Design and Evaluation of a Networked Game to Support Social Connection of Youth with Cerebral Palsy

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ABSTRACT

Youth with cerebral palsy (CP) can experience social isolation, in part due to mobility limitations associated with CP. We show that networked video games can provide a venue for social interaction from the home. We address the question of how to design networked games that enhance social play among people with motor disabilities. We present Liberi, a networked game custom-designed for youth with CP. Liberi is designed to allow frictionless group formation, to balance for differences in player abilities, and to support a variety of play styles. A ten-week home-based study with ten participants showed the game to be effective in fostering social interaction among youth with CP.

Categories and Subject Descriptors

H.5.2 [Information Interfaces And Presentation]: User Interfaces - User-centered design; K.4.2 [Computers And Society]: Social Issues - Assistive technologies for persons with disabilities;

General Terms

Measurement, Design, Experimentation, Human Factors.

Keywords

Cerebral Palsy, Video Game Design, Game Accessibility

1. INTRODUCTION

Cerebral palsy (CP) is a group of disorders that affects the development of motor function [11]. Youth with CP who require a mobility aid to walk (those classified at level III of the Gross Motor Function Classification Scale - GMFCS) have decreased opportunities to participate in social activities with peers, in part due to special needs in transportation, accessible facilities, and coordination of assistive services [7].

Networked video games represent a promising approach to allow youth with CP to interact with peers from the comfort of their homes. Video games can provide a common activity for players, forming a basis for social interaction. In networked games, players may compete against other human contestants, work cooperatively to achieve a common goal, or simply get together with others to chat [2].

The social benefits of commercial video games may not be available to youth with significant motor disabilities such as those associated with CP. Fast-paced video games that are typically popular among young people need to be designed specifically around the abilities of people with CP [5]. Since most of the interactions with the game and the other players happen in a virtual world, the computer can mediate these interactions, reducing the challenges of having a physical disability. Indeed, the virtual world can offer novel experiences that individuals with physical disabilities are not able to realize in "real-life" [13].

In this paper, we address two questions about the design of effective networked games for people with motor disabilities:

1. How should a networked game be designed to enhance social play among people with physical disabilities such as those associated with CP? and
2. How effective can such a game be in practice in promoting social engagement?

To answer these questions, we have developed Liberi, a networked game custom-designed for youth with CP. Liberi illustrates three high-level design principles for games supporting social interaction among people with motor disabilities:

- *Frictionless group formation:* It should be easy for players to join up with others for play sessions within the virtual world.
- *Dynamic balancing for player ability:* People of different physical ability levels should be able to play together.
- *Varied play styles:* The game should offer a wide range of game styles to support different preferences and abilities.

We evaluated Liberi as a means of fostering social interaction in youth with CP through a longitudinal study where ten participants, divided into successive cohorts of six and four participants, played the game from home for ten weeks. Our results were encouraging, showing that a networked video game based on our design principles can provide a social platform for youth with CP. Participants expressed high enthusiasm for being able to play with others. For example, "P5 was pretty quiet and just focused on playing the games. However, when P4 joined, he was very excited [and] said '*Yay! I don't have to play alone anymore.*'" As we shall see, participants were inclusive, picking mini-games that the whole group could play, and were creative, adapting mini-games to the abilities of the current group.

ASSETS, October 20–22, 2014, Rochester, NY, USA.

http://dx.doi.org/10.1145/2661334.2661370

This paper is organized as follows. First, we review related work on the use of video games to foster social interactions among people with physical disabilities and discuss barriers to group play in existing games. We then describe our Liberi game, and review the principles underlying its design. We describe our in-home study with ten youths with CP, and then discuss lessons for designers of social video games for youth with motor disabilities.

2. BACKGROUND

Participation in social activities helps in forming friendships, developing concept of self, and determining a sense of meaning in life [7]. Youth with cerebral palsy (CP) have been reported to have fewer social experiences with peers than youth without disabilities [7]. People with other physical disabilities can have similarly reduced social interaction [6].

Multiplayer video games can foster connections with family members, friends and others. Social interaction around these games can take place in co-located facilities or over a network, bringing physically separated people together [10]. Networked games have particular promise for people with special needs who are confined to their homes or care centres. People with physical disabilities have expressed that online video games offer them the possibility of reaching out to people in situations that would otherwise be difficult, helping the development of meaningful relationships and building a community outside the home [6].

Even within commercial networked games, there can be unintended barriers to group play, and this could partially explain reports that players of World of Warcraft spend as little as 25%-30% of their time playing with others [2].

Establishing player groups

Players may have difficulty meeting others within a virtual world. Players may be spread over a large virtual geography, requiring them to travel for a long time before being able to group for a shared activity [2]. Once players have arrived in the same location, they must formally band together as a group. This typically requires them to use a cluttered graphical user interface (GUI) to specify the group's membership and parameters. Networked games typically offer complex user interfaces for initiating or carrying on social interactions [1], which people with limited manual ability may find difficult to use [3]. Additionally, over 83% of children with CP present seriously affected visual-spatial processing abilities [9]. This can make it difficult to effectively navigate virtual worlds based on complex visual cues or to successfully find places or persons.

Differences in players' abilities

Players of commercial networked games can be hesitant to admit new players to their group, sometimes because advanced players see no benefit in cooperating with lower level players [2].

In many games, playing in groups requires strong manual ability and visual motor integration, both limited in children with CP. Multiplayer games can require players to quickly perform actions to effectively defend or attack during a competition or a group battle. Limitations in manual ability of children with CP can make it difficult to use common control schemes that involve pressing different buttons in rapid succession, using multiple buttons at a time, or selecting a specific button at exactly the right time [5]. Hand movements of children with CP are typically slower and less efficient than those of their typically developing peers [12], making it difficult for them to quickly react to time sensitive game events. These differences in ability may combine with existing groups' reticence to include new players, forming a barrier to establishing social ties.

2.1 Possible Solutions

Commercial networked games have experimented with strategies to encourage people to group. These include offering different in-game roles for the players to choose from [2], steering players towards social gathering points in the virtual world [1], giving players down-time in the game to be social with others [8], allowing players to show off their achievements [2], implementing social gestures for avatars [1], and providing matchmaking tools. These solutions may help foster social interactions, but even successful games implementing these solutions have been inconsistent at cultivating group play. For example, even though there can be thousands of people playing World of Warcraft at the same time using the same server, people tend to play alone [2]. Ultima Online offered towns with taverns where players could meet and socialize, but these spaces were almost always empty [1].

The existing literature shows promise for networked games to foster social interaction among youth with motor disabilities such as CP. However, we are the first, to our knowledge, to study how games themselves can be designed to enhance social interaction among youth with CP. In the following section, we describe the design of our game, Liberi, showing how we addressed these challenges to social interaction. In sections 4 and 5, we discuss the results of a study of the use of Liberi in ten peoples' homes.

3. DESIGN OF LIBERI

Liberi is a networked, cycling-based game designed to allow youth with motor disabilities to socialize with friends while participating in physical activity. Liberi is designed around the abilities of youth with GMFCS Level III CP. Liberi is played using a stationary recumbent bicycle specially designed for people with physical disabilities [4] and a traditional Logitech wireless game controller. Players pedal to move their avatars, aim using a joystick and invoke game actions with a single button.

Liberi was designed by a multidisciplinary team including youth with CP using a participatory and iterative design approach [5]. The team held seven design and evaluation meetings over a period of a year, learning about the youths' physical abilities, gaming experience, and game feature preferences.

The game takes place in a persistent world that allows a small group of players to meet up and play together. A central plaza gives access to six mini-games and various shops where players can purchase rewards gained from long-term play, such as avatar upgrades, costumes, weapons or a pet dragon. The mini-games embody a range of collaborative and competitive gameplay styles, and can be played in groups or "solo" with artificial intelligence "bots". Liberi provides a voice chat system that allows players to invite each other to the different mini-games, coordinate cooperative play, cheer or playfully gibe each other, or simply chat.

To support social interaction in Liberi, we followed three high-level design principles: support frictionless group formation, so that players can easily get together in a play session; balance for player ability, so that players of differing physical abilities can easily play together; and support a variety of play styles, to engage players of different physical abilities and preferences. We now review in detail how the game was designed to address these goals. In sections 4 and 5, we present our experience in deploying this gaming system in the homes of youth with CP.

3.1 Designing for Frictionless Group Formation

As discussed in section 2, players of online games often spend little time playing with others. One of the barriers to group play is the difficulty in forming groups: in finding others to play with,

Figure 1: One player stands on the launch pad to Dozo Quest. Players' stickers are enlarged to the sides of the image.

and in navigating complicated interfaces to form an in-game group. We designed Liberi to minimize these difficulties. Specific design decisions included automatic grouping, automatic establishment of voice communication, on-screen presence indicators, easily joinable activities, and short travel times within the virtual world.

Automatic grouping

Unlike traditional online games, players do not perform an explicit action to specify which other players they wish to play with. To enter a mini-game, players stand on a launch pad (Figure 1). When one of the players presses the action button on their game controller, all the players standing on the launch pad are taken into the minigame. This action implicitly forms a group for the purpose of playing that game; there is no process of requesting or granting access to a group or of specifying group membership. Players need only stand on the launch pad and press the button. Figure 1 shows a player (on the right) using the launch pad to enter the Dozo Quest mini-game.

Automatic voice communication

Most networked games support voice communication between groups of players. In most games, communication is started manually, with a user interface that allows the specification of who will take part in the voice session. The fact that some players are able to talk by voice and others (not in the session) cannot forms a barrier to grouping. In Liberi, all players are equipped with a headset and are automatically placed in the same voice channel as soon as they log in. The immediate establishment of a voice link to other players makes it easy to determine which other players are in the game, and to negotiate a group activity.

The decision to include all players in a global voice chat has the disadvantage of limiting the number of players in the game; we have found that up to eight players work well in a voice chat.

On-screen presence indicators

One of the most basic challenges in forming a group is locating other players within the virtual world. To supplement voice chat as a way of locating others, we provided visual presence indicators in the form of avatar "stickers". These consist of miniature pictures of the other players that appear on the borders of the screen. The stickers are positioned to indicate the direction in which the other players can be found. Figure 1 shows two stickers indicating that there is a player out of view to the east, and another player reachable through the portal on the left.

Easily joinable activities

In many online games, once the game has started, it can be difficult for others to join. As discussed, in Liberi, players can join an ongoing mini-game by standing on its launch pad and pressing the action button. The mini-games are designed to accommodate late-comers. For example, in the Pogi Pong team-based hockey-style game, new players are assigned to whatever side currently has fewer players. In the Wiskin Defence mini-game, the new player joins the group of defending players, and the game difficulty increases to account for the additional player's firepower.

Short travel times

One of the major barriers to grouping in virtual world games can be the size of the world and the time required to travel across it. Liberi has a varied virtual world in which players can travel between zones as varied as jungle, desert, space and an underwater world. However, Liberi was designed to allow players to congregate quickly to allow them to play together, with a goal that players can travel to any other zone within one minute.

3.2 Balancing for Player Ability

To ensure the game was accessible for players with GMFCS level III CP, Liberi was designed using the following principles: simplify level geometry, simplify level flow, reduce consequences of errors, and limit available actions [5]. The physical abilities of individuals within the GMFCS level III classification can vary a great deal, and so it was important to ensure that the games allow people with different abilities to play together.

Balance for ability level

Liberi's mini-games were designed to allow people of differing ability to play together, in order to avoid segregating players based on skill, limiting opportunities for social interaction. In Liberi, players move by pedaling a bicycle. To eliminate differences in avatar speed due to differing gross motor function, all avatars move at the same speed rather than mapping a higher pedaling cadence to faster avatar movements. Keeping all avatars at the same speed helps to shrink the disparity in the outcomes of mini-games where speed is important, such as the Gekku Race racing game, or the Biri Brawl fighting game; and additionally, it allows players to stay together more easily as they travel around the island as a group.

Group goals instead of individual goals

It can be difficult for players with differing abilities to play in a group because the players with lower skills can feel a sense of defeat if their ability to win or to contribute to the team is much lower than the others; conversely, players with stronger skills may become frustrated if another player is not keeping up. Several of the games adopted a single group goal in order to mask differences in ability. For example, in the Bobo Ranch round up game, players work as a team to move sheep to a barn. When this goal is completed, all of the players receive the same reward for completing the objective. By hiding differences in ability, we eliminate a source of friction between players.

3.3 Supporting a Variety of Play Styles

Liberi was designed to support a variety of play styles, with the goal of satisfying individual preferences and differences in physical ability. The mini-games include competitive, collaborative and team-based styles. One of Hanarra's Laws describes how over time players who stick with a game will be those who enjoy the style of the game offered [8]. By providing a variety of play styles, we can satisfy individual players' personal preferences. Additionally, mini-games require different fine motor skills, helping players with differing manual abilities to find a game they are all able to play. Games can also be played solo, where computer controlled "bots" fill in other player slots.

There are six mini-games in total, ranging over a single player platform game, a competitive racing game, a cooperative zombie defense game, a team-based space hockey game, a brawler fighting game and a cooperative round-up game. We describe three mini-games in detail, and briefly describe the others.

Figure 2: Three players compete in Gekku Race.

3.3.1 Gekku Race

In Gekku Race (Figure 2), players are "gekku" lizards racing to be the first to reach the top of a wall. Gekkus can slow their opponents either by spitting cashews or by breathing fire. Once one gekku reaches the top, the game ends, and all of the gekkus slide back to their starting position for another round.

Gekku Race is a competitive racing game that allows players' avatars to directly interact through breathing fire and spitting cashews. This encourages social interaction by allowing players to react to others' actions towards them. A good dodge or well-timed hit can provoke verbal interactions between players. Players can gibe or cheer each other on during the game. Outside the game, players can discuss strategies of when to attack others, which attacks they like best and recall interesting interactions between their avatars during gameplay. The racetrack is short, requiring about 45 seconds to complete, allowing players to quickly join in an ongoing competition.

3.3.2 Dozo Quest

In Dozo Quest (Figure 3), players maneuver a spiky ball by rolling and dashing through a desert maze. Within the maze lie a variety of enemies, obstacles, traps and loot. Players can choose to jump over enemies or attack them. At the end of the game, players must defeat a powerful boss either alone or in a group.

Dozo Quest can be played as a single-player or group game. A group of players can traverse the maze together, collecting loot and killing enemies along the way. Barriers increase in strength when more players join, making it difficult to reach a new section without working together. Once players reach the end of the game, they are faced with a large "boss" fight. The large boss (Muferoth) also increases in strength based on the number of players that are in the game. The increase in difficulty encourages players to discuss how best to attack and defeat Muferoth. This is an example of a dynamic difficulty adjustment algorithm, used to balance mini-games for varying numbers of players.

A key aspect of Dozo Quest that encourages group interaction is that players can join in at any time. A new player is placed at the beginning of the maze and can catch up to the others. Being able to join an existing game at any time removes the need for players to wait for others to finish the game, making it easy for an individual to join the group.

3.3.3 Wiskin Defence

In Wiskin Defence (Figure 4), the wiskins are small cute penguin-like creatures sitting in a nest in the centre of the game arena. Zombies of varying types emerge from the sides of the arena and travel inward. If a zombie reaches the nest, a wiskin is eliminated. The job of the players is to defend the wiskins by killing the zombies before they can reach the centre. Players choose, purchase, and upgrade weapons at the shops in the central plaza.

Since different weapons vary in effectiveness against the different types of zombies, success is far more likely when players coordinate their movements and attacks to keep the monsters at

Figure 3: Players team up to destroy a barrier in Dozo Quest.

bay. This cooperation mainly manifests in two ways. Most commonly, players will simply ask for help from others when they are being overwhelmed. Alternatively, a player can take a commanding role and direct the movements of others, coordinating the overall defense of the wiskins. Another form of social interaction stems from discussion about the effectiveness of personal preferences for different types of weapons, allowing players to learn more about weapons they haven't used.

3.3.4 Other Mini-Games

In *Bobo Ranch*, a co-operative round up game, the players are tasked with lassoing and dragging rebel bobos (flying sheep) back home to their barn. The game ends when all bobos are home. Bobos are easier to move when lassoed by multiple players at once, encouraging cooperative play.

Biri Brawl is a competitive brawl fighting game. A biri is a jellyfish with a fist inside it. Players punch other biris (both bots and other players) to accumulate points. A defeated biri can join the battle again after a short time.

In *Pogi Pong,* players take the form of space hedgehogs. Players are split into two teams competing to knock a star into the opposing team's goal. The team that scores the most goals wins.

4. STUDY

To evaluate the design principles underlying Liberi, we conducted a ten-week trial where ten youths with CP played the game from home. We have previously reported an evaluation of the game in terms of playability and fun [4,5]; in this paper, we report the results of a second, larger study where we focused on the effectiveness of the game in fostering social interaction.

We recruited ten participants, four of whom had participated in previous design sessions. Three of our participants were female and seven were male. The mean age was 15.2, ranging from 12 to 18. Seven had spastic diplegia (lower limbs are affected) and three had spastic triplegia (lower limbs and one arm are affected). Nine were at GMFCS level III, where the main form of mobility is with the use of a walker, and one was at GMFCS level IV, where a manual wheelchair is required. All participants were able to communicate verbally without problems. A minority of participants had existing social connections through attendance in sporting groups such as sledge hockey. The majority of the participants had experience with commercial game consoles such as Nintendo Wii, PlayStation 3 and Xbox 360.

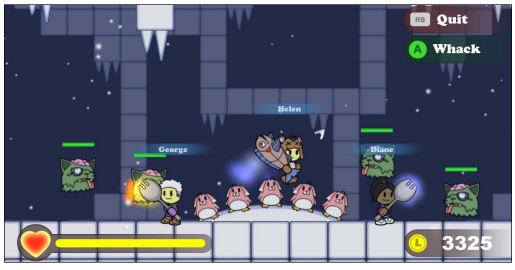

Figure 4: Three players play Wiskin Defence.

A research assistant set up an exergaming station in the home of each participant. This featured a custom-designed recumbent bike [4], a 23" screen all-in-one computer running the Liberi game, a wireless game controller, a wireless headset and a wireless heart rate monitor. Due to limited numbers of these special-purpose stations, the participants were divided into two successive cohorts, one with six participants and one with four. The game server was open six days a week for a 1.5 hour session. By opening the server for 1.5 hours instead of 24 hours a day, we intended to increase the opportunity for the participants to meet others online. Participants were free to determine when (and whether) they wanted to play within these periods; however, they were encouraged to play at least 3 times a week, summing up at least 90 minutes a week, and were limited to 60 minutes of play per day.

The game created log files when a participant joined the server. For each second they played, the game recorded the time, the mini-game or shop the participant was in, any in-game events, how many others were in that mini-game, and input from the game controller. This data allowed us to extract information about what games participants played, and who they played with.

A "game monitor" research assistant observed each game session during the trial using an administrator tool that showed the locations and activities of the participants' avatars. The game monitors were included in the open voice chat and were instructed to only interact with the participants in case of technical issues or inappropriate behavior. After each session, the game monitor wrote a report to record activities and interactions between participants. The monitors produced 119 reports, 6 per week over 20 weeks, minus one statutory holiday.

At the end of the study, participants completed a custom-designed Likert-scale questionnaire focused on their experience with the games followed by a short semi-structured interview.

To keep the novelty of the games high, we introduced the games progressively, starting with Gekku Race and Dozo Quest, and adding a new game every two weeks. The order was: Biri Brawl, Wiskin Defence, Pogi Pong, and Bobo Ranch.

A private Facebook group for the study was created. Seven of the ten participants joined the group. The game monitors posted video tutorials of upcoming games. Participants were encouraged to use the group to set up days to meet online and play together.

5. RESULTS

We found that Liberi met its design goals of enabling social interaction among youth with CP, while providing low barriers to forming and playing in groups. Our sources of evidence are data collected from the questionnaires, interviews, game session reports and the Facebook group, as well as quantitative information extracted from the log files recorded by the game. As we will see, this data indicates that, at least for this set of participants, Liberi was a highly effective platform for fostering social interaction. This allows us to conclude that when the games are designed correctly, networked gaming has great potential as a social outlet for people with motor disabilities.

We begin by giving a high level overview of the degree to which our participants chose to interact socially and the forms that this interaction took. We then tie these observations to an analysis of the effectiveness of our three design principles of frictionless group formation, balancing for ability, and supporting a variety of play styles.

5.1 Social Interaction Fostered by Liberi

Liberi successfully provided a platform for social interaction that inspired high engagement among our participants. On average, each participant played a total of 1,659 minutes over the 10 weeks (SD: 609), or an average of 2¾ hours/week. Participants played with others 69% of the time that other people were online. Figure 5 shows that all participants spent the majority of time playing with others when at least one other person was available to play. The 31% of the time played alone includes time travelling to meet others and time spent shopping, as well as solo play.

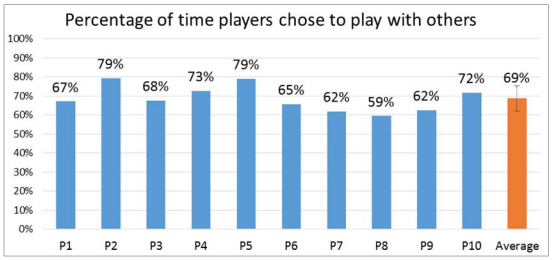

Figure 5: All players chose to play with others the majority of the time they could (average: 69% of the time).

The large percentage of time that players chose to spend with each other indicates that they highly valued group interaction. This high participation in group play also suggests that our design decisions about frictionless group formation and balancing for player ability were effective.

Participants' preference for group play is shown by differences in the length of daily gaming sessions when there were others online versus when participants were alone. We ran a two-sample t-test assuming unequal variances comparing participants' session length when online with others (M: 50.2, SD: 19.8) versus when they were alone (M: 37.1, SD: 19.4) and found that players stayed online longer when other players were online with them ($t(62) = 10.87$, $p < 0.01$). On average, sessions were approximately 13 minutes longer when players were able to play with others.

Game session reports describe players joining the server and, if others were not online, leaving the game soon after. This behavior suggests players were largely interested in playing the games together. A discussion with a participant recounts: "P10 said that Friday's session went well and that the only reason he left 20 minutes into the session is because no one else was on." To avoid playing alone, players would often use the voice chat to arrange times to meet online and play together in future sessions. One game session report explains: "When P5 had to leave, they decided to plan their next meeting on Facebook."

We also received an encouraging response from one of the participants' parents that highlights the social facet of the gaming experience for the participants and their families. One month after the study finished, we received an email from the participant's father highlighting the physical, social and entertainment benefits his child experienced during the study. He hoped to reach out to the other participants and their parents to create a community in which the youths with disabilities could continue socializing and playing networked games together.

Players used voice chat to coordinate their activities in the game, including deciding what mini-game to play, discussing strategy, and explaining gameplay. A game session report shows an example of such interaction: "When P9 came on, P10 asked him to play Wiskin Defense. P9 agreed. While P10 was waiting for P9 he played some Gekku Race. When they were playing Wiskins, P10 told P9 to buy ice gems to complement his fire gems. P10 vocally coordinate[d] P9's and his own movements to clear the fire and ice resistant zombies. After a few games, P10 suggested that they try the newly released game, Pogi Pong. Since P9 had not played Pogi Pong before, P10 offered to explain the rules of the game."

Social exchanges extended beyond gameplay. For example, one game session report states: "In between games of Wiskin Defense, these two participants talked about their mutual friends, the weather and school." Players used headsets to socialize even when playing different minigames. One monitor reported: "P1 wanted to play Wiskin Defence and P3 wanted to play Dozo Quest again. So they ended up separating but they did not stop talking. P1 was talking about strategies to beat the game and P3 participated in the conversation too. P3 got intrigued and wanted to play Wiskin Defence with P1. Although they did not get very far, they had a lot of fun!" The experience of hearing players in other games talking and having fun brought P3 and P1 together in the game where they could virtually interact.

One repeated form of social interaction was that some players took on the role of a coach. One excerpt from a game session report describes: "P2 taught P1 how to buy and place the dragon egg, and P1 taught P3 how to do the same. Although P3 did not pick up the instructions right away, P1 was patient to teach P3 again until she finally understood." This coaching behavior was not always welcome; from another report: "P1 is most active with his microphone and takes the 'team captain' role and orders P7 and P9 around. I can tell P7 and P9 get annoyed by P10 sometimes and they simply don't listen to him. However, with each passing wave, they get more excited and I believe P10 plays a huge role as a morale booster."

We were interested in whether players grouped in an inclusive way, or tended to form exclusive collections of friends who preferred to play together. Player log data showed that participants played with whoever was online, rather than forming cliques. Figure 6 presents the number of minutes the players in group 1 spent playing with the other participants in the group. Participants played with all others. Game monitors did not see incidences of exclusion of players.

Seven of the ten participants possessed Facebook accounts and were therefore able to participate in the study's Facebook group. All seven stated that this group was helpful for communicating with the other players. All seven considered it useful for arranging times to play together, with five of the seven saying it was as valuable as or more valuable than communication during the game sessions themselves. Five of the seven directly stated that access to the group encouraged them to play. The two cohorts used the Facebook group differently. In the first cohort, only two participants posted to the group, once each, at the beginning of the study. Nevertheless, the four first-group participants with accounts reported Facebook as being useful, and we see evidence from the game session reports that they were using Facebook to coordinate in ways we could not see, likely through direct messaging. In contrast, the second cohort made extensive use of the Facebook group by posting to the group's "wall". These observations led us to conclude that social media in the game is useful in coordinating game meeting times and that its use can differ greatly depending on the people involved.

To summarize, we saw strong engagement from participants in the game. Participants preferred to play with others, as evidenced by their playing together when possible and playing longer sessions when with others. There is evidence that a component of this preference was the social interaction afforded by group play, as seen by players' engagement in discussions beyond the gaming context, the social interaction even when not playing together, the adoption of the coaching role, and the contact from parents highlighting the positive social interaction in the study.

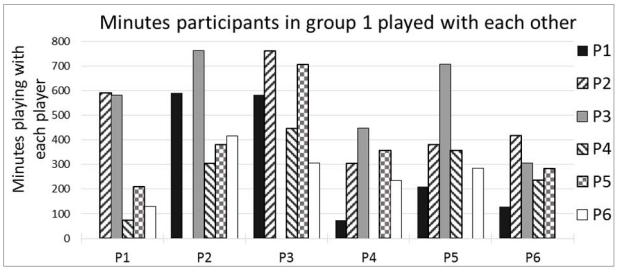

Figure 6: Players tended to play with whoever was online.

5.2 Frictionless Group Formation

As we have discussed, virtual world games often have structural barriers to forming groups with other players, and these barriers have the potential to be particularly severe for people with motor disabilities. As we have seen, participants in our study played with others most of the time that it was possible. This indicates that the mechanisms for finding others to play with and for establishing groups were effective. We describe now the most important design decisions for this: automatic voice communication, on-screen presence indicators and automatic grouping.

Automatic voice communication

Participants used voice communication frequently to locate each other in the virtual world. One game session report mentions that: "Sometimes the players will want to join a game together, but are all sort of heading in random directions, so they'll stop and coordinate."

A second common use of voice chat was to negotiate what game to play when participants wanted to play different games. The voice chat allowed players to communicate their preferences. An example from one game session report stated: "P4 asked P5 and P3 what game they wanted to play together. After a few seconds of discussion, they decided to play Wiskin Defense."

On-screen presence indicators

While the effectiveness of the on-screen presence indicators of Figure 1 was not formally tested, there are indications that they helped participants find others to play with. For example, during a technical outage of the voice chat tool, players were able to find each other despite not being able to speak; the players must have been able to follow the avatar "stickers" to locate each other.

Automatic grouping

The high frequency with which participants grouped when others were available to play indicates that the automatic grouping feature was effective.

Interestingly, the ease of forming groups led players to treat them fluidly. We frequently saw players disband from the group, play something else for a while, and then re-join the game they had left in progress. The reason reported by game monitors for this behaviour was often that players wanted to play different games but still wanted to retain contact with the others. The following excerpt from a game session report highlights the ease with which players were able to change the group formations throughout a single session: "As time passed, P1 wanted to play Wiskin Defense and P3 wanted to play Dozo Quest again. So they ended up separating but they did not stop talking."

5.3 Balancing for Ability

We found that players experienced few difficulties in group play despite significant differences in physical abilities. Evidence of this is that all the players played with at least one more player the majority of the time when others were available (as was shown in Figure 6). Two interesting features of group play have significant consequences to game designers: first, players exhibited a preference toward cooperative play as a way of reducing the impact of different ability levels; and second, our dynamic difficulty algorithms negatively impacted accessibility.

Cooperative play

Several of Liberi's mini-games allow cooperative gameplay, where the group has a common goal. As discussed in section 3.2, cooperative games help balance for players of different ability by allowing them to contribute towards the group's goal at whatever level they are capable of. For example, in Wiskin Defense, the players defend the wiskins from zombie invaders as a group; in Dozo Quest, players defeat the enemy "Muferoth" as a group. When well designed, in a cooperative game, it is not obvious which members of the group contributed most to the game's goal.

As evidence that this approach was successful, participants expressed a strong preference for cooperative group play versus competitive or solo play. During the interviews, when asked whether they preferred to play competitively with others, cooperatively with others, or alone, seven specified cooperative play, two specified competitive play, and one did not provide a clear preference. The game logs support this stated preference; Figure 7 shows that the cooperative Wiskin Defense game was the most played game by groups (and also the most popular game overall.) As an example, the game monitors reported that Wiskin Defense was particularly difficult for P3 (she had difficulty hitting the zombies). But she enjoyed playing it when others were online because she was able to interact with the other players while they held the zombies back. Here, the inability of P3 to contribute to the game was masked by the contributions of the others.

An interesting behavior was observed in the competitive Biri Brawl game. Biri Brawl is designed as a brawling game where all players fight for themselves. Computer-controlled "bots" are added in as enemies. In one session, instead of playing competitively, the players created an alliance and teamed up on the biri bots. Again, this compensated for the difficulties that one participant experienced playing the game. A monitor reported: "P3 said that 'it was intense,' and it looked like she was having a lot of fun even though she was not excellent at the game."

Challenges with dynamic difficulty adjustment

Since players are able to easily join and leave games, it was important that the difficulty of the games be dynamically adjusted for a varying number of players. To accomplish this goal, Liberi uses an adaptive balancing method where the games become more difficult as the number of players increases. For example, in Wiskin Defense, as more players join, zombies' strength increases and zombies attack from more than one direction.

We found that there is a risk in using this technique when designing a game for players with different physical abilities. If a player who finds the game difficult to play joins, the increased difficulty may make the game too difficult for the group. We witnessed this problem in Wiskin Defense with P3, who, as discussed earlier, had difficulty timing attacks on the zombies. Playing Wiskin Defense in a group of two was not a problem for any pair of participants, except for pairs including P3. In this case, the difficulty of the game increased at an interval greater than she and the other player were able to compensate for together. This situation is described in the following excerpt from a game session report: "P2 kept telling P3 to wait for him to finish Wiskins and then they would play together [Gekku Race]. He was hesitant about her joining him because then the zombies would come from both sides and he was not going to be able to help her." This situation highlights the importance of carefully scaling for all player abilities as well as the importance of removing in-game barriers for players with differing abilities in order to foster social interactions. In the case of P3, her inability to successfully perform all in-game actions meant she had to wait for P2 to finish before they could play together.

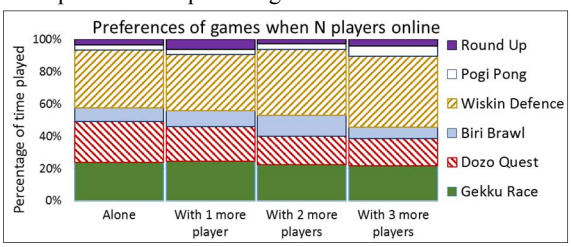

Figure 7: Preferred games based on number of players online.

5.4 Supporting a Variety of Play Styles

Liberi's mini-games support a range of play styles, including cooperative, competitive, team-based competitive, and solo play. While participants favoured cooperative play, there is evidence that they nonetheless valued having a variety of play styles available. To the question: "Which game did you like playing the most with the others?," eight participants specified Wiskin Defense, two preferred Bobo Ranch, and one listed Gekku Race (one participant chose two games). To the question: "Which one was your favorite game?," seven participants answered Wiskin Defense, two specified Gekku Race, and one preferred Biri Brawl. Figure 7 shows that the competitive Gekku Race and Biri Brawl games were heavily played. This indicates that despite the general preference toward cooperative games, it is important to support a range of game styles both to satisfy individual players' preferences and to provide a varied experience.

Players proved adept at negotiating among preferences within groups. For example: "There were times P2, P1 and P5 wanted to play different games, but they were able to discuss and to choose the games they would enjoy the most together." The variety in game choices allowed fluctuating groups to satisfy different participants' preferences. The negotiation with other players was itself a form of social interaction, helping participants to become familiar with each other.

Having a variety of games provided viable game options to players with different abilities. Earlier, we described that P3 had difficulties playing Wiskin Defense and that in one instance, the other player online agreed to change games after finishing the game in progress. P3 played Gekku Race while she waited for P2 to finish with Wiskin Defense. Despite being a competitive game, Gekku Race was a better choice for this group.

6. DISCUSSION

The social aspects of Liberi are especially important for children with physical disabilities, providing opportunities to socialize, particularly for those for whom leaving the house is difficult. Vital to this goal is the ability for players to interact and communicate, which Liberi delivers through its connected voice chat, supplemented by social media access in the form of a Facebook group. The voice chat proved to be an important component of the game, with players grouping less with others or sometimes outright leaving the game if this communication was interrupted. Players also played less when others were unavailable to interact with, meaning it was important that they be able to find times when other players were also online. The participants reported both the voice chat and the Facebook group to be useful in coordinating play times, to ensure they had others to play with.

Liberi is designed to have frictionless grouping mechanics, enabling players to play whichever games they like with any of the other players. Since players cannot be separated by ability without restricting grouping, the game is limited in how it can account for variations in physical ability among the players. This can occasionally cause problems, such as seen above when P2 was reluctant to play Wiskin Defense with P3 because he knew

the game would become harder. However, we found that players performed their own balancing by negotiating which games to play together, avoiding games that were difficult for individuals in the group. In general, the participants were inclusive, working to find a way for all members of the group to play together. This is indicative of the development of strong social links between players. It is interesting that players were able to organically compensate for the imperfections we have identified in our dynamic difficulty adjustment algorithms, changing games when the group composition rendered a game too difficult.

Oral communication is key to fostering social interaction. We found that in addition to the voice chat aiding engagement in gameplay, the game served as a seed for conversation. Often in the game session reports, we see that players began the session speaking mostly about issues related to the game, but then as they play, they begin discussing topics unrelated to Liberi. The game provides a ready-made topic for conversation, which then leads to interaction over broader topics. While further study is required, this aspect of the game indicates that Liberi is likely a better forum for social interaction than a simple chat room would be.

In terms of quantitative analysis of Liberi as a social platform, we saw that a large percentage of the time when it was possible, players actively played together. This result suggests that the aspects of Liberi designed to facilitate frictionless group formation—a small easily traversable world, immediate joining of games already in progress, and the simple non-exclusive group formation mechanic—are in fact successful.

A matter for further study is the general preference players have for cooperative games. This was seen in that 7 of the 10 players expressed a preference for cooperative play, the most popular game was the cooperative Wiskin Defense, and players transformed the competitive Biri Brawl game into a team game. A version of Biri Brawl in which players are teamed against the bots by default might prove more popular with players.

7. LESSONS FOR DESIGNERS

To summarize, we list the strategies used when designing Liberi that allowed strong social interaction among youth with CP, in hope that they will be helpful for designers of online games to promote social interaction among people with motor disabilities.

1. *Design for frictionless group formation*
   - Allow automatic grouping of players
   - Automatically establish a voice chat among all players
   - Provide clear on-screen indicators of the players presence
   - Make game activities easily joinable, and
   - Avoid virtual world designs that require long travel times.
2. *Balance for player ability*
   - Balance the mapping of player abilities to movement in the game, and
   - Provide a common group goal to mask the differences in players' abilities
3. *Support a variety of play styles*
   - Provide enough games to support individual preferences as well as differences in ability.

8. CONCLUSION

In this paper, we have shown that it is possible to create a networked video game that allows youth with CP to be socially active from the comfort of their homes.

We have identified barriers in existing online games that might prevent people with physical disabilities from socializing with others, and have described how our Liberi game helps to overcome these barriers. We discussed the effectiveness of Liberi's design through quantitative and qualitative data collected over a ten-week home-based study. To conclude, we provided a practical set of design strategies used for the design of our game, which we believe might be useful for designers of networked games that allow social interactions not only among youths with CP, but also among people with other physical disabilities.

Acknowledgments

We gratefully acknowledge the support of the GRAND and NeuroDevNet Networks of Centres of Excellence and of CIHR and NSERC through the Collaborative Health Research program.

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