strategy helps learners increase the size of their attentional field and explore it more effectively (18,36).

In addition, it was shown that external attention compared to internal attention during observation of learning led to a longer period of quiet eye in overarm throwing in children with autism spectrum disorder, which is consistent with the results of studies that show the effectiveness of external attention during observation (10,19) and studies that showed the effectiveness of external attention during the actual performance (10,32). Based on these results, it can be stated that combining gaze instructions with external attention potentially uses the same mechanism as research on quiet eye exercises. In quiet eye research, the learner's gaze focuses on important visual cues, which often promote external attention (26). These explanations help us understand the benefits of adopting external attention as gaze instruction for perceptual-motor performance.

Conclusion

Observational learning exercises combined with attention direction in the form of staring by providing important visual clues related to the task create provisions in the environment and facilitate the optimal pairing of perception and action. Children with autism spectrum disorder, in particular, benefit greatly from using external attention while observing a skill. Augmenting traditional attentional focus training with the gaze behaviors of a skilled facilitator helps ensure compliance with the attentional cue. In addition, this study highlights the importance of instructional content during traditional instruction or observation learning. Therefore, when using an observational model, autistic learners should focus on the effects of movement on the environment with the help of marking techniques to optimize observational learning.

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Authors' Contribution

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Competing Interests

The authors hereby declare no conflict of interest concerning this research study.

Ethical Approval

This study was approved by the Ethics Committee of the Sport Sciences Research Institute (SSRI.REC-2310-2476).

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