Designing Motion-Based Activities to Engage Students with Autism in Classroom Settings

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ABSTRACT
We report on a nine-month-long observational study with teachers and students with autism in a classroom setting. We explore the impact of motion-based activities on students' behavior. In particular, we examine how the playful gaming activity impacted students' engagement, peer-directed social behaviors, and motor skills. We document the effectiveness of a collaborative game in supporting initiation of social activities between peers, and in eliciting novel body movements that students were not observed to produce outside of game play. We further identify the positive impact of game play on overall classroom engagement. This includes an "audience effect" whereby non-playing peers direct initiations to those playing the game and vice versa, and a positive "spillover" effect of the activity on students' social behavior outside of game play. We identify key considerations for designing and deploying motion-based activities for children with autism in a classroom setting.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces.

General Terms
Design, Human Factor.

Keywords
Autism; motion-based games; social skills; motor skills.

1. INTRODUCTION
Individuals with diagnoses on the autism spectrum are a heterogeneous group, but all experience varying levels of difficulty with social and communication skills [18]. In particular, school-aged children with autism struggle with peer interactions and friendships [26]. Because such interactions and relationships play a critical role in social learning across the lifespan [21], many behavioral interventions specifically target social and communication skills with peers.

There has been an explosion of technologies for supporting these skills in children with autism [19]. Social behaviors have been targeted with platforms such as multitouch tabletop surfaces [7], tablets [17], tangible user interfaces [10], virtual agents [28], and games [2]. Individuals with autism may find the multi-sensory nature of social interactions overwhelming [1,24], so the potential to strategically mediate interactions through technology may represent a powerful stepping-stone to building these skills [22]. Sharing a virtual space with a peer may be particularly effective in scaffolding interactions in autism [1,3,6,28]. Motion-based games have the additional benefit of targeting movement, gesture, and coordination, which, while not unique to autism, represent common areas of difficulty.

Current research on "touchless" motion-based games (i.e., using technology such as the Kinect) in autism largely targets specific skills: making eye contact, pointing, imitation, etc. [4,6]. Evaluations typically involve deploying activities in separate experimental sessions, either one player at a time [14] or in the presence of an instructor [6] or therapist [1,2]. Fewer studies[1] focus on games designed to facilitate social interactions between the child with autism and his or her peers, with evaluation in the context of a classroom setting [1]. This is the gap we address.

We focus on motion-based activities for one or two children with autism that are played in the presence of peers (with autism) and mediated by the teacher. The goal of our research is explore the design of activities that can be used in a classroom setting, and to explore their impact on students' engagement and (social) behavior. We report on a nine-month-long observational study with teachers from a school for children with autism. We conducted classroom observations and teacher interviews to explore potential uses of the Kinect as a platform for creating interactive activities in a classroom setting. We worked with teachers to iteratively design three motion-based activities (interactive storytelling, a free-form interaction, and a game) and used them as technology probes to explore the impact on student behavior. With the teachers, we selected the most promising activity (game) for deployment in two classrooms over a period of two months and conducted video analysis to identify specific effects on student behavior, and how teachers use the game to support classroom-level peer interactions.

Contributions of our work include:
1) Documentation of the impact of motion-based games deployed in a classroom setting on engagement, peer interactions, and movement in children with autism;
2) Design recommendations for motion-based activities for students with autism to be deployed in a classroom setting.

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2. RELATED RESEARCH

We review relevant previous research on collaborative technologies and motion-based activities for children with autism, and deploying games in classroom settings.

2.1 Collaborative Technologies

Activities designed to encourage social interaction in children with autism on a multitouch platform have included collaborative games [1,23], collaborative story-telling [11], and interactive activities like drawing or making music [17]. In one study of a collaborative game, empowering the facilitator emerged as a primary guideline for coordinating social interactions among the children [13], which was subsequently accomplished by enabling the facilitator to customize controls in the activities [31]. The need for an adult moderator was also suggested by a participatory study with children with autism that focused on table top games [23]. A study comparing the use of tangible technology and physical objects with children with autism found more social interaction (cooperative and parallel play) and less disengagement when tangible technology was used [10]. In a study comparing peer-directed behaviors during activities involving drawing, puzzles, music and photographs on a multitouch tablet to behavior during equivalent activities without the tablet, more sentences and physical interactions were reported amongst peers with autism when using the tablet [17]. Storytelling activities over a tabletop interface have also shown positive effects in increasing response to peers with autism [11]. A study with mobile technology that detected and suggested crucial steps during peer interactions (e.g., making eye contact, replying to conversation initiators, disengaging appropriately at the end of interaction, etc.) documented improvements in peer communications and a decrease in social and behavioral missteps [9,30].

Social skills have also been targeted through storytelling conversations with autonomous virtual characters [3,28]. A study of collaborative storytelling in children with autism interacting with an authorable virtual peer and a typically-developing peer reported increased contingent discourse and more appropriate topic management with repeated interactions only with the virtual peer [28].

2.2 Kinect Activities

Munson and colleagues point out that the use of the Kinect on a large screen "*naturally creates a shared experience in which individuals with varied intellectual and communication abilities can participate"* [20]. The Kinect also allows for a natural form of interaction without additional on-body instrumentation [1]. Kinect-based games have served as a platform to study motor and social behavior in children with autism and to target specific skills like self-awareness, body schema, posture, communication, and imitation [2,14]. A study with commercially-available games for the Kinect found an increase in attention and higher rates of positive emotion in games where the players were represented as avatars and direct movement of the child affected a virtual object [1]. Another study using a Kinect-based environment with virtual dolphins emphasized the importance of studying the impact of such interactions on participant's social interactions outside the virtual space [8].

2.3 Designing for Classroom Settings

A study on games deployed in school settings to motivate good nutrition and exercise habits recommends designers align game design decisions with the objectives of the stakeholders and attend to the special needs and limitations of the target population [25]. A recent study on Kinect-based "exergames" discusses teachers' concerns about deploying games in classroom settings, such as disruptions and lack of space [12]. The teachers suggest specific strategies for games in classrooms, such as using them as rewards or to encourage turn taking.

Our study extends this previous work in two ways. First, we explore whether additional unique impacts on student behavior and design considerations arise when designing games to be deployed in classrooms for individuals with autism. Second, we incorporate teachers' suggestions into a final prototype that we deploy in two classrooms and evaluate over a period of two months to document the impact on student behavior.

3. RESEARCH DESIGN AND METHODS

We first describe our participants and the classroom setup. We then describe the user-centered design process, explaining the formative, iterative and evaluation phases in greater detail.

3.1 Participants

We collaborated with a school for children with autism that follows an educational philosophy based on the Developmental, Individual-Differences, Relationship-based (DIR) Intervention Model [15]. In addition to academics, general classroom activities at the school include storytelling, arts and crafts, yoga, farming, and animal interactions. Students are also pulled out for individual occupational, speech, and Floortime (a component of DIR) therapy sessions. The school places particular emphasis on relationships and engagement, abstract critical thinking, problem solving, and social cognition.

We worked closely with teachers in two classrooms. Each classroom includes a head teacher and a helper teacher. Discussions with the school involved the two head teachers from the target classrooms, the Executive Director of the school, the lead Floortime therapist, and a speech therapist. The study was approved by our university's Institutional Review Board, and parental consent for participation and video recording was obtained for all participating students. Video recordings of game play sessions collected in the final phase of the study included eighteen students between the ages of 8 and 19 years. Recordings from the first classroom included six students (Mean Age=9.8 years, SD=1.7). Recordings from the second classroom included seven students from that classroom (M=11.3 years, SD=2.1) and an additional five students who were regularly pulled in from other classrooms specifically to participate in game-play sessions (M=16.6 years, SD=2.1).

Students at the school are grouped into classes according to their chronological age and developmental profile, as defined by one of four broad clinical descriptive groups (I-IV) [16] that reflect increasing challenges in the area of communication, social engagement, motor planning, imitation skills, sensory reactivity, and auditory and visual-spatial processing. Of the 18 participants in our study, two were classified by the school in clinical group I ("high functioning" group), eight were classified in group II, and the remaining eight in group III.

3.2 Classroom Setup

Each classroom at the school has a desktop computer connected to an electronic whiteboard that supports touch interaction. Teachers use the whiteboard for a range of academic activities (e.g., math worksheets, drawing). We installed our prototype application on computers in two classrooms, and set it up to project the activities on the whiteboard. We mounted the Kinect sensor at the top of the whiteboard, facing the class. To capture video recordings in the final deployment phase, we mounted an HD camera at the head of each classroom such that it would record students' faces and bodies as they interacted with the activities (see Figure 1). We gave teachers a remote to start and stop the recordings. We conducted a training session with the teachers to instruct them on launching the application containing the activities. We also gave each teacher a handout with instructions on how to run the application and how to arrange the classroom to facilitate full-body detection by the Kinect.

Based on early trials of classroom deployments, we implemented specific strategies to support the activities. A bounding area ("stage") was marked on the floor with tape at the ideal distance where the Kinect could detect the students. Before starting the application, the teachers asked students to clear the desks away from the stage. Children whose turn it was to play were called up to the marked-off area by the teacher, while the other children were seated in a semi-circle around the bounding area, out of the range of detection of the Kinect.

Figure 1. Classroom setup: the Kinect (red circle) is mounted at the top of the electronic whiteboard. The video camera (orange circle) looks out over the classroom.

3.3 Description of Study Phases

In this section we describe the process of iteratively designing and evaluating our prototypes with the teachers, including how we solicited teacher feedback and specific features added to the activities based on this feedback.

3.3.1 Phase 1: Formative Research (Months 1 & 2)

This phase involved classroom observations and two initial meetings with the teachers at the school to demo potential activities and brainstorm uses of the Kinect as a platform for creating interactive activities to support movement and social engagement for students in their classrooms. During the demo sessions, the teachers called in some of their students to try out the activities. This phase resulted in the development of three prototypes, described below. These three prototypes were then deployed in the two classrooms at the end of month 2.

Game: The goal of this activity was to catch objects in order to score points. The player could be represented as their own live image or as an avatar (skeleton), and select from one of six themes with an accompanying soundtrack (e.g. jungle, outer space, etc.). Upon launching the game, three objects appeared at random locations on the screen with a blinking animation. The player had to reach toward an object and "touch" it virtually with his or her hands to "catch" it and score points. As the player collected one object, another object would replace it, at a different location. The score was displayed in the upper left hand corner of the screen and the remaining game time was displayed in the upper right hand corner of the screen.

Free-form interaction: This activity reflected the player's body and movements in real time via their own live image or an avatar. The player could select from a variety of avatars (e.g., a skeleton figure, popular characters like Iron Man, a princess, Mr. Bean, etc.) and one of six different backgrounds (e.g., white; underwater theme; jungle theme, outer space theme). Up to two players could participate when the avatar option was selected, and up to 6 players could participate simultaneously when the "live" image option was selected.

Interactive Story: The school uses storytelling as a pedagogical tool to encourage movement and imitation, language, and emotion expression. Teachers project still images of the story on the electronic whiteboard, play an accompanying audio track, and encourage students to enact parts of the story through movement and sound. We presented an interactive version of a story that the school had previously utilized, including similar gestures, images, and soundtrack. The goal was to encourage the player to make specific movements or gestures to animate elements of the story on the screen. At specific moments, the story and accompanying audio would pause and wait for the player to perform the target gesture; when the Kinect recognized the gesture, the animation would play and the story would proceed.

3.3.2 Phase 2: Iterative Prototyping (Months 3-7)

Starting with month 3, the teachers began to try out our prototype activities in their classrooms, in the course of the school day. We did not dictate when and how often the teachers should try out the activities with their students, but teachers reported doing so several times per week. Two weeks after the initial classroom deployments we met with the teachers in person at the school to discuss their experiences. The teachers provided us with feedback on the usage and impact of the activities, made specific suggestions for changes to the prototypes, and reported suggestions and comments from their students. Further feedback to gather requirements for making changes to the prototypes was subsequently solicited via email exchanges, Skype conversations, and in-person meetings.

Game: Several modifications were made over the course of these five months. To encourage a wider range of movements, the teachers requested the option to choose between use of either hands or feet to catch the objects. To help cue students as to whether hands or feet should be used to catch objects, the body part was circled on the player's avatar. Two additional themes were introduced in the game based on the interests of the students. Teachers reported some students were stressed by the countdown of remaining game time, so an "infinite" play mode was added. Most significantly, a two-player mode was introduced in the game to explicitly facilitate interaction. In this mode, both players had to decide which object to catch, and then to reach toward this object at the same time in order to catch it and score points. When using the skeleton avatar, one player was colored red and the other was green, as shown in Figure 2. After trying out the two-player mode, the teachers reported that some students had difficulties coordinating with their play partner about which object to catch jointly. To address these joint attention difficulties, an option was added whereby only one object would appear at a time in two-player mode.

Free-form interaction: Aside from additional themes (backgrounds) reflecting student interests, no modifications were requested, as this was essentially an open-ended activity. However, the teachers gave us feedback about the ways they were using this activity to facilitate classroom-level interactions, described further in the results section.

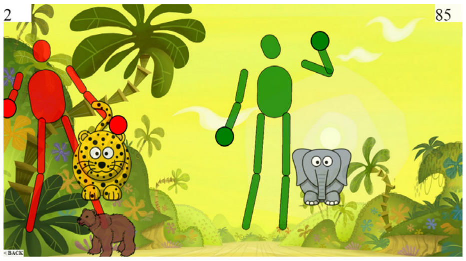

Figure 2. Two players in the game represented as skeletons, catching objects together to score points.

Interactive story: As the school was starting a new story at the beginning of Phase 2, we met separately with the teachers to discuss the design of an interactive version of this story. We worked closely with them to identify the gestures and movements the students would be expected to produce, the animations that would take place on the screen, and added an accompanying soundtrack narrated by one of the teachers. The teachers requested that we introduce a new feature whereby the student could be inserted into the story, either as one of the characters or as him- or herself (i.e., the "live" image of the child). Moreover, the teachers wanted to reward students for attempts at producing the correct gestures. Thus, we added a remote to enable teachers to manually trigger the animations, bypassing the Kinect-based detection.

Despite these iterations, at the end of month 6 the teachers continued to report practical difficulties with using the interactive story that they did not experience with the game and free-form interaction. The turn taking strategy used with the Kinect set-up, where one student at a time could drive the animations, proved problematic as the usual storytelling time practice was for all the students to participate and students continued to crowd the "stage" area. While performing the actions of the various animals, students presented at oblique angles to the Kinect that led to failed gesture detections. Moreover, the teachers wanted the students to be able to enact movements that were not compatible with the stage area and the gesture detection (e.g., crawling under furniture, using physical props). For these reasons, we collectively decided to abandon the interactive storytelling activity at the end of Phase 2. This decision and its implications for design is discussed in section 6.

3.3.3 Phase 3: Evaluation (Months 8 & 9)

We focused on the game for a longer-term deployment and evaluation, as the teachers reported that this activity was the most successful in supporting student engagement and interaction. During this phase, we stopped making further modifications to the game prototype and asked the two target teachers to initiate video recordings of game play sessions in their classroom at least two times per week. As discussed above, cameras were installed in both classrooms and teachers were given a remote to help them start and stop the recordings, Teachers reported that they incorporated game play in their class schedule on a daily basis. Over the course of these two months, we continued to receive teachers' feedback via emails and made several in-person observations of the game play sessions. Figure 3 shows a screenshot of students playing the game in two-player mode captured from one of the video recordings. The image projected on the whiteboard is shown in the lower left-hand corner to illustrate what the students were seeing on the screen.

Figure 3. Students playing the game in two-player mode, each represented as a skeleton avatar (inset).

4. ANALYSIS

In this section we describe our approach to analyzing teachers' feedback in all three phases of the study, and our analysis of the videos recorded by teachers in Phase 3.

4.1 Teacher Feedback

The data available for this analysis included: transcribed audio-recordings from in-person meetings with the teachers; our notes from these meetings as well as from Skype calls and direct observations; and copies of email exchanges with teachers. We also reviewed and took notes on videos that the teachers had voluntarily taken on their phones to record novel interactions they wanted to share with us. We grouped our notes and transcriptions together in the form of text and performed affinity-modeling, extracting key points and quotes on the impact of the activities on students' behavior. This generated the following common themes: engagement with the activity; impact on social behavior; impact on movement and motor planning; and other collateral effects on behavior. These themes are described in detail in the Findings section.

4.2 Video Recordings

From the 108 recordings captured by teachers in Phase 3, we selected a subset for analysis, using the following approach. We sampled sessions equally across month 1 and month 2 of the two-month deployment, and across individual and two-player (collaborative) modes of game play. We then selected as many sessions as possible while ensuring that each of the 18 students in the two classrooms contributed no more than one session per deployment month and mode of game play. This strategy led to a subset of 57 sessions, with average duration of 2 minutes and 35 seconds (SD = 1 minute 11 seconds)

In order to analyze the videos in a structured manner, we decided to focus on the frequency of specific behaviors (see Table 1). The choice of behaviors was driven by the themes derived from the qualitative analysis of teacher feedback and researcher observations in Phases 1 and 2, and our *a priori* goal of focusing on the impact of the activities on students' social behavior. The first and third authors independently coded 28 of the sessions using the template in Table 1. Inter-rater reliability was 89%, calculated as follows: the number of cells where the frequencies of the coded behavior that did not match was subtracted from the total number of cells coded by both researchers combined, as a proportion of total coded cells. Any discrepancies in these sessions were discussed until consensus was reached. The first author then coded the remaining 29 sessions, and transcribed verbal initiations and responses that related to the thematic groups from the qualitative analysis.

Frequencies of behaviors were converted to rates per minute to facilitate comparison across sessions of varying lengths. We calculated descriptive statistics for all variables, separately for one-player sessions ($n = 2$) and two-player sessions ($n = 29$). For each behavior, we further counted the number of sessions during which the behavior did not occur at all (see Table 2).

5. FINDINGS

We present data obtained across the three phases organized by themes from the affinity modeling, and provide qualitative and quantitative evidence for the same from the video analysis.

5.1 Engagement

An early observation from Phase 1 and 2 was the sheer joy the students experienced during these activities. They resonated with seeing themselves represented via avatars on the screen, and explored how their movements would be reflected in specific actions of the avatar. For example, during our first demo session with the free-play interaction, they jumped and waved their arms around to see the corresponding movements of the avatars; one child picked up objects to see if he could see himself holding them on the screen. In an early session from the Phase 2 deployments, a student was so delighted upon seeing himself on the screen for the first time that he hugged his teacher. In our initial feedback sessions during Phase 2, the teachers reported that the students were very engaged with the activities and displayed great excitement, repeatedly asking, *"When are we going to play with the Kinect?"* We also noted that students who might otherwise regularly detach from the class were less likely to do so when they were waiting their turn to play. One boy who would often leave the main classroom area to go jump on a trampoline only did so once the first time we observed the teacher introduce the Kinect activities to the class.

The video analysis confirmed that the students were engaged by the game play. This was evidenced by a high rate of positive facial expressions, body language and comments, evidenced in all but a handful of sessions (see Table 2). The students picked favorite themes, enjoyed naming familiar objects on the screen, sang, smiled and danced along as they collected the objects.

Rates of frustration and negative affect were low, and tended to occur during the two-player sessions. When frustrations occurred, they were usually due to difficulties collecting objects in the game *("It's kinda hard. I am not able to get the bird"*).

5.2 Social Behavior

5.2.1 Peer Interactions

In the first classroom, the open-ended nature of the free-form interaction proved especially effective in scaffolding classroom-level social interactions. The teacher would launch the activity in "live image" mode, put on music, and let the students play as they pleased. She reported *"They go and get friends to dance with them on the screen."* We observed the students developed their own innovative ways to engage with one another through this activity, initiating games like follow the leader *("Everybody up! Everybody down!)* that the whole class could participate in.

The game elicited social initiations and back-and-forth communication between peers (see Social turns/All in Table 2).

Table 1. Behaviors counted during review of game-play recordings captured during Phase 3.

Engagement 1) *Positive*: verbal comments and gestures that indicate enjoyment of the activity (e.g., smile, jump with excitement) 2) *Negative*: verbal/facial signs of frustration or disinterest
Social Behavior: Social turns with peers 1) *Initiations to peer*: looks, comments, gestural or physical acts directed to playing peer (two-player mode only) or non-playing audience peer (one- and two-player mode) 2) *Responses to peer*: looks, comments, gestural or physical acts in response to initiations by playing peer (two-player only) or audience peers (one- and two-player mode) **Social Behavior: Initiations to teacher** 3) *Initiations:* comments or gestural acts directed to teacher
Teacher support 1) *Instructions* to the student to perform specific actions without which play could not continue (e.g., moving behind the line, using the correct body part) 2) *Challenging comments* intended to encourage student to perform more advanced actions (e.g., lifting the leg higher instead of moving back to catch an object)
Motor skills 1) *Novel movements* produced to catch objects in the game (e.g., sitting down, crawling, bending down very low, kicking very high, back kicks) that are spontaneous (non-imitative). Novelty determined based on teacher comments or lack of evidence of similar behavior in previous sessions.

The two-player sessions in particular showed a higher rate of initiations and responses compared to the one-player sessions, with evidence of initiations in all but a handful of sessions. In two-player mode, the players had to coordinate and agree on which object they would jointly catch, which resulted in verbal and gestural initiations, such as *"Let's get the sea-horse thingy!"* The players also commented on the game; for example, one student who was having difficulty catching objects with his feet proclaimed *"This is adventurous!"* to which his playing partner responded, *"This is a workout for me."* We also observed that students who were more competent at the game would help out and encourage peers who had a harder time playing. For example, in a two-player session when one student said, *"You get that one, I will get these two, ok?"* her teammate reminded her *"We are supposed to get it at the same time."* Such initiations also included instructions such as *"You need to move back,"* gestural cues like pointing to where the peer should stand, and guiding a peer's hand to help him catch the object.

One teacher shared an anecdote about a student who would usually remain by herself but who readily responded to a peer and joined in the game play when he shouted out to her saying, *"Come on, get in here."* The teacher acknowledged, *"The engagement and two-way communication we are seeing from the students is already remarkable."*

5.2.2 "Audience" Effect

The fact that Microsoft's Software Development Kit (SDK) for the Kinect limited supported tracking joint coordinates for only two players at a time turned out to be an asset in a classroom setting. The need for other students to wait their turn to play the game led to the phenomenon of an "audience" that was actually

Table 2. Rates of behaviors from video analysis of one- and two-player game play sessions in Phase 3

	One-player (28 sessions)		Two-player (29 sessions)	
	M (SD)[b]	# none[c]	M (SD)[b]	# none[c]
Social turns[a]				
All peers	1.3 (2.5)	11	2.7 (2.5)	2
Audience peers	1.3 (2.5)	11	0.4 (0.5)	14
Initiations to teach.	1.0 (1.2)	10	0.6 (0.6)	1
Positive affect	1.5 (1.2)	2	1.6 (1.3)	6
Frustration	0.1 (0.4)	23	0.4 (0.6)	14
Novel movement	1.5 (2.8)	7	0.6 (0.9)	13
Teacher comments	0.9 (1.0)	11	1.2 (1.2)	6

[a] Initiations to peer + responses to peer; [b] Average rate, per min. of play; [c] Number of sessions the behavior did not occur

effective in eliciting further social initiations and responses to and from the non-playing peers. In video recordings from both classes, students who were not actively playing the game would often cheer and sing along, or make comments about their peer(s) who were in the midst of play, including suggestions for what to do (*"Get the lion!", "Kick 'em! Kick!", "Back up"*), encouraging words (*"Yay!"*), encouraging gestures like clapping or comments related to the game (*"I don't like pigs"*). Similarly, the students playing the game would often call out to members of the audience. In one instance, when a student in the audience commented, *"I wanna eat a turtle"* the student playing the game turned to him and responded, *"I don't see a turtle. Do you want a lion?"* In this way, what may have been a one- or two-player activity turned into a classroom-level activity with multiple students actively engaged in the interaction.

The video analysis revealed the audience effect was particularly relevant for the one-player game sessions. While obviously initiations and responses to audience peers was the only option for one-player mode, it is interesting to note that such social turns with members of the audience were far less frequent (though not absent) in the two-player sessions (see Table 2).

We further observed that the teachers played a key role in scaffolding these interactions between the players and the audience, directing comments to the audience to encourage further interaction. For instance, in one of the recordings, a student in the audience stands up and starts dancing to the music accompanying the game. The other students in the audience then also stand up and begin dancing. The teacher encourages them and brings this to the attention of the student playing the game (*"<Student4> is dancing for you"*), who then turns to the peer who is dancing and responds with a *"Thank you!"*

5.2.3 "Spillover" Effect

One of the most interesting observations made by the teachers was that the Kinect activities had a positive "spillover" effect on social behavior outside of game play. For example, one teacher mentioned that after the activities, students seemed more interactive and chatty. Students who had been paired off when playing the collaborative game or free-form interaction would pair off and play together after the Kinect had been turned off. One teacher remarked, *"The feeling stays even after they are done and they pair up to play with toys as well."* As a result, rather than transitioning the students to another activity, she decided to keep them in the classroom and let them continue to play to take advantage of the engagement that had been created. No empirical evidence was recorded for this in the study.

5.3 Motor Skills and Coordination

An early observation from Phase 1, subsequently reinforced by teacher feedback and our observations, was that students immediately made the connection between the avatar and their own body, and moved their limbs in characteristic ways to control the avatar's motions.

The teachers were so encouraged by the motivating impact of the Kinect activities on students' movement they reported using them on an almost daily basis. They even replaced regular classroom activities like "movement time" (previously dancing to music) with the free-form interaction set to music or the game. One teacher reported *"Moving their bodies in space like that is almost new to them...having them bend down and do whatever 'blup' noise that its [the game] doing...they love that."* Teachers' reports of the effect of game play on encouraging a wider range of movement were supported by the video review, which indicated students produced novel movements within the game. The one-player mode in particular encouraged novel movements (at an average rate of one/minute), likely because there was no need to coordinate the movement with another person (see Table 2). Novel movements included bending down to catch objects appearing on the bottom of the screen, jumping to reach objects, sitting and moving side to side to reach objects, and balancing on one leg to reach an object with the other.

Teachers also reported that students with specific coordination issues performed movements while interacting with the Kinect activities that they had not been observed to produce, or that represented an area of difficulty for them. For example, one student known to experience fatigue when asked to perform complex motor tasks and who had not been able to jump rope in his occupational therapy sessions readily jumped to "stomp" on the objects in the game. One teacher reported, *"A student who has a tough time moving his body but loves the jungle theme, was willing to use only his feet in the game. He did great with a few unsteady moments but all out to the end of the song."*

Teachers also reported that they were able to motivate the students to perform certain movements outside of game play activities by reminding them of how successful they had been during game play. One student who had trouble pushing a wheelbarrow during gardening activities was successfully encouraged to do so when the teacher reminded him about all the points he had scored "getting the monsters" in the game.

5.4 Other Collateral Effects on Behavior

Teachers indicated that the Kinect activities also addressed the school's goals of focusing on student regulation, attention, and problem solving. Students were sufficiently motivated by the activities that skills that would typically be quite difficult for them, such as waiting their turn, could be facilitated in the context of these activities. This occurred even in the face of technical difficulties, as illustrated by this report from a teacher: *"It is very difficult for him to stand, but the other day he religiously waited for the computer to shut down and restart the Kinect game,"* which she described as requiring *"a lot of effort on his part."* In another instance, observed in Phase 3 recordings, a student waits for six minutes for the teacher to restart the computer. When the game starts working, the student jumps for joy and the entire class breaks into applause

The teachers played a significant role in using the activities to facilitate regulation and problem solving. One teacher modulated the students' excitement and multiple requests for turns by saying, *"You already had a turn, your friend <student4> hasn't played at all today."* and *"If you can't respect your friends' turn, you will lose yours."* She would encourage the students to adjust to the needs of their peers as well: *"<Student5> doesn't like live image, are you okay in being the skeleton?"* or *"You picked live image, let <student3> pick the theme."* In one of the sessions a student in the audience who doesn't like to see minutes on the screen complains, *"No, I don't want 2 minutes…5 minutes!"* to which the teacher responds, *"On your turn you can do what you want buddy. But now it is <student 7>'s turn."* With selected children she would encourage competition—*"<Student2> was faster, you can do it too!"*—while for those who were struggling she made encouraging comments. For example, when a student from the audience commented, *"I can't do legs…it's too hard,"* the teacher motivated him by saying, *"Sometimes it's good to do hard stuff. Look how <student1> is doing it."*

6. DISCUSSION

We present considerations for designing and deploying motion-based activities for individuals with autism in a classroom.

6.1 Need for Customization

The need to customize technologies to the unique profiles of strengths and weaknesses in individuals with autism has been previously highlighted [12,20,24,25]. Sensory sensitivities, repetitive behaviors and restricted interests, variability in visuo-spatial reasoning and motor skills, along with vast differences in the ability to communicate and engage with others are all factors that must be considered when designing technologies for this population. In the context of the current study, specific considerations were highlighted by teachers' requests for features that could be tuned to encourage individual students' engagement. These included options for content that reflected student interests (the choice of backgrounds, themes, and characters); options to address sensitivity to how the self was represented (choice of avatar vs. live image); and controlling the level of game difficulty with regards to social and communication demands (one vs. two-player; single object option for two-player mode), visuo-spatial and motor skill demands (number of objects that would appear simultaneously; which body parts would need to be used to catch the various objects), and self-regulation (infinite game time vs. timed play).

6.1.1 The Importance of Avatar Representation

A key consideration that emerged was the importance of the avatar representation. In our initial demo sessions, we observed that representing the child's body and movements via an avatar helped the students connect their bodies and movements with actions on the screen. This was subsequently reinforced by teachers' request that we add the ability to insert the students into the interactive story via their live image. Beyond the avatar's role in providing visual feedback on movement, the teachers felt that the inherent motivation and reward stemming from the ability to control the avatar was key to encouraging the observed social and motor behaviors [27]. A further consideration, however, is that the *choice* of avatar representation matters in this population. Some children reacted negatively to seeing themselves represented as the skeleton avatar, and would only participate if they could see their live image on the screen. In one of the sessions, a teacher explains to a visitor, *"For some kids, seeing themselves is overwhelming and for some, they don't know how to move their body unless they see their own body."* Other children preferred the skeleton representation to their live image; one student, when given the option, stated *"I don't want to see myself on the screen."* The video analysis revealed that across one- and two-player sessions, there was a 60/40 split in the choice of live image/skeleton.

6.1.2 Considerations Unique to Classroom Setting

By using classroom deployments and enabling teachers to introduce the game over an extended period of time, we were able to identify additional unique considerations for designing motion-based activities for classroom settings. In a classroom, the customization does not just happen through specific tunable "settings" that increase or decrease the level of difficulty of the game. It also happens in how teachers use their knowledge of the students to select which settings to use over time. For example, while initially the teachers asked for features that reduced the difficulty of the game to minimize frustration, over repeated play, through their choice of settings, they would challenge students and give them opportunities to improve.

Teachers reported that they strategically used the two-player mode by selecting specific pairs of students that were matched in skill level, or by pairing students of varying abilities and asking one to adjust to the level of the other. This went both ways—a teacher might encourage a student to perform an action by noting their partner is able to do it (*"Sometimes it's good to do hard stuff. Look how <student1> is doing it*"), while other times she might ask a peer to adjust to their partner (*<Student5> doesn't like live image, are you okay in being the skeleton?*").

A relatively straightforward workaround—the teacher remote to trigger animations in the story—also highlighted the key role the teachers can play in customizing the experience to student skill level. Although the teachers wanted to encourage students to perform certain gestures during the interactive story—which was accomplished by having the story pause until the target movement was produced—they also wanted to reward specific children for imperfect attempts, and to gradually increase the demands for how closely the movement had to match the target. Due to the sheer variability in motor skills in this population, it would not be feasible to accomplish this with automated detection. However, introducing a remote that allowed the teacher to trigger the story animations manually, even if the child's gesture did not reach the previously agreed-upon threshold, made this customization quite easy.

Across these examples, the task of designing an interaction that can be customized for multiple classrooms and a range of students is facilitated by working closely with teachers to identify features that they can use to adjust the activity to varying levels of ability of their students. Moreover, by having teachers deploy the activity in their classroom and mediate the interactions, the designer benefits from the teachers' natural inclination to scaffold students' experience with the activity.

6.2 Designing for Social Engagement with Peers

The teachers wanted to engage the entire classroom and at the same time encourage individual students to interact with their peers. They also wanted to encourage constructive secondary skills in social behavior like waiting your turn, and developing an appreciation and tolerance towards the needs of their peers. We observed that a lot of these goals were attained with how the teachers used our activities—they used the two-person limit on skeleton tracking to facilitate turn taking; they paired specific students of matched or unmatched abilities; and they prompted and encouraged communication between playing and audience peers. However, specific design decisions also contributed to increased initiations and responses among peers.

The two-player mode of the game *enforced* collaboration by requiring both players to reach toward the same object at the same time to score points. This design decision was effective in eliciting social initiations and responses for some children, as the two players used gaze, gesture, and/or speech to coordinate which objects they would catch. However, a single-object option in the two-player mode effectively *scaffolded* collaboration for students who struggled with the social coordination needed to strategize with their partner about which object to catch. The ability to switch between or even combine elements that enforce and scaffold collaboration may be needed to facilitate social turns in games designed for classroom settings.

The audience effect identified in the present study suggests a unique design opportunity for classroom deployments. Provided the content is engaging—which we accomplished by working with teachers to identify themes and music that reflected common interests—the non-playing peers remain socially engaged by singing along, naming objects, commenting, etc. As one teacher emphasized, "*They won't talk about it unless they see it.*" We kept the game rules fairly straightforward, and observed that audience peers made initiations to playing peers by providing instructions and encouraging comments ("move back," "kick higher" etc.). While this effect was incidental in our study, future designers may use it strategically by adding specific features that encourage audience participation.

6.3 Designing for Movement

The teachers wanted the students to perform a wide range of movements (e.g., cross-body gestures, bending down low) using different parts of their bodies, and to reward the students based on their specific levels of motor skill. As presented in our results, the use of the avatar and the real time feedback about the body and movements that it provided may have been especially effective for individuals with autism in increasing awareness of one's body and encouraging movements (e.g., jumping, standing on one foot) that presented difficulties outside of game play.

Various features and options were added to the game specifically to increase the range and complexity of movements. Objects were made to appear at random locations on the screen, and we utilized the entire screen space to encourage natural and varied movements (as opposed to localized gestures). Tunable settings enabled teachers to require specific limbs to be used in catching objects (hands v. feet). At the end of Phase 3, teachers suggested additional options, such as scaffolding movements that cross the midline by requiring the right hand to be used to catch objects on the left side of the screen.

6.4 Adapting Classrooms to Technology

6.4.1 Supporting Classroom Norms and Rules

Most research in this space has evaluated technology in separate experimental sessions, run by the researchers, and targeting one student at a time. In contrast, we deployed our prototypes in classrooms over a two-month period, and enabled teachers to use them on a regular basis without our presence. Several factors were key to successful deployments. We relied on *existing facilities in each classroom* (computers, display board, room layout), and considered the *conditions our technology had to adapt to*, such as placing the Kinect out of reach and adding a remote so the teacher could remain focused on the students.

Importantly, we introduced *strategies that the teachers could adopt* in order to facilitate the use of the Kinect in a busy classroom environment. This included marking an X or a stage area on the floor with tape to indicate where the players should stand to be within the range of detection of the Kinect. We also educated the teachers about the need to limit the number of players, and to arrange the desks and the audience outside of the range of detection of the Kinect. While there was an overhead with the need to rearrange desks in the class before and after the Kinect activities, the teachers encouraged the students to help out and reported, *"This is the fastest the kids have helped me move the desks. They will all help do it."* In the video recordings, we observed that the students playing the game had a tendency to constantly move towards the screen to get the objects. The bounding area marked on the floor served as a reference to help teachers instruct the students to "*Move behind the X*" or "*Move from side to side along the line.*"

6.4.2 Supporting Teachers' Goals

As others have noted [12,25], a key consideration for any technology to be deployed in a classroom setting is to design activities that closely match teachers' goals. We followed two approaches in designing the activities. First, we worked with teachers to create a digital version of an existing classroom activity (story time). Second, we introduced new activities (free-form interaction and game), and worked with teachers to refine our prototypes to match their pedagogical goals of encouraging engagement, positive affect, self-regulation, and motor skills.

To that end, the decision to discontinue the interactive story at the end of Phase 2 presents an interesting case. On the one hand, there was a clear match between the activity and the teacher's goals—we designed every aspect of the interaction with the teachers, including the story structure, gestures, and animations. On the other hand, there turned out to be a mismatch between the limitations of the Kinect SDK and the classrooms' current practices around storytime. Students were used to all participating in the story, so they continued to crowd the "stage" area, and while enacting the animal movements they presented at oblique angles to the Kinect. These factors led to near constant failures of gesture detections. Moreover, the teachers encouraged students to enact movements that were not compatible with Kinect-based gesture detection, such as crawling under desks and using physical props.

This experience highlights the need to ensure that teachers have a clear mental model of the Kinect and how gesture detection is accomplished via tracking joints. Our impression is that when we jointly planned the animal movements with the teachers, the constraint that the player should be always facing toward the Kinect was not clearly communicated. Thus, when the teachers suggested an action like "hopping" or "flying," for them that action was not constrained to a particular orientation as it was for us when implementing the gesture recognition for the Kinect. Moreover, because there was a precedent in how the story might be enacted (e.g., using props), the teachers did not want to limit the range of activities students could do just because the gesture detection might fail. In this sense, the game was a better match for the technology: the classrooms had no *a priori* history or expectations for this activity, so it was easier for us to dictate how students should interact with it while ensuring that the activity supported teacher's goals.

6.5 Limitations

We worked with a school that already uses technology in classrooms and places a strong emphasis on classroom-level interactive activities. This school may have been a particularly good match for our approach. The teachers were skillful in using our activities to mediate classroom-level interactions and working through technical issues, so they may be a crucial additional variable responsible for the success of the system. We also elected to ask teachers to control the recordings so they would be captured in the course of everyday activities on a regular basis. Consequently, we did not have recordings for each child across both early/later and one/two player sessions, preventing us from formally documenting changes in individual students' peer-directed behaviors across context and time.

7. Conclusion

Our study takes a first step toward exploring the potential for using motion-based activities in a classroom setting to facilitate social interactions among students with autism. We documented the positive impact of these activities on students' engagement, social behavior, and motor skills. Our results highlight the benefits of interactive technologies for children with autism that move beyond didactic instruction to create more naturalistic social contexts within which peer interactions may take place [27] and bootstrap interactions between children with autism and peers in a group setting [29]. To that end, we build upon the work by Cassell and Tartaro demonstrating interactions with virtual authorable peers support reciprocity and turn-taking in language-mediated interactions (conversations) between high functioning children with autism and their peers [29]. We extend the focus to children with autism with more compromised cognitive and communication skills and to a group setting, and demonstrate motion-based activities serve a similar function as virtual peers, bootstrapping "lower-level" building blocks of peer interactions including peer initiations and responses that involve looks, gestures, and simple verbal expressions.

An open question remains as to the mechanism(s) underlying the observed impact on student engagement and social behavior. While sheer novelty may have played a large part in students' engagement with the technology, the scaffolding of social initiation and responses *among peers* over a two-month period of play suggests something other than novelty is promoting social engagement. We propose that the combination of a fun (not explicitly didactic) activity tailored to students' preferences and interests, the embodied nature of the interaction, and the facilitative role played by the teacher all contributed. In the present study we could not disentangle the relative contribution of these factors in facilitating socialization, and this remains an important area for future research.

A related question concerns the extent of the advantage specifically conferred by the motion-based aspects of the activity in supporting peer interactions, compared to, say, interactions mediated by concrete objects. Two previous studies that directly compared technology-enhanced activities to similar activities using physical objects found subtle advantages for the former in promoting social behaviors in children with autism [10,17]. Given increasing evidence of the influence of embodied interaction on thought and learning [5], the affordances created by movement-driven avatars may have created an optimal context for scaffolding engagement in children with autism.

We documented initiations and responses to both play partners and audience peers, suggesting children were not merely playing side by side and looking ahead toward a shared screen. More fine-grained analyses of the nature of these social turns are needed to quantify the extent to which key behaviors, such as eye contact, are elicited when players interact side by side. Future research should evaluate the impact of *specific* features of motion-based activities deployed in classrooms on social behaviors. For example, a comparison of game play with and without the audience is needed to quantify social initiations that come about as a result of the presence of these peers. Similar comparisons could quantify which customization options are more or less effective in eliciting social interactions within game play, such as choice of avatar, choice of rewards (scoring points, visual/auditory feedback), features that enforce vs. scaffold collaboration, and end-goal (collaboration vs. competition).

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