

Teaching Turn Taking to Autistic Children Using an Individualized Virtual-Reality Game

David Liu

Crystal Springs Uplands School
Hillsborough, CA, USA
dliu27@crystal.org

Eva Liu

The Harker School
San Jose, CA, USA
eva4liu@gmail.com

Abstract—This paper presents a personalized virtual-reality (VR) game designed to teach turn taking to children with moderate-to-severe autism. Integrating applied behavior analysis, the game design was iteratively adjusted to accommodate individualized reinforcers and sensory needs. In an experimental evaluation, four of five participants with Level 2 autism demonstrated breakthroughs in turn-taking skills after engaging in gameplay, with one participant withdrawing due to sensory overload. The results provide promising evidence for the effectiveness of personalized VR-based interventions, especially on children for whom traditional approaches fail. Our experience indicates that the individualized approach in the iterative design flow is the key to our success. This calls for closer collaborations between software developers and therapists in the design of such VR-based interventions.

Index Terms—applied behavior analysis, autism spectrum disorder, virtual reality, turn taking, serious game

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by persistent challenges in social communication, restricted interests, and repetitive behaviors [1]. The severity of autism symptoms varies widely, and individuals are categorized into three levels based on the support needed: individuals with Level 1 autism typically exhibit milder symptoms, such as relatively skillful verbal communication and independence in daily tasks, while those with Level 2 and 3 autism experience more significant difficulties, particularly in social communication and daily living, requiring substantial (Level 2) or very substantial (Level 3) support [2]. The prevalence of autism has risen dramatically in recent years. According to a recent estimate by the US Centers for Disease Control and Prevention, one in 36 children in the United States is diagnosed with autism by age 8 [3].

Early intervention is critical in helping children with autism build essential skills, improve developmental outcomes, and thus enhance quality of life. Applied Behavior Analysis (ABA), a scientific approach to understanding and improving behavior, is widely used in autism interventions [4]. Grounded in the principles of learning theory, ABA uses the *three-term contingency* to model and change behaviors. The three-term contingency, often abbreviated as A-B-C, includes an *antecedent* (the environment along with cue/prompt that leads to a response), a *behavior* (the response), and a *consequence*

(an event following the response for reinforcement). In an ABA intervention, the therapist analyzes and manipulates the antecedent and consequence to either increase or decrease the target behavior.

Virtual reality (VR) is considered a promising tool in autism intervention. A VR system, typically including a head-mounted display (HMD), motion sensors, cameras, and AI-driven algorithms, can track movements and gestures, thus enabling natural movement-based interactions in an immersive environment. The availability of consumer-grade VR systems over the past decade has sparked considerable interest in its use in autism interventions [5]–[7]. Past research has attempted to use VR to teach skills that include joint attention [8], emotion cognition [9], [10], social communication [11], and social interaction [12], [13]. A key advantage of VR lies in its ability to leverage the visual strengths commonly observed in autistic individuals. Moreover, incorporating gamification within VR environments has been shown to enhance motivation, engagement, and sustained attention, all of which are essential for mastering complex social interactions [14].

Despite the demonstrated potential in the literature, VR-based autism interventions remain uncommon in clinical practice due to some key limitations. First, most existing research focuses on adults, adolescents, or individuals with Level 1 autism [15], [16]. Since these populations tend to respond positively to traditional interventions, the incremental benefit of VR remains unclear—and the potential of VR for harder-to-reach populations remains unexplored. Second, most VR interventions are pre-designed without accounting for individuals' environmental preferences, special interests, and learning styles, which are particularly relevant in the intervention for moderate-to-severe autism. Even when research reports the inclusion of therapist consultation in the game design process (e.g., [17], [18]), the designs are not adapted dynamically to the specific and changing needs of individuals. This lack of personalization is inconsistent with ABA practice, which emphasizes a highly personalized approach, with intervention plans regularly updated based on data on individual responses.

In this study, we aim to bridge the gap by integrating evidence-based ABA elements in an iterative VR game design process. We designed a VR game following this idea to teach autistic children *turn taking*, i.e., the ability to engage in reciprocal interactions such as conversations, sharing toys,

or participating in group activities. Children with autism experience difficulties mastering turn taking due to challenges with social cue recognition, temporal processing, and adaptability to the fluid nature of interactions. These challenges can prove persistent even after sustained intervention, especially for individuals with severe communication impairments. By tailoring the three-term contingency framework following feedback from therapists and caregivers, our game leverages each child's special interests to encourage positive behaviors. We demonstrate that this method can be effective for achieving targeted behaviors in children with moderate-to-severe autism, and may serve as a practical supplement to current ABA intervention.

II. METHOD

A. Target Behavior, Participants, Setting, and Material

Taking turns while playing games or sports is a goal in the Social Skills Domain of the Vineland Adaptive Behavior Scales, 3rd Edition [19]. The specific goal for this study is that when presented with a turn-taking ball game, the child will independently exchange the ball with a peer at least 40 times across three consecutive sessions.

Following a prescreening process, five children with Level 2 autism were recruited for this study. Recruitment involved caregiver completion of a questionnaire including age, diagnosis, verbal skills, special interests, and current turn-taking ability. Inclusion criteria specified the inability to consistently engage in reciprocal ball-throwing with a peer. All participants had ASD diagnoses, and had received prior ABA therapy in Northern California. The intervention was conducted in each participant's home, typically with caregiver assistance, and utilized a Meta Quest 3 VR headset, a MacBook laptop, and a television for external display.

B. Game Design

The game simulates reciprocal ball throwing with a virtual character in an immersive environment (Fig. 1). When playing, the player interacts with the ball using either *grab mode* (direct manipulation of the virtual ball with hand motions) or *gesture mode*, which employs simplified hand gestures (clapping to receive the ball, and a thumbs-up to send the ball to the peer). The gesture mode was introduced to facilitate participation for children who struggle with fine motor control or experience difficulties with VR hand tracking.

The game's flow follows the three-term contingency: the antecedent (presence of the ball and a peer ready to interact), the behavior (player throwing the ball to the peer), and the consequence (the peer returning the ball, accompanied by immediate auditory and visual rewards). The immediate positive reinforcement is designed to promote sustained engagement and participation.

Generalization of turn-taking skills is fostered through diverse virtual environments, such as an apartment room or a playground. A key feature of the game is its personalized reinforcement system, allowing for the customization of both



Fig. 1. Gameplay screenshots. The four images show a stop-motion display of the game in one of the environment setups. The ball is initially at the player's side, then thrown to the peer, and then thrown back to the player.

auditory (e.g., verbal praise, white noise) and visual (e.g., ceiling fan spinning) rewards based on each child's preferences.

Progress is tracked with a built-in system that records target behavior and session duration. Real-time monitoring is enabled by projecting gameplay onto an external TV screen (as shown in Fig. 2). This allows the therapist or parent to observe, give prompts, and assist when needed, ensuring the fidelity of the intervention's implementation.



Fig. 2. VR game projected to a TV screen. Player is using hand gestures to control the ball.

It is worth noting that the game was developed through an iterative software design methodology, similar to the framework described in [20]. Modifications to the original game, including new options on environment settings (e.g., amount of furniture) and additional reinforcers based on participants' special interests, were implemented based on feedback from caregivers or therapists, typically after one or two sessions.

The game is developed using the Unity 3D game development platform with the OpenXR package for interactions. Functionalities provided by the Meta Quest 3 VR headset, such as playing sound, tracking hand gestures, recording gameplay, and projecting to an external display, are used in the intervention.

C. Intervention Procedure

The study began with a baseline assessment for each participant. During this phase, the child engaged in a simple back-and-forth ball-throwing game with a peer. The number of successful consecutive passes was recorded.

After the baseline assessment, the intervention phase began, following the step-by-step testing procedure outlined in Fig. 3.

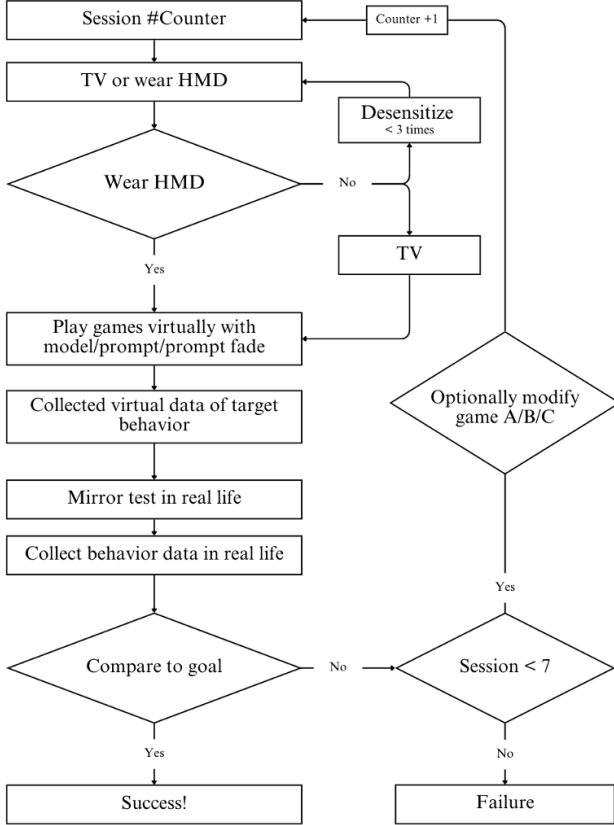


Fig. 3. Intervention procedure.

To familiarize the child with the VR system, a stepwise approach was implemented. Initially, the child observed the therapist playing the game projected onto a TV screen. Subsequently, guided by an adult, the child practiced essential gameplay gestures (such as grabbing, throwing, or thumbs-up). Following successful imitation of these actions, the VR headset was introduced.

Each weekly session consisted of 2-5 minutes of VR gameplay, followed by a 5-15 minute break, repeated up to five gameplay trials per session to minimize the risk of headaches or cybersickness. During the game, adults provided verbal and physical prompts to guide the child in making the correct gesture to send the ball back to the virtual peer. Once the child successfully completed this sequence five times, the prompts were gradually faded to assess their ability to perform independently.

After completing the VR intervention in each session, the child participated in a real-life ball-throwing game with a peer, given three opportunities. We measured the maximum number of consecutive throws the child could complete independently, and compared that value to the baseline assessment to evaluate progress. Adjustments to the VR game design, such as modifying specific features or options, were made in the next version when needed. This process continued for up to six weeks, with sessions considered successful if the child achieved predefined social behavior goals.

III. RESULTS

Table I outlines demographic data (age, sex, verbal skills) and performance metrics, such as ability to wear a headset, game appreciation ratings (on a scale of 1-5, where 1 = not at all and 5 = very much).

TABLE I
PARTICIPANT INFORMATION

Name	Age	Sex	Verbal	HMD start	Appr.
L-1	9	M	limited	2nd session	4
L-2	9	M	limited	1st session	4
L-3	8	M	limited	4th session	5
L-4	8	M	limited	never, TV only	3
L-5	9	M	limited	never	1

Fig. 4 illustrates the progression of turn-taking skills in real-life settings for four participants (L-1 to L-4) across three phases: baseline, intervention, and followup. At baseline, most of these children managed an average of fewer than 10 turns, while L-1 exhibited a rigid pattern of 20 turns, due to prior ABA training.

During the intervention phase, four out of five participants showed progress, though their responses varied. Participants L-1, L-2, and L-3 adapted to wearing the HMD and mastered the VR gameplay by the second, first, and fourth sessions, respectively. L-4 and L-5 faced challenges. L-4 was unable to wear the HMD but participated by watching the gameplay on TV and mimicking the gestures while the therapist played. L-5 exhibited aggressive behaviors and was unable to engage in the intervention (likely due to sensory overload), so L-5 withdrew from the study after the first session.

Measurements during post-intervention followup revealed sustained improvements in real-life turn-taking skills for participants L-1, L-2, and L-3, as indicated by their ability to engage in 50 consecutive throws without external support during follow-up tests. L-4, who engaged with the VR game on TV, also showed slow and steady improvement.

IV. DISCUSSION

The results suggest that the VR-based intervention may be more effective than traditional methods for teaching turn-taking skills to some children with Level 2 autism. In fact, all participants in this study had previously undergone 5+ years of ABA therapy, with turn-taking identified as a critical goal to improve their social interactions; yet, the progress achieved through traditional methods was limited.

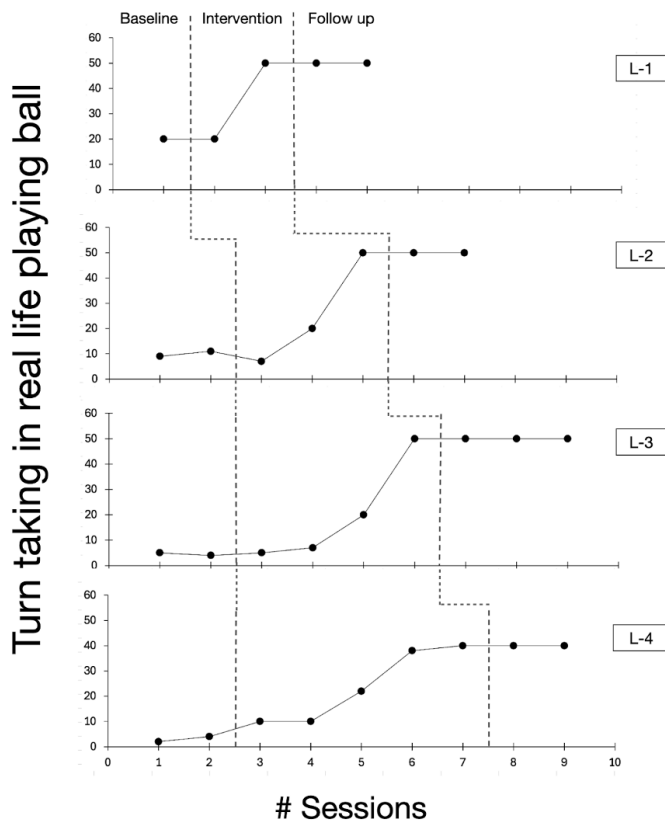


Fig. 4. Results on real-life turn-taking skills.

One illustrative example is participant L-3, who had an Individualized Education Plan goal from 2019 to 2024: “L-3 will engage in a turn-taking activity with a peer for a minimum of three turns with no more than one gesture prompt per activity in 80% of given opportunities across two weeks of data collection.” Despite five years of consistent support from professional therapists, L-3 was unable to meet this goal. Even when turn-taking was reintroduced as a focus in 2024, progress remained limited to three or four consecutive turns, achieved only with significant effort in structured settings. L-3’s baseline behavior consistently showed a tendency to disengage or avoid participation after three or four turns during the initial baseline assessment. In contrast, L-3 initially approached the VR game with hesitation, but gradually grasped the concept of turn taking in the game without any prompts after three sessions. By the fourth session, he had become comfortable wearing the HMD. Following his engagement in the immersive VR game, L-3 demonstrated a breakthrough in real-life ball game activity. He sustained 50 consecutive turns—a dramatic improvement from his baseline of 3-4 turns.

Perhaps most profoundly, this VR-based intervention created lasting impacts beyond the game itself. After mastering turn taking within the VR game, L-3 experienced a breakthrough in social interaction, successfully joining a group ball activity at school for the first time in five years. This newfound ability has led to improvements in expressive language

and social skills, as noted by parents, teachers, and speech therapists, highlighting the potential of VR interventions to build foundational skills that generalize to real-world social contexts.

The success of the VR intervention can be attributed to three key factors. The first factor is motivation. Personalized environments and reinforcers based on individual special interests proved highly effective in motivating participation. Among our participants, two were highly interested in spinning fans, two in elevators, and one in a bathroom fixture. For example, the child referred to as L-1, who had previously rejected VR headsets and displayed initial resistance, showed immediate eagerness to put on the HMD after an elevator was introduced to the game scene during the second session. Initially driven by these personalized elements, participants who later mastered turn-taking skills exhibited intrinsic motivation to play the game even when the reinforcers were not present. This child-led, self-motivated engagement aligns well with naturalistic ABA methods, and makes it easy to generalize the behavior in other settings.

The second factor is engagement, a well-documented challenge in real-life ABA therapy for children with Level 2 autism, who often struggle to maintain focus during therapist-directed activities. This difficulty partly explains the limited progress of traditional methods on the participants. In contrast, the VR game introduced a novel and immersive experience that naturally captures participants’ attention. The use of the HMD minimized outside distractions, thus enhancing focus and willingness to participate.

The third factor is the adaptability of VR in accommodating sensory sensitivities, a common challenge for children with autism. For example, participant L-2 experienced sensory overload caused by the visual complexity of the virtual environment, which included a cluttered background filled with furniture and objects. Simplifying the scene by removing nonessential background elements directly addressed this issue and allowed participant L-2 to engage more effectively after the second session. This underscores the potential of VR to provide flexible sensory-friendly settings that exceed the adaptive capabilities of standard ABA environments.

Beyond these three factors, the experimental evaluation revealed significant variability in social behaviors and sensory sensitivities among children with Level 2 autism. This heterogeneity underscores the importance of personalization through an iterative design process. For instance, the initial version of the game relied solely on the grab-and-throw hand movement, which proved challenging for multiple participants. The subsequent addition of gesture mode led to significant improvements in accessibility and engagement.

Several limitations, such as the small sample size, limited age range, and the absence of female participants, should be acknowledged. Moreover, the study encountered challenges with the overall applicability and tolerability of VR for children with severe autism. Specific instances (e.g., participant L-4’s distress related to visual occlusion and participant L-5’s sensory overload) underscore the need for further development

of VR technology to ensure inclusiveness, particularly regarding diverse sensory sensitivities. Nevertheless, the positive results observed in participants who tolerated the VR-based intervention are encouraging.

V. CONCLUDING REMARKS

The findings of this study highlight the potential effectiveness of VR-based interventions on children with Level 2 autism. By addressing common challenges in real-life ABA therapy, such as lack of motivation and difficulties in engagement, individualized VR games that incorporate ABA principles offer a promising approach to autism intervention, especially for children with moderate-to-severe autism who did not respond well to traditional ABA therapy.

While satisfactory results were obtained in our study, scaling individualized VR interventions to clinical settings poses challenges regarding cost and complexity. This is especially true if the individualization process has to be implemented by submitting new requirements to the software vendor and waiting for the development-test-release cycle, which can take weeks or longer and incur a high cost.

To address the cost of individualization, we propose three recommendations. First, individualized VR interventions should be considered as a second-line therapy, reserved for cases where traditional approaches prove insufficient. Second, VR programs should be developed with modularity in mind, allowing therapists to add new game elements from an external asset library through configuration, without requiring software updates. Finally, emerging artificial intelligence tools for 3D model generation can reduce the cost of creating highly specific personalized elements on demand [21]. Given these pragmatic solutions, we are optimistic about the future scalability of individualized VR interventions.

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