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ORIGINAL ARTICLE

Designing a Digital Visual-Analogy Motor Learning Program for Children with Autism Spectrum Disorder: Development, Implementation, and Preliminary Outcomes

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Abstract. Children with Autism Spectrum Disorder (ASD) often experience significant motor-learning difficulties, including impairments in coordination, balance, motor planning, movement timing, and postural control. Traditional motor-learning approaches frequently rely on explicit verbal instruction, which may be less effective for children with ASD due to challenges in language processing, working memory, attention regulation, and executive functioning. In contrast, many children with ASD demonstrate strengths in visual processing and visually guided learning, suggesting that visual-based instructional approaches may better support motor-skill acquisition. The present study developed a Digital Visual-Analogy Motor Learning Program (DVAML) specifically designed for children with ASD. The program integrated principles of visual-analogy learning, implicit motor learning, and sensory-sensitive digital design. Using a developmental–applied framework, Preliminary findings demonstrated improvements in motor accuracy, movement consistency, engagement, and short-term retention following participation in the intervention program. Children showed increased attention to visual demonstrations, greater willingness to repeat movements, reduced reliance on verbal prompting, and stronger participation during sessions. Personalized visual themes and digital reward

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systems also appeared to enhance motivation and engagement. The findings suggest that DVAML may represent a promising, accessible, and scalable intervention for improving motor learning in children with ASD.

Keywords: Autism Spectrum Disorder; Motor Learning; Visual Analogy; Implicit Learning; Digital Intervention; Neurodevelopmental Disorders

Introduction

Motor learning is one of the most fundamental components of child development and plays a major role in participation in physical activity, education, social interaction, self-care, play, and independent living (Schmidt & Lee, 2011; Schmidt & Wrisberg, 2008; Shumway-Cook & Woollacott, 2017; Hirsh-Pasek & Golinkoff, 2018; Magill & Anderson, 2023). Efficient motor learning enables children to acquire, refine, and adapt movement patterns in response to environmental demands. When motor learning is disrupted, the effects may extend beyond physical performance and influence emotional well-being, confidence, participation, and quality of life.

Children with Autism Spectrum Disorder (ASD) frequently experience substantial motor-learning difficulties (Fournier et al., 2010; Green et al., 2009; Zwicker et al., 2018; Srinivasan et al., 2021; Bhat, 2021; Licari et al., 2020). Although ASD is primarily characterized by deficits in social communication and repetitive patterns of behavior (American Psychiatric Association, 2013), increasing evidence over the last two decades has highlighted the importance of motor impairments within the disorder (Fournier et al., 2010; Green et al., 2009; Zwicker et al., 2018; Srinivasan et al., 2021; Bhat, 2021; Licari et al., 2020; Dziuk et al., 2007; Sinzig et al., 2008; Steenbergen & Wilson, 2008). Research has documented impairments in balance, bilateral coordination, movement timing, postural stability, fine-motor coordination, motor planning, motor sequencing, gait, and adaptive motor control (Green et al., 2009; Zwicker et al., 2018; Srinivasan et al., 2021; Bhat, 2021; Licari et al., 2020; Dziuk et al., 2007; Sinzig et al., 2008; Hannant et al., 2022).

Motor difficulties in ASD may emerge very early in development and may significantly affect participation in school activities, sports, playground interaction, handwriting tasks, and daily routines (Hannant et al., 2022; Healy et al., 2023; Whyte et al., 2015). Many children with ASD avoid physical activities because of repeated movement difficulties, frustration, or low confidence. Reduced motor competence may also limit opportunities for peer interaction and social participation (Hirsh-Pasek & Golinkoff, 2018; Healy et al., 2023).

Traditional motor-learning approaches typically rely on explicit instruction, verbal explanation, repetitive correction, and conscious rule-based learning (Schmidt & Lee, 2011; Schmidt & Wrisberg, 2008; Shumway-Cook & Woollacott, 2017; Hirsh-Pasek & Golinkoff, 2018; Magill & Anderson, 2023). These methods often require intact language comprehension, working memory, attentional flexibility, sequencing ability, and executive functioning. However, many children with ASD experience challenges in precisely these domains (Klinger et al., 2007; Mayes & Calhoun, 2008; Pennington, 2009; Reynolds & Fletcher-Janzen, 2014; Solomon et al., 2015). As a result, verbally intensive instruction may increase cognitive load and interfere with movement acquisition.

For example, when children receive multiple verbal instructions simultaneously—such as "bend your knees," "look forward," "balance carefully," and "land softly"—they must process language, maintain attention, organize sequencing, and execute movement at the same time. For many children with ASD, these cognitive demands may exceed available processing capacity.

In contrast, children with ASD often demonstrate relative strengths in visual learning and visual-perceptual processing (Mottron et al., 2006; Soulières et al., 2011; Braun et al., 2020; Zhang et al., 2025; Kim et al., 2024; Singh & Kumar, 2024). Studies have reported enhanced visual search abilities, strong pattern recognition, detail-focused attention, and preference for visual information over verbal instruction (Mottron et al., 2006; Soulières et al., 2011; Braun et al., 2020; Zhang et al., 2025). These characteristics have contributed to widespread use of visual supports within ASD interventions, including visual schedules, picture systems, visual stories, and visual task analysis approaches (Rapp & Colby, 2020; Dettmer et al., 2000).

Visual supports are often effective because they reduce unpredictability and provide stable information that remains continuously accessible. Unlike spoken instructions, visual information does not disappear immediately after presentation and may therefore be easier for children with ASD to process (Rapp & Colby, 2020; Dettmer et al., 2000).

One promising motor-learning strategy that aligns closely with visual strengths in ASD is visual-analogy learning. Analogy learning replaces complex technical explanations with simple metaphorical representations that communicate the essential characteristics of movement (Gentner, 1983; Masters, 1992; Masters & Poolton, 2014; Wilson et al., 2017; Maxwell et al., 2023; Chen et al., 2024). Instead of verbally describing every movement component, a therapist may simply say "jump like a bunny" or "stand like a tall tree."

Analogy learning is closely associated with implicit motor learning (Masters, 1992; Masters & Poolton, 2014; Wilson et al., 2017; Maxwell et al., 2023; Chen et al., 2024). Implicit learning involves acquisition of motor skills with reduced dependence on conscious verbal rules. Research suggests that implicit learning reduces working-memory demands and promotes more automatic movement execution (Masters, 1992; Masters & Poolton, 2014; Wilson et al., 2017; Maxwell et al., 2023; Chen et al., 2024). These features are particularly relevant for children with ASD, who often experience overload during verbally intensive tasks.

Visual-analogy learning simplifies complex motor actions into meaningful metaphoric representations that reduce cognitive load and facilitate more intuitive and automatic movement execution (Gentner, 1983; Masters, 1992; Masters & Poolton, 2014; Wilson et al., 2017; Maxwell et al., 2023; Chen et al., 2024; Zhang et al., 2025). Rather than consciously remembering multiple movement rules, children can focus on a single meaningful image that represents the movement globally.

Visual analogies may also improve emotional engagement and motivation. Many children with ASD participate more successfully when interventions include preferred interests, predictable routines, visual themes, and emotionally meaningful imagery (Healy et al., 2023; Rapp & Colby, 2020; MacDonald et al., 2024). Animal-based analogies, fantasy themes, nature-related imagery, and personalized characters may therefore enhance motivation and repetition.

Several theories have been proposed to explain motor difficulties in ASD. One major explanation involves atypical neural connectivity and impaired integration between sensory and motor systems (Steenbergen & Wilson, 2008; Solomon et al., 2015). Efficient movement requires coordination between perception, planning, timing, sensory feedback, and motor execution. Children with ASD may experience disruptions in these processes, leading to delayed movement initiation, inconsistent motor timing, and inefficient motor adaptation.

Another explanation relates to executive-function limitations. Many children with ASD experience challenges in working memory, attention shifting, sequencing, and planning (Klinger et al., 2007; Mayes & Calhoun, 2008; Pennington, 2009; Reynolds & Fletcher-Janzen, 2014). These cognitive demands are heavily involved in traditional explicit motor instruction. When children are asked to consciously remember and execute multiple movement rules simultaneously, cognitive overload may occur.

Implicit motor learning may therefore offer a particularly valuable alternative. Unlike explicit learning, implicit learning reduces reliance on verbal rules and conscious monitoring (Masters, 1992; Masters & Poolton, 2014; Wilson et al., 2017; Maxwell et al., 2023; Chen et al., 2024). Instead of memorizing technical instructions, the learner acquires movement patterns more naturally through imagery, repetition, and experience. Research has shown that implicit learning often produces more stable performance under stress and lower cognitive load (Masters, 1992; Masters & Poolton, 2014).

Digital technologies provide additional opportunities for supporting motor learning in ASD through interactive, sensory-adaptive, and AI-supported systems (Chen et al., 2020; Boucenna et al., 2014; Yang et al., 2022; Lee et al., 2025; García-Redondo et al., 2024; Patel et al., 2024; Nakamura et al., 2024; Torres et al., 2025; Alvarez & Kim, 2025; Morgan & Peterson, 2025). Tablets, touchscreens, interactive learning systems, serious games, virtual environments, and animated applications have become increasingly common in therapeutic and educational settings. Digital systems offer several advantages, including predictability, repetition, visual consistency, adjustable pacing, and sensory customization.

Digital environments may also reduce anxiety and social pressure by allowing children to practice movements independently in visually controlled environments. Children can replay demonstrations, slow down movement sequences, and interact with predictable visual systems aligned with their learning preferences.

Recent research has demonstrated increasing interest in AI-supported interventions, virtual reality systems, immersive rehabilitation environments, motion-based gaming, and digital motor-learning approaches for children with ASD (Yang et al., 2022; Lee et al., 2025; García-Redondo et al., 2024; Patel et al., 2024; Nakamura et al., 2024; Torres et al., 2025; Alvarez & Kim, 2025; Morgan & Peterson, 2025). However, relatively few digital systems specifically target motor learning using visual-analogy principles grounded in motor-learning theory.

Materials and Methods

Research Design. The present study employed a developmental–applied research design to create and evaluate a Digital Visual-Analogy Motor Learning Program (DVAML) for children with ASD. The methodology was organized across three phases:

1. needs assessment and analogy development;

2. digital production and system design; and
3. implementation and preliminary evaluation.

This structure was selected to ensure that the program remained developmentally appropriate, visually accessible, sensory-sensitive, and aligned with evidence-based motor-learning principles.

Participants. Participants were children aged 6–11 years with formal diagnoses of ASD based on DSM-5 criteria (American Psychiatric Association, 2013). Children were recruited through autism-support organizations, therapy centers, and educational networks. Inclusion criteria required that children:

- had a confirmed ASD diagnosis;
- could visually attend to animated stimuli;
- could follow simple one-step instructions;
- had sufficient motor ability to attempt target skills;
- had no severe orthopedic or neurological disorders unrelated to ASD; and
- had parental consent for participation.

Children with uncontrolled epilepsy, severe sensory intolerance to screen-based learning, or severe behavioral dysregulation were excluded. Demographic information, developmental history, adaptive functioning, sensory preferences, and previous therapy experiences were collected through parent interviews and intake forms.

Development of DVAML

*Phase 1: Needs Assessment***.** The first phase focused on identifying motor-learning needs in children with ASD. Semi-structured interviews were conducted with parents, therapists, and educators. Parents described common movement difficulties including poor balance, hesitation during movement, clumsiness, reduced coordination, low confidence during physical activity, and difficulty following verbal instructions. Therapists identified major challenges related to motor planning, sequencing, timing, postural control, and attention regulation during motor-learning tasks. The needs assessment also explored sensory preferences and motivational factors. Many children demonstrated stronger participation when activities included visual themes, predictable structure, movement imitation, and preferred characters.

*Phase 2: Development of Visual Analogies***.** Based on findings from the needs assessment, a series of visual analogies was created to represent target motor skills. Analogies were selected according to:

- familiarity for children;
- emotional engagement;
- simplicity of meaning;
- visual clarity; and
- suitability for digital animation. Examples included:

- "jump like a bunny";
- "stretch like a tree";
- "spin like a windmill";
- "walk like a penguin"; and
- "reach for a star."

These analogies were intentionally simple and visually memorable.

Phase 3: Digital Production. The visual analogies were translated into animated 2D and 3D instructional sequences. The digital system included:

- high-contrast animations;
- adjustable visual settings;
- adjustable auditory settings;
- replay and slow-motion features;
- personalized characters and themes;
- visual rewards and reinforcement systems; and
- progress indicators.

Animations were intentionally designed with minimal background distraction, sensory-adaptive visual presentation, and smooth visual transitions to reduce sensory overload and improve attentional regulation (Singh & Kumar, 2024; Torres et al., 2025). Pilot testing was conducted with a small group of children before full implementation. Feedback from children, parents, and therapists was used to refine pacing, visual complexity, and reward systems.

Procedure

Children participated in 6–8 structured training sessions lasting approximately 20–30 minutes each. Each session followed a standardized sequence:

Observation of the Visual Analogy. Children watched the animated demonstration of the target movement.

Guided Practice. Therapists encouraged imitation while minimizing excessive verbal instruction.

Independent Practice. Children practiced movements independently while receiving visual reinforcement.

Repetition and Engagement. Voluntary repetition was encouraged through digital rewards and visual motivation systems.

Recording and Evaluation. Sessions were video-recorded for later analysis and scoring. Outcome measures were collected at four points:

- baseline pre-test;
- immediate post-test;
- retention test after 48 hours; and
- generalization assessment in modified environments.

For this Results section, only one IEEE citation appears. Converting to APA does **not** require changing any content, tables, wording, or length—only the citation format.

Results

Children demonstrated noticeable improvements in motor accuracy, movement consistency, engagement, and short-term retention following participation in DVAML. Movements became more coordinated, rhythmical, and controlled during post-test assessments. Children demonstrated fewer abrupt corrections, smoother sequencing, and improved timing compared with baseline performance.

Engagement also increased substantially across sessions. Many children showed stronger visual attention to animations, increased willingness to repeat movements, and greater emotional responses to visual rewards and personalized themes, consistent with recent findings regarding motivation-centered and personalized ASD interventions (MacDonald et al., 2024; Torres et al., 2025). Therapists reported reduced reliance on verbal prompting across sessions, suggesting that visual analogies simplified movement understanding and reduced cognitive load. Retention findings after 48 hours suggested that children maintained many motor improvements even without additional practice.

Generalization outcomes were also encouraging. Children were able to perform several learned movements in modified environments, suggesting that the visual metaphors supported transfer beyond the original training setting.

Table 1. Mean Composite Motor Accuracy Scores Across Assessment Phases

Outcome Measure	Pre-test	Post-test	Retention (48 h)	Generalization
Motor Accuracy Score	22.83 ± 6.29	42.33 ± 6.30	38.42 ± 5.92	37.25 ± 5.38
Coordination Rating	Low	High	Moderate–High	Moderate
Movement Timing	Inconsistent	Improved	Stable	Stable
Postural Control	Weak	Improved	Improved	Moderate

The findings presented in Table 1 indicate considerable improvement in overall motor accuracy following participation in DVAML. Children demonstrated higher coordination scores, improved movement timing, and greater postural stability during post-test and retention assessments compared with baseline measurements.

Table 2. Qualitative Ratings of Movement Consistency Across Sessions

Skill Category	Pre-test	Post-test	Retention (48 h)	Generalization
Jumping	Inconsistent	Consistent	Consistent	Partially Consistent
Reaching	Variable	Stable	Stable	Stable
Balance	Unsteady	Improved	Improved	Moderate
Rotation	Disjointed	Smooth	Smooth	Smooth–Moderate
Bilateral Coordination	Weak	Improved	Improved	Moderate

As shown in Table 2, movement consistency improved across all assessed skill categories. Prior to intervention, children frequently demonstrated fragmented movement patterns, abrupt stopping, and inconsistent rhythm. Following exposure to DVAML, movements became smoother, more continuous, and more rhythmically organized.

Table 3 demonstrates progressive improvement in engagement and participation throughout the intervention period. Children showed increasing attention to visual demonstrations, stronger responses to reinforcement systems, and reduced dependence on therapist prompting. Emotional engagement and willingness to participate also increased substantially during later sessions.

Table 3. Observed Engagement and Participation Indicators During DVAML Sessions

Engagement Variable	Early Sessions	Mid Sessions	Final Sessions
Attention to Animation	Moderate	High	High
Voluntary Repetitions	Low–Moderate	Moderate	High
Response to Visual Reinforcement	Moderate	High	High
Need for Verbal Prompting	High	Moderate	Low
Emotional Engagement	Moderate	High	High
Overall Participation	Moderate	High	Very High

Discussion

The present study aimed to design and evaluate a Digital Visual-Analogy Motor Learning Program (DVAML) specifically tailored to the perceptual, cognitive, and sensory characteristics of children with ASD. The findings demonstrated improvements in motor accuracy, movement consistency, engagement, and retention. These outcomes support previous literature suggesting that children with ASD may benefit from visually guided and implicit motor-learning approaches (Mottron et al., 2006; Soulières et al., 2011; Braun et al., 2020; Zhang et al., 2025; Kim et al., 2024; Gentner, 1983; Masters, 1992; Masters & Poolton, 2014; Wilson et al., 2017; Maxwell et al., 2023; Chen et al., 2024).

One particularly important finding was the reduction in verbal prompting required during sessions. Children increasingly performed movements independently after observing visual analogies. This suggests that analogy-based instruction reduced working-memory demands and facilitated more intuitive movement understanding.

The findings also align with literature emphasizing visual strengths in ASD (Mottron et al., 2006; Soulières et al., 2011; Braun et al., 2020; Zhang et al., 2025; Kim et al., 2024). Because visual information remains stable and continuously accessible, it may be easier for many children with ASD to process compared with rapidly disappearing spoken instruction.

The digital structure of DVAML likely contributed significantly to engagement. Digital environments provide predictability, repetition, and sensory-sensitive presentation, all of which are particularly important for many children with ASD (Boucenna et al., 2014; Chen et al., 2020; Yang et al., 2022; García-Redondo et al., 2024; Patel et al., 2024; Nakamura et al., 2024; Singh & Kumar, 2024; Lee et al., 2025; Torres et al., 2025; Alvarez & Kim, 2025; Morgan & Peterson, 2025).

Personalization features also appeared highly valuable. Children demonstrated greater motivation when they could select preferred characters, themes, and visual rewards. This finding aligns with previous research emphasizing the importance of interest-based learning in ASD interventions (Healy et al., 2023; MacDonald et al., 2024).

Movement consistency improved substantially following intervention. Prior to training, many children demonstrated fragmented sequencing, abrupt movement interruption, and inconsistent rhythm. After repeated exposure to DVAML, movements became smoother and more continuous. These changes may reflect improved motor planning. Visual analogies may have helped children organize movement as a coherent whole rather than processing isolated movement components separately.

Retention outcomes were also encouraging. Children maintained many gains after 48 hours without additional practice, suggesting that visual-analogy instruction may support deeper motor encoding and more automatic execution.

Generalization findings were somewhat more variable. Although many children transferred skills successfully to modified environments, some performance reduction occurred. This finding is consistent with previous literature suggesting that generalization remains challenging for many children with ASD. Nevertheless, the fact that generalization occurred at all is clinically meaningful. Stable visual metaphors may have supported transfer by providing conceptual anchors that remained meaningful across settings.

Recent advances in artificial intelligence and immersive digital rehabilitation systems may further enhance motor-learning interventions for children with ASD. AI-supported systems may eventually provide individualized feedback, adaptive pacing, movement analysis, and personalized learning pathways based on each child's motor profile and sensory characteristics (Lee et al., 2025; Alvarez & Kim, 2025). Similarly, immersive virtual-reality systems may increase motivation and motor engagement by allowing children to interact dynamically with visually meaningful environments (García-Redondo et al., 2024; Morgan & Peterson, 2025).

Sensory-adaptive digital environments may be especially important for children with ASD because sensory overload frequently interferes with learning and participation. Recent studies have emphasized the importance of customizable sensory presentation, adjustable pacing, and visually predictable digital systems in ASD intervention (Singh & Kumar, 2024; Torres et al., 2025).

Conclusions

The present study introduced and evaluated a Digital Visual-Analogy Motor Learning Program (DVAML) specifically designed for children with Autism Spectrum Disorder (ASD). The program was developed based on principles of implicit motor learning, visual-analogy instruction, sensory-sensitive digital design, and personalized intervention approaches tailored to the perceptual and cognitive characteristics commonly observed in children with ASD.

The findings demonstrated meaningful improvements in motor accuracy, movement consistency, engagement, and short-term retention following participation in the intervention program. Children also demonstrated reduced dependence on verbal prompting and increased independent participation during motor-learning sessions. These outcomes suggest that visually structured and analogy-based teaching methods may reduce cognitive overload and facilitate more intuitive movement learning in children with ASD.

The study further highlighted the importance of digital learning environments in supporting motor development. Predictable visual presentation, adjustable pacing, sensory-sensitive design, and personalized reinforcement systems appeared to increase motivation, attention, and willingness to participate. The integration of visual analogies within digital environments may therefore represent an effective strategy for improving movement learning while simultaneously enhancing emotional engagement and participation.

Another important finding of the present study was the potential value of neurodiversity-informed intervention design. Rather than expecting children with ASD to adapt to conventional instructional systems, DVAML was intentionally designed to align with learner strengths, including visual processing abilities, preference for predictability, and visually guided learning. This learner-centered approach may contribute to more accessible and meaningful intervention experiences for children with ASD.

The results also suggest several important practical implications for therapists, educators, rehabilitation specialists, and families. Clinicians may benefit from reducing excessive verbal instruction during motor teaching and integrating more visually meaningful movement representations into intervention programs. Adapted physical education programs may similarly incorporate visual-analogy systems to support participation, comprehension, and movement engagement in group settings. In addition, digital home-based interventions may provide families with accessible tools for reinforcing therapeutic goals beyond clinical environments.

Despite the promising findings, additional large-scale studies are needed to further evaluate the long-term effectiveness, generalizability, and clinical applicability of digital visual-analogy interventions for children with ASD. Future research should include randomized controlled designs, larger participant groups, longer follow-up periods, and integration of advanced technologies such as artificial intelligence, motion-tracking systems, augmented reality, and immersive virtual-reality environments.

Overall, the findings of the present study provide strong support for the continued development of visual-analogy–based digital motor-learning systems for children with ASD. DVAML represents not only a digital intervention tool, but also a broader conceptual shift toward more accessible, personalized, visually guided, and neurodiversity-informed approaches to motor learning and rehabilitation.

Declarations

Study Limitations. This study faced several limitations, including restricted access to sports facilities, limited availability of appropriate training spaces, scheduling constraints for intervention sessions, and the relatively small sample size available during the study period. These limitations may reduce the generalizability of the findings to broader populations of children with ASD. Additionally, the study primarily focused on short-term outcomes, and long-term retention and transfer effects were not fully examined. Future studies with larger samples, extended intervention periods, and multi-center implementation are recommended.

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Competing Interests. Authors declares no competing interests.

Ethical Approval. This study is derived from the doctoral dissertation approved under the ethical code **122712615287057**, endorsed by the Iran Autism Association and the Islamic Azad University, Science and Research Branch.

***Informed Consent*.** Written informed consent was obtained from the parents of all participating children prior to data collection and participation in the study.

***Warning for Hazard*.** None. The study involved non-invasive motor-learning activities and presented no unusual physical or psychological hazards for participants.

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