A Mixed Reality, Full-Body Interactive Experience to Encourage Social Initiation for Autism: Comparison with a Control Non-digital Intervention

Ciera Crowell, Batuhan Sayis, Juan Pedro Benitez, and Narcis Pares

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Abstract

Despite a proliferation in digital intervention tools for autism, many studies lack comparison to standard intervention tools, and are not evaluated with objective and standardized measures. In this paper, we present research on the potential of Mixed Reality (MR) experiences using Full-body Interaction to foster social initiation behaviors in children with autism while playing with a child without autism, in a face-to-face co-located configuration. The primary goal was to test whether practicing socialization in a virtual environment catered towards individuals with ASD could be a way to reduce anxiety while simultaneously forming collaborative behavioral patterns. Building on the results of a preliminary study, this second phase compares our system to a typical LEGO social intervention strategy using construction tools and toys as an aid to the psychologist, therapist or caregiver. Results are based on four data sources: (a) video coding of the externally observed behaviors during the video recorded play sessions (b) log files of our system showing the events triggered and the real-time decisions taken; (c) physiologic data (HRV & EDA) gathered through child-appropriate wearable; (d) and a standardized anxiety questionnaire. The results obtained show that the mixed reality setting generated as many social initiations as the control condition, and no significant difference existed in the reported anxiety levels of the children after playing in the two conditions.
Introduction

Autism Spectrum Disorders (ASD) are a collection of neurodevelopmental conditions which manifest in difficulties in social and communication behaviors and repetitive or restricted interests\(^1\). Children with autism have difficulties relating to others, but show a marked interest in digital media, resulting in a high affinity that previous studies have observed between these individuals and computerized tasks\(^2\). Recent intervention tools for autism have focused on the incorporation of digital media as a way to motivate the interests of children with autism in social skills training. However, few projects have involved long-term controlled experimental trials which compare digital interventions to pre-existing therapy tools. Furthermore, many studies lack the inclusion of standardized or objective data such as physiological indicators which may allow these new interventions to be compared across platforms.

This study builds upon the results from a previous study which indicated the potential of a mixed reality intervention in fostering social and collaborative behaviors in children with ASD in exploratory play with a non-ASD partner. In the present study, we developed an experimental protocol using standardized and objective data collection. A control setting was arranged using elements of LEGO play therapy, a common tool in social skills training for autism. The primary goal was to test whether practicing socialization in a virtual environment catered towards individuals with ASD could be a way to reduce anxiety while simultaneously forming collaborative behavioral patterns. A secondary goal was to test multimodal data collecting methods to detect changes in the children’s willingness to collaborate and their active state throughout. To detect willingness to collaborate, we used system data logs and video coding of social and collaborative
behaviors. To detect changes in their active state, we used physiological response indicators of Electrodermal Activity (EDA) and Heart Rate Variability (HRV), and used a standardized questionnaire to detect anxiety state. As the results of the physiological study will be described in detail in another paper, this report will focus on results from the other three data collection methods in comparison to the LEGO play therapy condition.

**Background**

The first intervention strategies for autism had roots in behavioral analysis and positive reinforcement of desired behaviors, as early as the 1970’s. One such method was Applied Behavioral Analysis (ABA), which focuses on how changes in the environment might affect behavior. Based upon this emphasis of environmental factors, the search for intervention practices in a natural environment has led to the emergence of Naturalistic Developmental Behavioral Interventions. These interventions are unique in their balance between the child’s and therapist’s control. This practice is based upon the developmental psychology idea that children’s learning is bolstered by their position as active participants in the environment. These intervention strategies may have a general focus, or may focus on a specific area like social skills, such as Social Communication/Emotional Regulation/ Transactional Support and the Early Start Denver Model. However, the heavy burden on caretakers due to intensive treatment times has led to the search for digital intervention tools which seek to relieve the amount of manpower necessary to carry out long term treatment.

With the intention of reducing the focus on the media device, full-body interaction technologies aim for interaction with the digital media through naturalistic gestures and movements. In the research of full-body interaction systems for children with ASD, various projects have aimed to implement embodied interaction for the purposes of motor movement therapy, play
therapy, and socialization via collocated interaction. Large scale full-body interactive environments also allow for physical exploration and face-to-face interaction between users. Bhattacharya et al. presented research using Microsoft Kinect in a classroom setting to promote engagement with peers and social behaviors in children with ASD. In addition, collocated full-body interactive environments allow multiple users to interact in the context of a digital environment which adapts to their input, providing an adaptive context for the practicing of social skills face-to-face with others.

**Context**

To test the link between social behaviors elicited in a virtual environment and changes in internal state, as indicated through measurements collected via physiological sensing, we used the Lands of Fog system. Lands of Fog is a Mixed Reality, full-body interactive environment created to foster social and collaborative behaviors in children with autism. The system was previously tested with children with autism and non-ASD children to see the effects of the exploratory play environment over the course of multiple sessions. Preliminary testing revealed that children with autism significantly increased in total social behaviors over the course of three play sessions.

For the current project, we developed a formalized experimental protocol to test the system in comparison to a standard activity used in naturalistic therapy for autism, which used LEGO play blocks. In addition, we expanded the data collection protocol to include video recording, system logs, standardized questionnaires, and physiological data (HRV and EDA) while the children were playing in both settings.
Both activities were based around fostering collaboration between a pair of children through shared discovery. In the LEGO condition, children were instructed to find six Lego characters hidden among buckets of multicolored blocks, then use these blocks to build a boat together. In the Lands of Fog condition, children were instructed to find keys hidden in props through the virtual environment, and use these keys to open a trap door. Tasks were designed to require a basic level of coordination between the players. The main difference was that the Lands of Fog condition responded and provided feedback to the progress of the players, while the LEGO setting was entirely passive, i.e. the pieces did not inherently respond to the children’s actions.

**Content**

The Lands of Fog system aimed to give an automatic and consistent response to the progress of the players. When children collaborate within the virtual environment, they are provided with a positive response from the system, i.e. a new feature or upbeat tune. The system responses are in place to provide a sense of positive reinforcement to players which would otherwise be provided by the therapist running the session, whose job is to guide children through the tasks and provide support when positive behaviors are achieved. The Lands of Fog system provides structure and assistance to therapists in mediating the interaction between players, while providing a controlled context for children to put into practice social behaviors.

The system consists of a floor projected virtual environment on a 6 meter diameter projection surface (Figure 1). The children hold a physical object, a butterfly net fitted with LED lights that is tracked by the system. In addition to interacting with the virtual elements, the physical object was designed to help children focus their attention on the environment through cognitive offloading.
The system consists of a range of visual and sonorous effects to encourage creative exploration between the child with autism and a non-ASD peer. The premise of the game is a fantasy world partially obscured by a dense layer of virtual fog, where children can find and capture insects which evolve into creatures. The system uses subtle strategies to bring the children closer, such as the possibility to collaboratively manipulate props and merge creatures. For a full description of the game design, refer to (Mora Guiard, et al.).

**Methods**

For the purposes of this experiment, we decided to test the system with pairs of children, with one child with autism and one child without autism, to replicate the collaborative activities
that could be found in a mixed cognitive abilities classroom. The experimental sessions were divided into two parts: the Lands of Fog condition, and the LEGO based control condition. The pair attended both conditions within a single experimental session, in between completing questionnaires, a five minute break and a baseline exercise. The order of conditions was randomized using an online statistical web program. Pilot trials indicated that 15 minutes was suitable for the children to discover all items in the game design, and that attention spans drifted off after this amount of time. Therefore, children played both Lands of Fog system and the LEGO control condition for 15 minutes each.

For the LEGO condition, the activity was modeled after an activity found in social skills therapy\(^9\), where a group of children is asked to work together to complete a short task using LEGO blocks. In our case, the children were asked to find a set of “lost” LEGO figurines, then build a ship for the figures. Each pair of children played once in both settings, and the order of conditions was randomly assigned to counterbalance the effect of order of tasks.
At the beginning of the session, each child was introduced to the experimental setting, which was a laboratory at the university. Parents of the children, two researchers, and a psychologist who ran the sessions were present. Taking into account the emotional sensitivities that could occur with children with autism during the experiment, the psychologist began the session in a manner similar to a therapy session. This was done with a visual support called “Jumby is Calm” of the type used in social skills therapy, relying upon visual cues as a tool to anticipate outcomes of the new situation. Children were then introduced to the materials used during the experiment, shown a brief video of how to hold the pointer devices, and were fitted with sensors for the physiological sensing. These sensors were integrated in a wearable we designed as a “su-
per hero’s cape” to make it fun and acceptable by the children. Most children did not show discomfort at wearing the sensors, but some were wary about removing the adhesive pads. Before and after each condition, children responded to interview questions administered via tablets.

**Population**

Children with autism were recruited through the Hospital Sant Joan de Déu in Barcelona, which has a specialized unit dedicated to autism. Non-ASD children were recruited via flyers distribution in educational centers near the university and via social media diffusion. A total of 36 children between the ages of 8-12 years old participated in the study (N=6 female, N=30 male). The study recruited high-functioning children with autism who had a diagnosis for autism determined by the scale of Observation for the Diagnosis of Autism (ADOS) module 3, designed for young people with verbal fluency, with a minimum severity diagnose of 4. Non-ASD children were those with no diagnosis of autism or any other condition. Both ASD and non-ASD had to score a minimum IQ of 70 as determined by the Wechsler Intelligence Scale for Children.

**Data gathering and analysis**

Information was collected on social behaviors, with a specific focus on social initiations, anxiety level, physiological indicators including HRV and EDA, and collaborative actions.

**Social Initiations**

All sessions were video recorded via two cameras stationed at opposite sides of the play arena. Videos were cut into 5 minute sections, and the first and last 5 minutes of both the experimental and control conditions were coded for social behaviors, which provided a sufficient time window to gather information on the tendency of social behaviors throughout the session.
In order to evaluate the main social interaction components of the observation scheme, including occurrences of social initiation, response and externalization, the inter-coder reliability has been calculated for these classes, both through percent agreement and Kappa (Cohen’s Kappa) in a randomly selected video. Kappa Scores ranged from 0.60 – 0.69 and the percentage level of agreements ranged from 0.71 - 0.78 between three coders. Boris video coding software was used, and the social behaviors were coded using an observational grid with categories derived from Bauminger’s Social-Emotional Intervention study\textsuperscript{15}.

**Anxiety level**

To gather data on the child's trait anxiety level and the changes in anxiety level before and after each experimental condition, we used a standardized questionnaire called STAIC (State-Trait Anxiety Inventory for Children)\textsuperscript{13}, where children responded to questions such as “I feel relaxed.” Questions were read aloud to the children from a tablet, who could also read the questions and mark their responses, “Not at all,” “Somewhat”, or “Very much.” Parents also filled out the Child Behavior Checklist (CBCL\textsuperscript{14}) prior to experiments, and the project’s psychologist also held interviews with the children after each condition to understand the children's reception to the games and collaborative activities. Post session interview questions included open ended items such as “Do you remember a moment in which you spoke to or collaborated with your partner in the game” and closed ended items such as “Would you prefer to play with your partner in the game or on the playground?”

**HRV and EDA**

Physiological data was recorded using a Biosignal PLUX device which recorded heart rate variability (HRV) and electrodermal activity (EDA). Sensors were placed on the children's neck and chest at the beginning of the trials, and remained in place through both experimental
conditions. A wireless transmitter on the device allowed the children to move freely while data was visualized on a computer in the same room.

**Collaborative Actions**

The Lands of Fog system also recorded data on player activity through internal logs. This data recorded a timestamp when players triggered individual and collaborative actions, and also tracked player movement through the scenario. Collaborative actions included the completion of game mechanics which could only be triggered by both players simultaneously coming into contact with the same virtual object. Individual actions included game mechanics which a single player could engage in without the help of their partner. After the trials, the logs were parsed to distill an overall view of player progress through each session, and to triangulate moments of collaboration in the system.

**Results**

As all children participated in both conditions, a paired-samples t-test was used to search for significance (p < .05). No significant difference was found between the number of initiations made by children with autism between sessions playing Lands of Fog and the control condition. During the first 5 minutes of play, children made significantly more responses t(16)=−2.37, p=.031 in the control condition (M=4.29, SE=.751) than in the Lands of Fog condition (M=2.56, SE=5.82). In contrast, during the last 5 minutes of play, we saw a trend of more initiations t(16)=1.975, p=.067 in the Lands of Fog condition (M=5.25, SE=1.27) than the control condition (M=3.25, SE=.67). We also saw a significant increase t(16)=−2.048, p=.05 in the number of responses during the last 5 minutes playing Lands of Fog (M=5.25, SE=1.27) than the first 5 minutes (M=2.56, SE=5.82). We also saw a trend t(16)=1.912, p=.074 of more non-verbal behaviors in Lands of Fog (M=4.88, SE=1.131) than in the control condition (M=2.76, SE=7.93).
A Wilcoxon’s signed rank test revealed that the children with autism felt like they knew their partner significantly more after both the control condition and the Lands of Fog condition than before the experiments. No significant difference was seen in the reported anxiety levels after either condition. When the children were asked what the purpose of the activity had been, non-ASD had a higher tendency to report comments such as “meet others” and “trust in others”, and children with autism focused more on aspects related to the game concepts such as “unlocking new worlds” and “catching the insects.”

The game log files were filtered for actions occurring within 10 seconds before or after the child with autism made a social initiation. The most common game events occurring within 10 seconds of an initiation were hunting insects and greetings made by characters when they came in close proximity with another player. However, hunting insects and greeting other characters had the highest prevalence of total occurrences during the sessions, so although they accompanied social initiations most frequently, the percentage of times that those events led to a socialization was relatively low. The least common events to accompany a social initiation were creatures merging, manipulation of props, and creatures changing textures. However, as these events happened much less often during a session, the percentage of times that these events led to a social initiation was much higher.

When we separate the events which occurred before an initiation from the events which happened after an initiation, we see that although prop manipulations occurred before initiations 11.1% of the time, these prop manipulations never happened after an initiation. In contrast, creature greetings were more common after an initiation (32.5%) than before (22.2%).

**Discussion**
In the log files, we saw that the game’s collaborative events coincided with social initiations at a higher rate than solitary actions. This leads to the understanding that children working together on a common task gives an opportunity for the children with autism to initiate conversation with their partner. In addition, we saw that creature greetings were more common after an initiation than before. As creatures greet one another when the children get close to each other, we can assume that those initiations were made with the intent of getting near their partner. As the game bases the collaborative interactions on joint actions, we can understand that children’s proximity was a factor in fostering initiations.

The video coding of social behaviors revealed a higher level of non-verbal behaviors in the Lands of Fog condition than in the LEGO condition. The most common non-verbal behaviors were tagged as “Close Proximity,” recognized as when a child came within three feet of their peer without completing a social initiation or response\(^\text{15}\). We might assume that the large scale setting led to a higher importance of locomotive actions, as players would accomplish collaborative actions by moving within close proximity of their partner, sometimes coming from across the play arena. In this case, players could accomplish the joint actions without verbal communication. As the LEGO setting provided a context where players were already within close proximity with each other, sharing a focal point of joint attention, the non-verbal behavior of Close Proximity was not as common.

With regard to the questionnaires, we saw that no significant difference existed in the reported anxiety level of the children after playing in the two conditions. When we consider that the children with autism made an average of 11.06 initiations per Lands of Fog session and 11.56 initiations per session of the control condition, we can see that both naturalistic environments serve as a positive context for fostering social behaviors. In addition to creating social initiations
in the Lands of Fog condition, we also see that the children were relatively relaxed while doing so, as seen by the similarity in perceived anxiety state to the familiar context of playing LEGO. As children could choose to play with their partner, and also had the opportunity to step back and play individually, we believe the choice to gently encourage collaboration created a comfortable setting for socialization. Future work could compare the effect of encouraging socialization to a setting where children must socialize in order to progress in the game.

**Conclusion**

In this study, we aimed to compare a passive tool to an active, mixed reality tool that holds potential to be inserted into therapy protocols. Data collected from this study has improved the understanding of how the children with autism interacted with the tool alongside a peer and the collaborative behaviors they engaged in both settings. This study furthers the idea of developing a tool that is actively mediating the interaction between kids, fostering intervention to aid human mediation, by demonstrating that the settings are comparable. Further studies could see how using this tool might impact the uptake of social skills over the course of a long term intervention study. In this case, the tool might be inserted into a pre-existing social skills intervention protocol in place of a passive tool, such as open ended games during unstructured play, which is a time in which psychologists currently mediate small groups of children in the use of social behaviors.

From the data analysis, we can see that no major differences existed between the experimental setting and the control setting with regard to the number of social behaviors. The differences that existed might be attributed to the design of the system, such as an increase in activities related to socialization as the children became familiar in the scenario and possibilities for collaboration which appeared later in the game. Also, the use of standardized anxiety measures such
as the STAIC and CBCL questionnaires gave an understanding of how the system related to the children’s state anxiety level before and after each activity. The combination of video coding, which tends to be vulnerable to subjective bias, and objective measures such as system data logs, allowed us to gain an understanding of which aspects of the system were related to moments of social initiation, providing the idea that interaction design can influence internal state.

**Author Disclosure Statement**

No competing financial interests exist.

**Bibliography**


Figure legend:

Figure 1. Two players can collaboratively manipulate props in the scenario by bringing their nets together
Figure 2. A control condition included LEGO social skills training elements where children were asked to collaborate in a shared building task.