Playful Interactions for People with Intellectual Disabilities

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For people with intellectual disabilities, there are significant barriers to inclusion in socially cooperative endeavors. This paper investigates the effectiveness of Stomp, a tangible user interface (TUI) designed to provide new participatory experiences for people with intellectual disability. Results from an observational study reveal the extent to which the Stomp system supports social and physical interaction. The tangible, spatial, and embodied qualities of Stomp result in an experience that does not rely on the acquisition of specific competencies before interaction and engagement can occur.

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1. INTRODUCTION

The pursuit of fun is a dominant theme within modern cultures, and a remarkable amount of time is devoted to the pursuit of entertainment experiences [Vorderer et al. 2004]. However, at present it is difficult for people with disabilities to access games and other technologies that support engaging social interactions. Sixty-seven percent of American households play computer and video games [Entertainment Software Association 2010], yet opportunities for people with intellectual disabilities to engage with immersive interactive experiences that are social, intellectual, physical and, above all, fun, are limited. While technologies such as the Nintendo Wii are making gaming accessible for a wide range of people, these technologies are usable for only a small percentage of people with intellectual disabilities (ID).

We address the issue of accessibility for people with ID through the development of technology that embraces natural interaction and consequently has the ability to engage people who have a range of skills and abilities. This paper describes an observational study of Stomp, a system where input relies on simple gross motor actions. Stomp has been designed to create accessible and inclusive experiences through the full-bodied interactions enabled by a tangible user interface (TUI). The paper explores how the embodied interaction enabled by Stomp creates opportunities for people with ID to experience the fun of playing computer games, to become immersed in challenges,

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to physically participate in shared activities, and to enjoy the social connection resulting from cooperative play. Specifically, our research investigates the extent to which the Stomp system supports people with ID through active social and physical engagement.

The observational study was undertaken in a community-based center that provides support for people with ID. Intellectual disabilities are complex and variable, and our research challenge involved analyzing Stomp interactions across such a diverse user group. Observation, focus groups, and interviews provided the best means to flexibly examine the complexity of interactions within this space.

The paper proceeds by explaining the issues of inclusion and exclusion for people with ID and presents the idea that TUIs provide an avenue for inclusive participatory gaming experiences. The paper examines the characteristics of bodily interactions within tangible user interfaces that are used to guide the design process. The observational study illustrates the participatory characteristics of Stomp experiences that encourage playful physical and social interactions.

2. BACKGROUND

Characteristics of intellectual disability include a significantly reduced ability to understand new or complex information, a reduced ability to learn new skills, and a reduced ability to cope independently [Department of Health 2001]. The motor, sensory and cognitive impairments of people with ID impede opportunities to influence their environment and to recognize the results of their actions [Weiss et al. 2003]. Common conditions for people with intellectual disabilities include cerebral palsy, communication disorders, mental retardation, autism, auditory and visual impairments, emotional disorders, disorders of attention and hyperactivity, learning disabilities and epilepsy [Capute et al. 1996].

Research examining the use of technology for people with intellectual disabilities covers a diverse range of topics. There has been substantial work on systems for children with Autistic Spectrum Disorder [Hirano et al. 2010; Piper et al. 2006; Pares et al. 2005; Farr et al. 2010]. Such research is interested in the effectiveness of technology in supporting engagement [Pares et al. 2005], social interactions and communication [Farr et al. 2010; Piper et al. 2006], and structuring daily activities [Hirano et al. 2010]. The focus of many research projects involving children is on how novel technology offers new interaction opportunities. Tangible user interfaces [Farr et al. 2010], tabletop computing [Piper et al. 2006], and multisensory interactions [Pares et al. 2005] have been examined. Research in this area has shown the benefit of computational structures that enforce the rules of engagement [Piper et al. 2006], systems that are responsive to very simple actions [Pares et al. 2005] and that allow children to take active control and determine the pace of activity, and interactions that are consistent and predictable [Farr et al. 2010]. Results also show that interactions that are tangible or include the whole body may be effective in facilitating physical action [Pares et al. 2005] and social interaction [Farr et al. 2010].

The investigation of technology use for adults with ID is primarily focused on the use of assistive technology to support daily activities or communication [Carmien et al. 2005] and the use of off-the-shelf technologies [Dawe 2007; O'Connor and Fitzpatrick 2010]. The research examines personal technology such as mobile phones [Dawe 2007], digital assistants [Carmien et al. 2005], or video recorders [O'Connor and Fitzpatrick 2010] and focuses on how such technology supports tasks that people with ID find challenging during their day-to-day living. Much of the research around adults with ID using technology highlights the importance of experiences that allow for autonomy and independent activity [Dawe 2007; Weiss et al.

2003]. Simplicity of interaction and removing complexity are also essential [Carmien et al. 2005; Dawe 2006].

While much of the research involving children is focused on engagement and social interaction, the focus for the adult population shifts to more personal, task-oriented technology. An exception is research conducted by Weiss et al. [2003] that examines the effectiveness of virtual reality to provide opportunities for independent leisure activities for people with cerebral palsy. Their research demonstrated the value of virtual games in allowing adults with intellectual disability to make choices and to indicate preferences [Weiss et al. 2003]. The Stomp project looks to extend this research, which focuses on individual interactions, to examine technology designed for adults with a wide range of intellectual disabilities as they participate in engaging interactive experiences that are both physical and social in nature.

2.1. Intellectual Disability and Geographies of Inclusion

It is widely acknowledged that social connectedness positively influences health and well-being and that community engagement plays a significant role in connecting people in socially cooperative endeavors [OECD 2001]. For people with intellectual disabilities, such engagement is not assured. Even though many people with an intellectual disability function relatively well in the familiar routines of self-care and domestic life, they often have considerable difficulty in managing emotions and relating to other people [Australian Institute of Health and Welfare 2008]. Indeed, people with learning disabilities represent one of the most socially excluded groups [Department of Health 2001]. The pervasive lack of independent leisure-time activity choices for people with ID may lead to the development of dependent behavioral patterns, learned helplessness, and depression [Weiss et al. 2003].

In the past decade, consideration of the social and cultural dimensions of inclusion and exclusion for people with ID has provided a basis for challenging assumptions about the relationships between participation and inclusion in the social space [Hall 2004]. Initiatives promoting social inclusion by providing opportunities for people with ID to participate in community life frequently ignore how the rules for participation are established and preserved by the “able” majority [Milner and Kelly 2009].

In this context, when designing technology that aims to facilitate and create new opportunities for inclusion and participation for people with ID, significant attention must be given to continuously challenging our assumptions with regard to what inclusion looks like for people with ID. It must be recognized that physical closeness does not directly translate into inclusive participation and engagement. Meaningful inclusive engagement is built through shared, collaborative experiences. Experiences that have the potential to be universally accessible [Grammenos et al. 2009] need to be capable of allowing all people, irrespective of their individual characteristics, to have fun and participate on an equal basis. This requires engagement with different perspectives on what legitimate participation in activities looks like for people with intellectual disability and assessing how the broader social context influences participation.

2.2. Technology for Shared Engagement

In order to develop technology that facilitates inclusive participatory experiences, we need to address the barriers that restrict access to participation by embedding functions and affordances in the tools themselves that permit readily accessible interaction. For people with ID, we need to focus on designing technology that does not rely on the acquisition of specific kinds of competencies before interaction and engagement with technology can occur. Therefore, in considering technology design for adults with intellectual disability, it is useful to have an action-based perspective. Jacob et al. [2008] describe a new type of interaction, reality-based interaction, which builds on users' preexisting knowledge of the everyday, non-digital world. By considering users' understanding of naïve physics, their own bodies, the surrounding environment, and other people, interactions with technology may be readily mapped to interaction in the real world [Jacob et al. 2008].

Recently, TUI research has examined tangible technology in terms of bodily interactions [Klemmer et al. 2006] and as resources for action [Fernaeus et al. 2008], highlighting the importance of digitally mediated action, perception and sensory experience, and thinking through doing. Similarly, Hornecker and Buur [2006] identify spatial interaction, the interaction that occurs through movement in space, and embodied facilitation, how material objects and space affect and direct emerging group behavior, as important themes within TUI research. These themes identify the importance of both place and space as people interact with TUIs.

Stomp utilizes an embodied cognition approach that emphasizes the importance of sensory and motor functions in guiding successful interactions within the environment [Wilson 2002]. A starting point for embodied cognition is the notion that cognition is situated. A core assumption of situated cognition is that cognition draws on our sensorimotor abilities and environments as well as our brains [Smith and Semin 2004]. Situated cognition is cognition that takes place in the context of task-relevant inputs and outputs. It involves interaction with the things that the cognitive activity is about.

Inclusion, agency, and control were seen to be central to determinations in the design of a tool to promote participation. The Stomp system represents an attempt to allow people with ID to have new opportunities to engage with each other and the world through activity that is both physically enabled and socially situated. Readiness-to-hand, a concept that underpins Dourish's notion of embodied interaction [Dourish 2001], describes task-focused activity with concrete materials. Immersion in activity may be achieved when people perceive and react to events in a "seamless" manner. There is no cognitive barrier to becoming engaged with an activity. Such behavior is exploratory, as it allows people to develop an understanding of the system through action, observation, and reaction. Such tangible technology builds on the idea of interactive systems as resources for shared sense-making [Hornecker and Buur 2006].

2.3. Design-Based Research Approach

Design-based research (DBR) was developed to address issues related to the study of learning, such as the need to address questions about the nature of learning in context, the need to go beyond the narrow measures of learning, and the importance of deriving research findings from formative evaluation [Collins et al. 2004]. Within this project we have used design-based techniques to design new engaging technology that accounts for the needs, abilities, and experiences of adults with intellectual disabilities. A feature of design-based research is that it is interventionist [Barab and Squire 2004]. It involves progressive improvement as a way to refine designs based on theoretical principles [Collins et al. 2004]. Section 2.2 details the theories of tangible, reality-based, bodily, and embedded interaction that we have considered for this project. Interventions are designed so that systematic adjustments are based on evaluations that take place in naturalistic contexts [Barab and Squire 2004].

The decision to use DBR was based on the dynamic nature of context in which we are working. Design-based research provides an agile design process that meets our aim of better understanding how to design engaging activities for a wide range of adults with intellectual disability. The process takes into account the complex interplay between the target audience, resources, the environment, and the activity.

The design of the first iteration of the Stomp system was based on field studies conducted within two Endeavour Foundation Learning and Lifestyle centers. These centers are community-based day centers, catering to adults with a wide range of intellectual disabilities. The studies were conducted over two days and were designed to better understand the needs, capabilities, and interests of adults with intellectual disability. Two researchers were involved in talking to staff and service users, as well as observing the activities that typically take place in these centers and the types of interactions that occur. These initial revealed a range of ways in which service users currently participate in music, art, and sport.

During initial interviews, all participants identified music as something they liked, with the exception of one participant who liked music only "sometimes." Participation in music described by participants included listening to music and participating in a music program. This program involved facilitated music activities such as singing, dancing, and playing instruments. Most participants nominated a favorite percussion instrument, such as shakers, symbols, and drums. Almost all participants claimed to like art; however, several participants did not/could not distinguish between the different kinds of art, inferring that participation was linked to whatever activities were facilitated by staff at the center. Preferences nominated by other participants included painting and drawing.

Most participants claimed to like at least one sport, and participants engaged with sport in a number of ways. Many enjoyed sporting activities as part of the center's program, including ten-pin bowling, golf, and gym. Television was the most common way for service users to "participate" as fans in different kinds of sports. Most participants watched sports on TV with someone in their household, usually their father. Some played sport on the Nintendo Wii. Ten-pin bowling was their favorite, and some also liked tennis.

Our observation of services uses and staff, along with our informal interviews, demonstrated the importance of music, sport, and art activities for the Endeavour service users. While many participants engaged in these activities individually or in groups, there were examples where such activity formed the catalyst for social interaction.

3. THE STOMP SYSTEM

Stomp is a floor-based system that allows users to interact with digital environments by triggering pressure sensors embedded within a 2×3-meter floor mat. The floor mat contains 56 pressure sensors, which are then mapped, through a keyboard encoder, to system input. We have developed 14 interactive experiences that use this sensor information as input. These experiences are projected onto the mat using a short throw projector (Figure 1).

The Stomp platform effectively turns the floor into a large, pressure-sensitive computer screen. Stomp can be used by a single participant, pairs, and larger groups. Users interact with experiences through stepping, stomping, pressing, jumping, and sliding. The pressure sensors are relatively sensitive and can be triggered by hand pressure. Despite that sensitivity, these pressure sensors are made for industrial use within the security industry. As a result they are hardy and can withstand significant pressure, including that applied by adults wearing leg braces. Interactive experiences have been developed using Flash and are stored on a Mac Mini within the Stomp hardware box (Figure 2).

3.1. Stomp Software

Over the period of the project, we developed 14 interactive experiences for people with ID. Notably, the menu system for Stomp, like all interactions, is floor-based. Users stomp on icons to make their selection. The only interaction with the system that did not occur through the mat was that of stopping an experience and moving back to the main menu. This is achieved through pushing a button positioned on the top of the box.

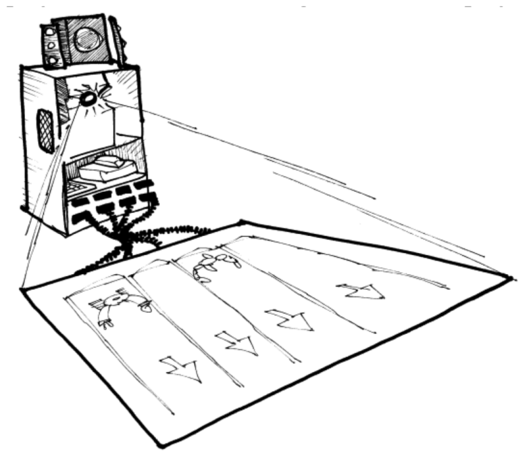

Fig. 1. A conceptual overview of the Stomp system.

Fig. 2. Stomp's underlying hardware.

Building on knowledge gained during our initial field studies, three of the Stomp experiences involved musical instruments; we created a piano keyboard, a guitar, and a drum kit (see examples in Figure 3). We also developed three sports experiences: soccer, car racing, and pong (Figure 4). A creative painting experience (Figure 5) was developed to allow users to create large canvas "paintings" using the floor mat.

Another experience involved fish swimming in a pond. As people paddle in the pond, they make ripples, and any fish nearby swim away. A frog on a lily pad sticks out its tongue when it is stepped on.

Research that demonstrated the value of choice and autonomy in virtual games for people with ID led us to develop four arcade-like experiences that involved blowing things up. The main characters of these games are robots (see Figure 6) and spacecraft that users can whack as they emerge from their houses (Whack-a-Bot), stomp on to stop from crossing a map (Robot Defense), shoot or stomp to stop the alien invasion (Invader), and hit as they travel down four tunnels (Robot Hero).

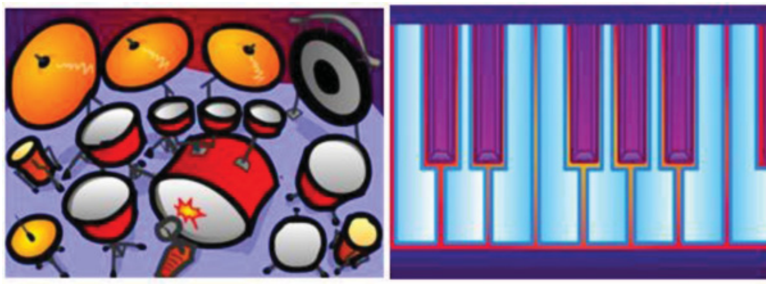

Fig. 3. The Stomp drum kit and piano keyboard.

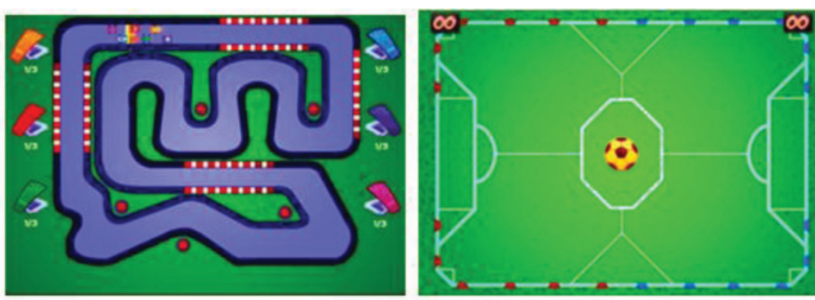

Fig. 4. Car racing and soccer.

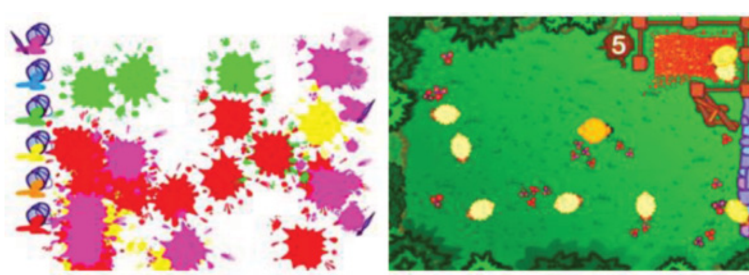

Fig. 5. Paint experience and the sheep-herding game.

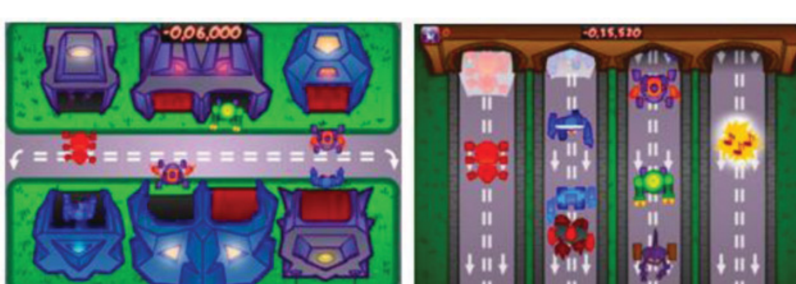

Fig. 6. Whack-a-Bot and Robot Hero.

3.2. Interaction Design and the Stomp System

All design decisions were considered autonomy support, experience structure, and social involvement [Deci and Ryan 1991]. Designing for autonomy support ensures that experiences provide choice, minimize pressure to perform in specified ways, and encourage initiation. Structure describes the extent to which outcomes are understandable, expectations are clear, and feedback is provided and involvement considers the degree to which significant others are interested in and devote time and energy to a shared experience. Specific design criteria considered during the design and development process are detailed in Wyeth et al. [2011].

Stomp is an example of embodied interaction [cf. Dourish 2001]. The floor mat acts as both input and output of digital information. Pressure sensors sitting under the mat take information from the environment and pass that information on to the computer for processing. The projector then projects output from the system onto the floor mat. From a user's perspective, the entire state of the system is embodied within the Stomp mat; all participation and action occur through it.

The physical form of the mat suggests a certain way of interacting. A mat affords sitting, standing, walking, and lying down. These are all valid ways to interact with the Stomp system. Interactions with Stomp can be defined as spatial interactions [Hornecker and Buur 2006], as they take up real space, they are situated in places, and users need to move in real space when interacting with the system. In terms of embodied facilitation [Hornecker and Buur 2006], the Stomp mat clearly identifies the interaction space. It constrains interaction to a particular area of the room, and the grid-based pressure sensors offer additional interaction constraints, requiring participants to use a small amount of force (hand or foot pressure) to trigger actions. The system allows for multiple users, is highly visible, has multiple access points and embodies a range of representations with which users are familiar (e.g., musical instruments, soccer fields, car races). Such design features aim to facilitate social interaction. As a space for shared engagement, the large open mat—with its vibrant colors and animations—is designed with multiple points of access. The space is clearly defined and appropriately constrained, while at the same time providing lures to participation.

The Stomp system can be considered in terms of bodily interaction [Klemmer et al. 2006] and as an example of reality-based interaction [Jacob et al. 2008]. The system is designed so that stomping, stepping, and sliding in Stomp are like stomping, stepping and sliding in the real world. Kicking a soccer ball in Stomp is closely related to kicking a soccer ball on the soccer pitch. Stomp is a resource for action [Fernaeus et al. 2008].

3.3. Playtesting Stomp

Our initial Stomp experience underwent play-testing in one Endeavour Foundation Learning and Lifestyle center. After one play-test session, we realized that many of the service users were strongly motivated to solve problems, to compete, and to strive for improvement. Consequently, we made some significant changes to certain Stomp experiences. For example, we added a high-score element to the invaders game, as we noticed participants asking about scores and winning, and support staff indicated that clients would appreciate this feature.

Other improvements based on initial play-testing included:

- adding difficulty levels to one of the game experiences (Robot Hero) to cater to a range of service users;
- including a road-safety game based on requests from Endeavour staff to consider experiences that support the development of important life skills;
- creating barriers covering some robots in the Robot Hero game to create more challenges for players; and

- the addition of the sheep-herding game (Figure 5), which requires people to herd the correct number of sheep into the sheep pen, to further explore opportunities for learning and collaboration, based on feedback from staff.

These changes were initiated to create further challenge and excitement, as we quickly realized that the service users enjoyed the stimulation and were excited by the idea of winning a game.

There were two software improvements related to control that were made as a result of play-testing. These were:

- creating a new graphical layout for the piano experience so that the piano keys aligned more accurately with the pressure sensors; and
- making the fish and frog more responsive in the pond experience so that service users felt their actions produced a response.

These changes demonstrated the importance of clear, simple visual and auditory feedback, which effectively reveals the cause and effect relationship between action and outcome.

4. STOMP EVALUATION

Given the focus on the use of the Stomp to promote participation in social activity, the evaluation examined the relationship between the use of the tool and participation outcomes for people with intellectual disabilities. The evaluation builds on research that examines interactions with technology that involves the body, that is action-based and built on real-world interactions, and that involves situating tasks within both physical and social contexts.

The evaluation is designed to examine how Stomp promoted participation in terms of:

- Physical activity: the extent to which Stomp facilitates ready access to activities through interactions that build on real-world, whole-body actions;
- Social activity: the extent to which the configuration of the Stomp space facilitates group behavior and social interaction.

4.1. Study Participants

The initial Stomp evaluation took place at an Endeavour Foundation Learning and Lifestyle center, and our study included the 40 service users present during our evaluation sessions. Due to ethical constraints, it was not possible to gather information on specific conditions. However, it was clear that participant disabilities included cerebral palsy, communication disorders, mental retardation, autism, and Down syndrome. Many participants had multiple disabilities. As a result, the study involved participants with a wide range of skills, abilities, and interests. Five of the 40 participants observed had the ability to independently use a Nintendo Wii.

4.2. Study Methodology

The research conducted in this project has sought to utilize ethnographic methods to develop an understanding of adults with ID and their interactions with the Stomp system. Study findings are based on observations of participants' engagement with the Stomp system, combined with focus group interviews with staff and service users after the study. Stomp system observations took place over a two-week period, on three separate days. Each observation session lasted approximately three hours, with 40 people with intellectual disabilities being observed during this time. Three researchers were involved in observing service user interactions with Stomp. During the observation period, researchers took notes and talked to service users and Endeavour staff to get their impressions. Researchers recorded how and when participants interacted with the Stomp system, patterns of behavior, types of interactions, and challenges encountered. After observation sessions, notes were collated and analyzed to identify the types of physical and social activities facilitated by Stomp.

The observational study also involved two focus groups with service users from the center, the first including five service users and the second involving four service users. These participants were selected based on their ability to communicate thoughts and feelings. The focus groups occurred after the participants had used the Stomp system on day 2 and day 3. Two staff members from the center also participated in an interview together to provide feedback on Stomp experiences. One researcher was responsible for running both focus groups and the interview. Data from focus groups and interviews were audio recorded and later transcribed for analysis.

5. STUDY FINDINGS

This section discusses the study findings based on observations of people interacting with Stomp, as well as focus groups and interviews conducted after the participation sessions. The first section examines participation with Stomp in a general sense. We then focus on participation in terms of physical and social activity.

5.1. Participation

The Stomp system generated significant interest across the three days it was installed at the Endeavour Learning and Lifestyle center. A range of services users engaged with the system, with both males and females with varying levels of disability participating in activities. Service users who immediately engaged with Stomp games displayed significant appreciation of the experiences. While seven participants interacted with the system for over one hour on each of the days of our field study and clearly enjoyed all of the experiences, other participants were more sporadic in their usage. Many participants developed favorite games and would engage in game play when their favorite was selected.

In focus groups, service users highlighted a number of Stomp features that they enjoyed. Favorite games and features cited included the helicopter (Robot Defense) game, the paint experience, soccer, the guitar, the robots, and the sheep-herding game. The two staff members interviewed were impressed by Stomp games and the range of opportunities it provided.

> Craig[1]: *The guys haven't got sick of it which is a good sign I think. They're still keen every time and even though there's that break in the middle, it's still a three hour session.*
> Jessica: *That's a really long time for them.*

5.1.1. Participant Preferences. Our observations and focus groups showed that Stomp experiences were responsive to the preferences and dispositions of the participants. Some of the activities were designed to encourage open engagement with an experience. For example, one experience, the pond, allows for service users to "walk on water" and observe and experiment with the effects of stepping on the water, fish, lilies, and a frog. Other experiences encouraged service users to work towards a particular goal, e.g. arcade-style, with immediate goals of stomping on the robots and aliens. Other experiences encouraged service users to work toward a less immediate goal in collaboration with each other. For example, the sheep-herding experience begs for collaboration among participants as they attempt to herd the sheep around other sheep and other participants on the mat. Some Stomp experiences encouraged competition among service users to either reach a goal first and/or to get around the barriers

[1]All names have been changed to protect the privacy of study participants.

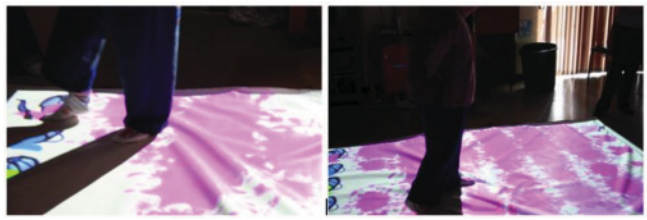

Fig. 7. Painting a purple canvas.

created by their competitors. For example, the soccer game requires service users to "kick" the soccer ball into the goals protected by other service users. The car-racing game allowed for eight competitors to race their cars over several laps. While all games can be played whether or not participants have an understanding of the intent and goals, they encourage a competitive spirit through declaring a winner at the end.

During observation sessions, we saw preferences develop as users with different interaction styles gravitated toward certain Stomp applications. There tended to be a split between those participants who enjoyed explorative experiences, such as the musical instruments, the fish pond and the painting experiences. Other participants were more competitive and clearly enjoyed the sports and arcade-style games. These participants were generally more verbal and confident in their interactions.

One specific vignette demonstrates the wide appeal of Stomp experiences. Kelly showed an interest in the Stomp experiences as she hovered at the edge of the mat but could not initially be persuaded to participate. When asked why, she indicated that she liked only purple and would interact only with a purple experience. One of the researchers suggested that she could use the paint application and paint a purple canvas. She agreed and subsequently became engaged in this activity (see Figure 7).

5.1.2. Choice of Activities. Many service users appeared happy to continue to play the same game over an extended period (i.e., over 10 minutes) and selecting new games frequently required facilitation from staff and researchers. Some service users took on a directing role in this respect, through suggesting game changes and directing others to move from the mat in order to select a new game.

Two issues were identified that related to starting and stopping applications. While participants quickly learned how to select experiences from the menu and get them started, only one service user was observed independently pressing the button on the control panel in order to reset the game menu. There appeared to be two reasons for this. First, participants appeared happy to act in the here-and-now and continue with the currently selected activity. It was uncommon to hear a participant suggest a change of game, with these suggestions primarily coming from researchers, staff, or other observers. As service users became more familiar with the experiences, they were more inclined to move from one to the next. Second, most of the interaction involved looking at the floor, working out where to stomp next, and observing the results of particular actions. To move from one experience to the next, the point of focus needs to move from the floor to the Stomp hardware box.

The second issue relates to the selection of experiences from the menu. As the menu choices were triggered from the mat and the mat allows multiple inputs, there were cases of conflict over the experience chosen. For example, one service user may choose to paint while another wants to play the drums. The system defaults to running the application that is triggered first, potentially leading to disappointment. There were examples where participants expressed dissatisfaction that their chosen game was not triggered.

5.2. Physical Activity

Study participants seemed to readily understand how to engage with an experience. Many service users were immediately keen to "have a go" at Stomp experiences; a majority of study participants who used the mat were observed quickly coming to terms with the physical interaction paradigm. System control was readily mastered, and there appeared to be no confusion about how input was triggered.

5.2.1. Whole-Body Interactions. Study participants were observed stomping, stepping, jumping, and walking to trigger system input. They quickly identified the need to kick the soccer ball into the opponent's goal and to herd sheep into pens. Service users understood interactions that typically involved gross motor, and particularly, foot-based movements such as paddling in a pond or kicking a ball. They appeared equally comfortable when engaged in activities that are not typically done with whole-body movements, for example, painting a picture or playing a piano. The bodily interaction involved in stomping on the mat created strong associations for the service users, and they were generally able to understand when and where to step, stomp, and walk to achieve their goal or engage in a task.

While not all actions were deliberate, on many occasions the output from stepping actions generated interest and a subsequent, more deliberate input action. For example, the first time Sophie played the drums, she expressed surprise when a cymbal crashed. Upon discovering this interaction, she deliberately replicated it and then stepped on a drum to see what happened. Our interviews with Endeavour staff indicated that Stomp may be a useful resource for challenging service users and engaging them in active problem-solving activities. For example, Jessica commented that:

> *It got their attention straight away. And I think it's quite physical for them so a bit of fitness and exercise for them. And it gets them to think. You know like you said Mandy, she was having to think and she could work out what to do without being told which I think is a good skill to encourage.*

5.2.2. Level of Physical Activity. According to Endeavour staff, the experiences encouraged several service users to engage in a level of physical exercise that would typically not be undertaken. Repeated stomping, dancing, and moving around the mat resulted in some service users becoming quite puffed, although for many, this did not hamper their enthusiasm or willingness to continue to play. As Craig noted:

> *It's like the mental application but the physical application – the combination of both at times. That's a really good sign.*

During the interview, staff commented on the benefits of Stomp experiences for a number of clients. For example, one client was noted to have become less active in recent times despite his orientation toward sport and competition. This client actively engaged with Stomp experiences, particularly the arcade-style games and experiences that incorporated competitive features. While generally positive, the physical demands of Stomp games may have limited some service users to short stints and/or discouraged participation.

5.2.3. Issues with Variations in Physical Activity. While it was clear that stomping, stepping, kicking, and walking were activities readily accessible to the Endeavour service users, other types of interactions presented some problems. It appeared that some participants struggled to break away from these whole-body actions to engage in different modes of interaction, such as standing still or leaning forward. For example, both Invader and Robot Defense included two methods for blowing up enemies (aliens or robots). The first involved the service users stomping on the enemies to destroy them. The second involved standing still to trigger the deployment of an attack unit

Fig. 8. Participation modes available through Stomp. Clockwise from top left: individual, shared, individual competitive, team competitive, individual competitive, collaborative interactions.

(e.g., helicopter), which would shoot at the enemy and destroy it. In both experiences, stomping was the dominant strategy for destroying enemies. Service users were heard to comment when the second strategy was deployed asking "Where did that come from?" or "How did you do that?"

Another difficulty was observed in the car-racing game. In this game, participants were aware of the need to press the pedal and did this successfully, but not all readily understood that pressing forward with more pressure would increase the acceleration of the car they were controlling. While the underlying action is related to the action of driving a car (applying pressure with the ball of the foot increasing acceleration and speed), very few service users would have experience in driving a car. Five participants were notable because of their emerging proficiency with these types of interactions. However, for a majority of service users, these nuances remained difficult to manage.

5.3. Social Activity

Stomp facilitated social interaction in a number of ways (see Figure 8). Participants in Stomp experiences could:

- Engage in explorative shared or individual experiences (e.g., painting, drums, piano);
- Engage as individuals, yet in a competitive context comparing performance against other participants (e.g., car racing);
- Compete against each other individually or in teams (e.g., soccer and pong); and
- Work together to achieve a goal (e.g., Invader, sheep herding)

Staff felt that this breadth in interaction offered opportunities for many of the Endeavour service users to find something of interest and become active participants in Stomp experiences.

Table I. Stomp Participation Modes

Collaborate	∼20%	Active
Engage	∼30%	Involvement
At the edges	∼20%	Passive
Watch	∼20%	Involvement
Ignore	∼10%	No Involvement

5.3.1. Group Interactions. It was clear that Stomp encouraged group interactions. The large mat attracted the attention of the services users as soon as the system was installed, and for a majority of the time there was more than one participant on the mat. Some would be stomping heavily and actively moving from place to place, while others were more inclined to stay in one place and movement was more restricted. There were occasions when there were up to nine participants engaged in a Stomp activity. The invader game was particularly popular, and many participants enjoyed engaging in stomping on alien invaders before they reached the home bases at the bottom of the mat. While the large number of participants interacting at one time didn't cause any problems during our study, the potential for head clashes was identified by Endeavour staff.

It should be noted that the success of Stomp in encouraging group interactions made it difficult for individuals who wanted to use the mat by themselves (e.g., to play a tune on the piano). This type of interaction required the intervention of Endeavour staff, who asked other participants to move off the mat.

5.3.2. Social Participation Modes. Participation modes are represented in Table I. There were a small number of services users (approximately 10 percent) who appeared uninterested in the Stomp system and did not participate in any Stomp activities. Around 40 percent of service users were involved in passive participation, either through watching from a distance, or standing around the edge of the mat. Some of those at the edges would offer comments and support. These participants appeared eager to be involved in activities as an active audience, talking and laughing with participants and offering encouragement and suggestion.

Active participation involved both individual and collaborative (or competitive) engagement. Approximately 50 percent of service users involved in the study participated in this sense. We were able to identify two categories of active involvement. There were those participants who were actively observed interacting with others in a competitive or collaborative sense. They would discuss goals, suggest strategies, and discuss outcomes. Other participants were more focused on individual engagement, happy to interact with others. These participants only occasionally engaged in fleeting cooperative or social interaction.

Some participants would engage infrequently, while others were constantly interacting with Stomp experiences. It was interesting to observe the most active of participants encouraging less engaged services users to join them. Figure 9 demonstrates how one participant went from passive participation at the edge of the experience to active engagement and social connection within the experience.

Of the service users who initially took on an observational role, some required only minimal initial encouragement to try Stomp experiences and, after this, engaged with the games for an extended period. Others were more inclined to have a try and then retreat back into the observational role. In this respect, it is possible that the number of people participating at once acted as a barrier for those who are more socially reserved.

Staff noted how Stomp experiences encouraged some service users, who typically would not associate with each other, into the same space. It was suggested that Stomp

Fig. 9. Moving from watching to social engagement.

may provide a platform for service users to broaden their associations with each other and build friendships.

6. DISCUSSION

Our research is focused on understanding the extent to which the Stomp system supports social and physical engagement. Our study demonstrated that Stomp set up a zone of inclusion, which was readily accessible to a wide range of people with ID. Endeavour service users were able to participate in Stomp experiences without direct facilitation or supervision. It was clear that they participated physically and socially in a diverse range of Stomp activities. Some were involved in working through problems, addressing challenges, and achieving milestones. The variety of Stomp experiences catered to the diverse interests, skills, and abilities of service users. Stomp provided participants with different personalities, orientations, and preferences to engage with each other through immersive interactive experiences.

The Stomp mat is a large and public display, drawing the attention of service users throughout the center. It created active, excited, and vocal social participation. While this feature is largely advantageous—it extends social participation as people move from observers to actors—it may also have drawbacks for those with less outgoing dispositions.

Through mutual participation with Stomp, service users were engaged in a common task that enabled "embodied" cooperation and engagement with each other. This cooperation did not demand verbal negotiations and also enabled task self-selection where the selection of different kinds of tasks did not prevent co-engagement. The shared social experiences of Stomp, whether companionable, cooperative, or competitive, were seen in a positive light by both service users and staff. The range of social interactions exhibited during the study—from individual to group, in parallel and through association, and from collaborative to competitive—is a significant contributor in promoting new zones of inclusion for people with ID. These experiences have been shown to be playable by people with diverse abilities and consider the needs and capabilities of the whole population.

The reality-based interaction of Stomp provided an opportunity for service users to engage immediately with a space "recognizable" as reflections of real-world contexts. In doing so, Stomp afforded opportunities for experiences that would otherwise be inaccessible to service users. For example, some sports of a competitive nature, such as soccer, are difficult to access for people with ID. Playing soccer games using a computer or a console may also be difficult due to limitations in the fine motor skills required to hold and operate controllers. Car racing can be considered in a similar light.

From the observational study, it is clear that the action-based foundation of the Stomp TUI was extremely effective in creating new opportunities for accessible interactions by people with ID. Active engagement and participation emerged as the large, colorful floor drew service users in and implored them to stomp, step, kick, walk, and slide. There was no wrong way to engage with Stomp; there were just different ways to explore the action space. The simplicity of control, enabled through embodied interaction, ensured that barriers to entry were minimized. Observations and focus group interviews demonstrated how comfortable service users were in engaging with this new and slightly foreign experience. They never asked if they were doing it incorrectly, and there were very few examples of frustration exhibited while using the system.

6.1. Key Design Lessons

The key design lessons learned during the process of developing the Stomp system include:

- Ensuring that the form of the motor movements suggests a certain way of interacting, that there is no wrong way to move or act, and that experiences are responsive to the movement preferences of participants.
- Closely coupling movement input and visual/audio/haptic output to create the perception of cohesive control.
- Incorporating a range of representations with which users are familiar.
- Output from all user movements should be positive and promote interest and multimodal feedback needs to be clear and unambiguous.
- Ensuring that the system has multiple access points and the space for interaction is clearly defined and appropriately constrained.
- Carefully consider mechanisms (e.g., color, animation) to craft a vibrant, compelling visual landscape that creates a lure to participation.
- Design whole-body interactions that make sense for multiple users and allow for a variety of social participation styles (e.g., individual, cooperative, team-based and competitive) and modes (e.g., active, passive or observer).

7. CONCLUSIONS

Stomp is a TUI that encourages collaborative, action-based interactions involving the whole body as it engages in real-world movements such as kicking a soccer ball. Activity is situated in both a physical and social sense, effectively facilitating social and physical engagement for people with intellectual disability. From this we conclude that careful technology design that embeds interactions in real space and considers configurations that encourage group interaction has an important role to play in encouraging shared participation for people with ID.

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