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Developing visual-motor coordination through ABLLS-R-based training in children with moderate autism spectrum disorder

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ABSTRACT

This study examined the effectiveness of interventions based on the revised assessment of basic language and learning skills (ABLLS-R) in improving visual-motor coordination (VMC) and related functional skills in children with moderate autism spectrum disorder (MASD). Sixty children with MASD, aged 9 to 12 years (mean = 10.8, SD = ±1.23), were selected from a daycare center in Al-Ahsa and randomly assigned to experimental and control groups (n = 30 each) using a quasi-experimental design. The Visual-Motor Coordination Scale (VMCS), standardized for the Saudi environment, was used to assess performance. The results showed that the experimental group demonstrated significant improvement on the VMCS assessment compared to the control group and exhibited enhanced performance in post-measurement compared to pre-measurement. Furthermore, there was no significant difference between the post-measurement and one-month follow-up scores for the experimental group, indicating the program's effectiveness in developing targeted skills and maintaining improvements over time. The study recommends implementing more ABLLS-R-based training programs to enhance various skills in children with MASD and regularly evaluating their effectiveness in care centers.

1. Introduction

Childhood represents a critical period for the development of children's social, emotional, cognitive, and motor needs to build a strong and comprehensive foundation for lifelong learning and well-being (Sung et al., 2024). However, some children may face challenges in various developmental areas during this stage, such as children with autism spectrum disorder (ASD) (Gaber, 2024). This disorder is a widespread neurodevelopmental condition whose symptoms begin to appear in childhood (Ceccarelli et al., 2020). Despite starting from the age of 6 months, it is usually diagnosed at a later stage, which leads to a delay in the appropriate interventions and the desired outcomes (Minissi et al., 2023). This disorder negatively affects communication and social interaction skills and leads to repetitive and restricted behaviors (Begic and Kolar, 2024). In addition to other deficits, there is hypo- or hyper-reactivity to sensory input and unusual interest in sensory aspects of the environment (APA, 2022). Longo et al. (2023) confirmed that these children have significant deficits in stereoscopic vision, convergence deficits, and refractive errors, which are known changes in motor skills and sensory processing in ASD. ASD is therefore a growing public health concern, especially in low- and middle-income countries (Pillay et al., 2024).

Martel et al. (2024) showed that the vast majority of children with ASD have poor motor skills and can also have difficulties with sensory input (Bick et al., 2024). Children with ASD have problems organizing and integrating sensory input, which leads to an inability to respond appropriately to these inputs, affecting their daily activities, as a result of sensory disturbances that lead to inappropriate responses to environmental events (Behrouzmanesh et al., 2023). Therefore, early intervention for ASD is crucial because it is effective in developing various life skills and reducing socially unacceptable behaviors at an early age, in addition to saving costs for the families of these children (Wuang et al., 2020). However, the child reaches a stage where the intervention is not beneficial, especially in early childhood and most

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children with ASD suffer from sensory problems. Any action to improve, modify, and integrate the senses may reduce emotional and behavioral problems (Hemati and Mradi, 2021). Therefore, the suffering of children with ASD from the risks of weak and delayed visual-motor coordination (VMC), along with deficits in gross and fine motor skills, requires identifying effective motor interventions and determining the appropriate intervention (Gaber et al., 2025; Jin et al., 2023). Several categories of children with special needs, including children with ASD, suffer from difficulties in movement, orientation, and VMC (Papadopoulos and Vasileiadis, 2024). VMC refers to the ability to perceive visual input, interpret information, and coordinate motor responses. Deficits in VMC can negatively affect participation in activities and children's self-concept (Carsone et al., 2023). VMC can be divided into three main skills: Accuracy, grasp, and speed. In order for children with ASD to practice activities and tasks that require VMC, they must possess these skills. VMC is associated with many functional skills and skills of participation in daily tasks, through the interactive coordination between fine motor skills and visual perception (Bektaş and Ercan, 2023). VMC disorders often stem from issues in sensory processing, including visual, auditory, taste, smell, self-sensation, touch, pain, and temperature/pressure sensitivity (Carsone et al., 2022). Poor VMC contributes to poor imitation of movements and difficulties in developing communication and social interaction skills. The deficit in VMC is more pronounced than the deficit in fine motor coordination in these children (Carey et al., 2023). Understanding the neural mechanisms underlying poor VMC in children with ASD is key to discovering interventions that alleviate the symptoms of this disorder (Lidstone and Mostofsky, 2021).

The revised assessment of basic language and learning skills, revised (ABLLS-R), is a commonly used assessment of language development in educational and clinical settings for children with ASD. It can guide professionals and parents and help identify the skills these children need to communicate effectively and learn in a natural environment (Belisle et al., 2022; Myers et al., 2022; Partington et al., 2018). The ABLLS-R program can facilitate identifying developmentally appropriate educational goals for these children and includes instructions, an individualized education plan development guide, and detailed information about the assessment, its features, guidelines, and goal development, and provides assessment grids for tracking progress (Padilla et al., 2023). The ABLLS-R provides a review of 544 skills from 25 major skill domains (Schnell et al., 2023) and divides these skills into those that are typically acquired before first grade, including, cooperation, visual performance, receptive and expressive language skills, toileting, social skills, and gross and fine motor skills. The data acquired through each skill set is divided into multiple skills that are arranged according to typical development or complexity. For example, the skill "sign request" is a simpler skill than "request for help." Typically, lower-level skills are required before moving on to teaching higher-level skills. The ABLLS-R is conducted by observing the child's behavior in each skill area; the specialist provides a stimulus to the child and, based on what the child does (the behavior), his or her skill level is determined. This program is used with children with ASD between the ages of 3 and 9 years. Re-evaluation is conducted periodically every 6–12 months and requires 10–14 hours to complete (Pongoski, 2020). One limitation of the ABLLS-R is that it is a very lengthy process.

In the current literature, there are few studies on the effectiveness of interventions, such as ABLLS-R, in developing VMC skills in children with ASD and the effectiveness of ABLLS-R in improving visual and auditory attention and the effectiveness of ABLLS-R in developing sensory integration skills. Abid et al. (2024) proved the effectiveness of ABLLS-R in improving social interaction skills.

Despite daycare centers for children with ASD showing interest in training programs specifically directed to meet the needs of these children, few of these centers focus on using ABLLS-R. Therefore, this study aimed to determine the effectiveness of a training program based on ABLLS-R in developing VMC skills in a sample of children with ASD. The study questions were as follows: 1) Is there a difference in the VMCS assessment in its three dimensions between the mean scores of the experimental and control groups in the post-application? 2) Is there a difference in the VMCS assessment in its three dimensions between the mean scores of the experimental group in the post-application compared to the pre-application? 3) Is there a difference in the VMCS assessment in its three dimensions between the mean scores of the experimental group in the follow-up measurement compared to the post-application?

2. Methodology

2.1. Approach and design

The study followed a quasi-experimental approach to test the effectiveness of a training program based on ABLLS-R. A two-group design (experimental and control) was used. The experimental group of children with MASD underwent the program, while the control group was not exposed to any type of intervention.

2.2. Participants

The total number of participants was 70 children registered in one of the childcare centers with MASD in Al-Ahsa in the Eastern Province of Saudi Arabia. They were randomly divided and distributed into two equal groups, one experimental and the other control. Equivalence was achieved between the two

groups in terms of age, intelligence, MASD, and VMC skills. The p-value was less than 0.05. The sample was selected intentionally according to the following criteria: Age between 9 and 12 years; intelligence score 36–49 on the Stanford–Binet scale, fifth edition; diagnosed with MASD; weaknesses in VMC skills so that their scores were below average, according to the Visual-Motor Coordination Scale (VMCS); no other accompanying disabilities; and they did not take any drugs that would improve developmental or behavioral aspects throughout the training program.

2.3. Tools

2.3.1. Visual-motor coordination scale (VMCS)

The scale consists of 36 statements, divided into three dimensions: accuracy skills, grasping skills, and speed skills. Each dimension includes 12 statements. A three-point Likert scale was used for responses: Always = 3, Sometimes = 2, and Rarely = 1. The total score can range from 36 to 108, with higher scores indicating stronger VMC skills.

To assess the psychometric properties of the scale in Egypt, the developers conducted factor analysis using the principal components method based on Kaiser's Criterion. This analysis was performed on responses from 120 children with autism spectrum disorder (ASD). The results identified three factors corresponding to the three dimensions. The factor loadings ranged from 0.462 to 0.713 for accuracy, 0.476 to 0.706 for grasping, and 0.451 to 0.701 for speed.

Internal consistency was examined by calculating the correlation between each statement and the total score of its respective dimension. All correlations were significant at the 0.01 level. The correlation between each dimension score and the total scale score was 0.537 for accuracy, 0.851 for grasping, and 0.549 for speed.

Reliability was tested using Cronbach's alpha and the Spearman–Brown split-half method. The Cronbach's alpha coefficients were 0.816 for accuracy, 0.791 for grasping, 0.808 for speed, and 0.823 for the total score. The corresponding split-half coefficients were 0.822, 0.804, 0.814, and 0.831, respectively.

The scale was also adapted for use in Saudi Arabia by evaluating its psychometric properties with 98 children diagnosed with mild ASD enrolled in several day centers in Al-Ahsa. Validity was assessed using one-way comparisons of p-values with the total score, yielding significant results for all dimensions ($p = 0.024$ for accuracy, 0.038 for grasping, and 0.009 for speed). Reliability was again confirmed through Cronbach's alpha and split-half methods. The Cronbach's alpha values were 0.834 for accuracy, 0.810 for grasping, 0.829 for speed, and 0.842 for the total score. The corresponding split-half coefficients were 0.846, 0.825, 0.833, and 0.853. These results indicate that the scale has acceptable validity and reliability for use in both contexts.

2.3.2. The training program

The researchers prepared the training program in accordance with the ABLLS-R program to develop VMC skills (accuracy, grasp, and speed) among members of the experimental group of children with MASD. Participants performed various activities and tasks, based on tools designed specifically for this purpose, in addition to using techniques that facilitate the training process, and we measured the program's effect after the completion of the program.

The training program was presented to a group of faculty members and experts in the field of ASD to ensure its suitability for application. The program included in its final form 36 sessions that were applied over a period of three months, at a rate of three sessions per week, with a session duration of 30 minutes. It was applied to the experimental group throughout the period specified for the program application, and the control group underwent no intervention. The training program was divided into three main stages, each of which includes a specific number of sessions that work to achieve a set of objectives. The introductory stage comprises four sessions that aim to familiarize the researchers and the children participating in the experiment with each other and to familiarize them with the program, activities, and tasks that they will be trained on. The training stage includes 26 sessions that aim to train the children in the activities and tasks in the program. The evaluation stage comprises six sessions to evaluate the children on their performance in the activities and tasks that they were trained on in the training stage (Table 1).

2.4. Data collection

Data collected included age, gender, IQ, and degree of ASD. In addition, data from the children were collected using the VMCS assessment before, immediately after, and one month after the program from the beginning of May to August 2024.

2.5. Data analysis

Data were collected in Excel and then transferred and coded in Jamovi version 2.6.2. The normal distribution of the data was confirmed. The t-test was used for independent samples to measure the difference between the mean scores of the experimental and control groups, and the t-test for paired samples was used to measure the difference between the mean scores of the experimental group before and after the program, as well as in the post- and follow-up measurements.

3. Results

An independent samples t-test was used to determine whether there was a difference in the mean VMCS scores in the three dimensions between the experimental and control groups after the

program. There was a statistically significant difference (t=48.9, p<0.001) between the general mean score of the experimental group (M=98.3) and the control group (M=62.5) on the VMCS and its dimensions (Table 2).

Table 1: Training program sessions, objectives, tools, techniques, and description

Session No.	Objectives	Tools	Techniques	Description
			Introductory stage	
1–4	Introduction between researchers and children. Pre-assessment of VMC	Various toys VMCS	Positive reinforcement	This includes four sessions for the authors and participants on the program, exercises, and tasks that they would be trained on, as well as a pre-assessment of VMC using the study scale.
			Training stage	
5–30	Training visual tracking skills and hand-eye coordination Training motor control and speed of performance Enhancing visual discrimination and concentration Training fine motor skills Motor obstacle training Training balance and motor control using various activities Training concentration and attention skills using sensory tools Training on object manipulation Training in musical activities	Balls, balance games, and visual cards Dough, construction tools, drawing tools Color pictures, cards, star machine Scissors, paper, clips, beads Barriers Wooden boards, balls, ladder Sensory materials (sand and water) Puzzle, cubes Drum, tambourine	Modeling, indoctrination, feedback, continuous reinforcement	The program included 26 training sessions aimed at developing the participants' skills in the specified activities and tasks. These activities were carried out in an organized manner during each session under the supervision of the researchers. Each activity began with a presentation, followed by group practice, where participants were encouraged to complete the activities at their own pace. Regular assessments were conducted to monitor progress and make necessary adjustments to the activities to meet individual needs. Before training: The researchers removed any items that might distract the children's attention from the room and ensured that the children did not need food, a bathroom, or sleep. They also ensured that the tools for the targeted session were ready in the room. During training: At the beginning of the training, the children's attention was drawn through visual stimuli. The training started by directing the children using signals with immediate reinforcement of correct behaviors. The process gradually progressed to intermittent and varied reinforcement, culminating in teaching the children successful skills that were praised. After training: This phase included a comprehensive workshop that covered the objectives and techniques employed in the original sessions, with a focus on positive reinforcement, verbal and manual instruction, modeling, role-playing, and providing constructive feedback. The training also featured practical demonstrations and role-playing situations to ensure that the activities were effectively implemented by the researchers. Additionally, training tools such as manuals and instructional videos were provided to support continuous learning and application. Applications of VMC: The targeted activities included improving eye-hand coordination through exercises requiring children to grasp small objects, draw shapes, or arrange pieces. Movement-based games that enhance the ability to track visual targets were also used, contributing to the development of their VMC skills.
	Comprehensive review and application of daily activities based on visual-motor coordination	Construction tools, sensory materials, musical instruments		
			Evaluation stage	
31–36	Final assessment of VMC	Evaluation forms, program tools		This included six sessions to assess the participants' performance in the activities and tasks they had been trained on during the training stage using the study scale.

Table 2: Comparison of the mean VMCS scores of the experimental and control groups following the program by the independent samples t-test

VMCS	Experimental group (n=30)		Control group (n=30)		t	df	P
	M	SD	M	SD			
Accuracy	31.7	1.39	20	2.10	25.4	58	<0.001
Grasp	33.9	0.73	21.6	1.43	41.8	58	<0.001
Speed	32.7	1.53	20.9	1.80	27.4	58	<0.001
Total	98.3	2.15	62.5	3.38	48.9	58	<0.001

SD: Standard deviation; df: Degree of freedom

Next, the t-test for paired samples was used to determine whether there was a difference in the mean VMCS scores of the experimental group after the program compared to before. There was a statistically significant difference (t=49.5, p<0.001) between the mean VMCS scores of the experimental group before (M=62.6) and after (M=98.3) the program (Table 3).

Table 3: Comparison of the mean VCMS scores of the experimental group before and after the program by the paired samples t-test

VMCS	Tests	Mean	Mean difference	SE difference	t	df	P
Accuracy	Post Pre	31.7 19.3	12.37	2.36	28.8	29	<0.001
Grasp	Post Pre	33.9 22.3	11.53	1.10	57.1	29	<0.001
Speed	Post Pre	32.7 21	11.73	2.63	24.5	29	<0.001
Total	Post Pre	98.3 62.6	35.63	3.94	49.5	29	<0.001

SE: Standard error

The paired samples t-test was used to determine if there was a difference in the mean VMCS scores of the experimental group in the period after the program compared to immediately after the program. There was no statistically significant difference (t=1.005, p=0.323) between the mean VCMS scores of the experimental group at the end of the program (M=98.3) and one month later (M=97.8; Table 4).

4. Discussion

This study shows the effectiveness of a training program based on ABLLS-R in developing VMC skills among children with MASD. The experimental group outperformed the control group on the VMCS and its dimensions (accuracy, grasping, and speed) following the program, and there was a difference between the experimental group before and after the program in all three dimensions and the total score. This result is consistent with the literature that indicates the effectiveness of ABLLS-R for children with ASD (Abid et al., 2024; Papadopoulos and Vasileiadis, 2024; Gaber et al., 2025). One of the main goals of the training program based on ABLLS-R is to coordinate movements with what children see, which requires using their visual information to guide their body movements to perform the activities. VMC skills depend on the ability of children participating in the program to process visual information and make direct movements. The training program provided activities designed to enhance the interaction of perception with movement, which helped these children improve their ability to coordinate their movements with what they see. These activities include visual guidance activities, such as tracking balls and moving lights; drawing and coloring activities, such as simple drawing and coloring simple shapes; motor activities that require visual coordination skills; activities targeting handling sensory materials that enhance hand-eye coordination, such as water and sand; object manipulation activities, such as assembling puzzles and building models from cubes; musical activities, such as drums; and motor experiment activities that require balance, such as walking on wooden boards or walking on lines. The gradual transition from easy to difficult activities for children in the program and providing corrective feedback contributed to implementing these activities during the program period and completing them as required. The results did not show a difference within the experimental group in the follow-up measurements of the three dimensions of the scale and its total score, indicating that the development achieved during the training program continued after the end of the program for a month. This result is consistent with the literature that shows that the benefits of training persist for at least a month (Gaber et al., 2025). This can likely be attributed to the last phase of the training program and the benefit of routine and repetition that characterizes children with MASD, as they were motivated and the participants in the experimental group were retrained on the activities and tasks that they were trained on during the training phase. Hence, there is sufficient empirical evidence in the literature to suggest that training programs based on the ABLLS-R program have clear benefits in the development of many children with ASD.

Overall, while numerous studies have explored ABLLS-R treatments for children with MASD, this study specifically targets a unique demographic: children with MASD in Saudi Arabia. Previous research, particularly that conducted in Western contexts, often encompasses larger age groups or different cultural settings, which may overlook the sociocultural factors that influence motor skill development in Saudi children. Additionally, many existing studies do not thoroughly assess the long-term effects of interventions, whereas this study incorporates follow-up assessments to evaluate the sustainability of visual-motor skill (VMC) improvements after the intervention. The methodology of this study employs a meticulously structured ABLLS-R-based training program tailored to the specific needs of the participants, resulting in a more nuanced approach to enhancing VMC. This distinct methodology sets this study apart from others that may employ general ABLLS-R activities without considering the individual developmental circumstances of the participants. Consequently, this study contributes to the existing body of knowledge on ABLLS-R treatments while addressing a critical gap by providing culturally relevant insights and a focused evaluation of VMC development in Saudi Arabian children with MASD. This uniqueness underscores the significance of these findings and their potential implications for future interventions in similar contexts.

Table 4: Comparison of the mean VMCS scores of the experimental group at the end of the program and at one-month follow-up by the paired samples t-test

VMCS	Tests	Mean	Mean difference	SE difference	t	df	P
Accuracy	Post	31.7	0.13	1.50	0.486	29	0.631
	Pre	31.6					
Grasp	Post	33.9	0.20	0.805	1.361	29	0.184
	Pre	33.7					
Speed	Post	32.7	0.13	1.68	0.436	29	0.666
	Pre	32.6					
Total	Post	98.3	0.47	2.54	1.005	29	0.323
	Pre	97.8					

5. Limitations

This study has some limitations. These include that the selection of participants was intentional, and their number was small because the study was implemented within one center and within one governorate. The focus was only on children with moderate ASD (i.e., children who could undergo a training program) of 9–12 years. The program duration of 3 months may not be sufficient to achieve greater improvements in VMC skills, so future studies need a program duration of 6 months in addition to two months as a follow-up period to ensure the continuity of the training effect on the program.

6. Conclusion and recommendations

This study indicates the effectiveness of the training program used in developing VMC skills (accuracy, grasp, and speed) among children with MASD. The experimental group showed a significant improvement after the program compared to the control group, which indicates the effectiveness of the program in developing the skills targeted in this study. The differences between before and after the program within the experimental group support this result. The results also indicate that the training effect continued until at least one month after the conclusion of the program.

We recommend further studies on larger samples from communities from more than one region within Saudi Arabia with the aim of generalizing the results to all children with MASD. It also recommends conducting future studies that need to be applied to children with mild ASD and to participants under the age of 8 years. In addition, periodic assessments of VMC skills (accuracy, grasp, speed) after the end of the program to determine the persistence of the improvement should be conducted. We also recommend holding workshops for specialists, special education teachers, and parents on how to use the training program at home or in care centers to support these children in developing their skills. Finally, we suggest studying the impact of the program on other skills, such as gross motor skills, which may contribute to increasing the level of social interactions among children with MASD.

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Compliance with ethical standards

Ethical considerations

The researchers in this study adhered to all ethical standards, ensuring the anonymity of the participants and their families' consent to their children's participation in the study experiment and commitment to its conditions. The Deanship of Scientific Research at King Faisal University in Al-Ahsa, Saudi Arabia, granted ethical approval to conduct the study (approval number: KFU-REC-2024-MAY-ETHICS2356).

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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