Utilizing Displayless Space in Collocated Games

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ABSTRACT
Digital games have often been viewed as anti-social. However, this view has been recently changing as social aspects of games are gaining more emphasis. We explore the usage of physical space to enable socially richer game experiences. In particular, we utilize the spatial relationship between portable gaming devices to show multiple views into a shared game world. Similar multi-display systems have been studied in desktop PC environments to address the usability problems caused by gaps and bezels between the displays. In this paper, we demonstrate that this source of problems in utility applications can be a design opportunity in games. We implemented and evaluated two games that are played by two players using touch-screen controlled portable devices on a table. Results of our qualitative study show that the displayless space between the devices can be used to increase challenge, create positive surprises, stimulate imagination, and provoke social interaction in games. We also identified some design pitfalls that may break the illusion of a coherent space.

Author Keywords
handheld games, game design, displayless space, amodal completion

INTRODUCTION
Although many early digital games had multiplayer features, it is not until recently that games have been designed specifically to emphasize the social factors. Increasing popularity of massively multiplayer online games (e.g., World of Warcraft) and family entertainment games (e.g., SingStar) are clear evidences of this change.

Online games enable playing together over distance, but lack the sense of being together. Game consoles allow players to physically get together to play games, but they are restricted in specific places, e.g., in players' living rooms.

Portable devices are a unique gaming platform as they allow playing in various locations and situations. In addition, current portable devices have network capabilities that enable playing with remote or co-located friends. This would allow players to play games physically together, practically anywhere. Social aspects of handheld gaming are studied in [13], where it was found that players are motivated to play together in various contexts, but the Nintendo DS device is not designed to support it. This was due to the lack of a shared screen and the device's form factor that prevents others from easily observing the display.

We address this problem by utilizing multiple portable devices and their spatial relationships to create a shared social game space. However, such a setup with multiple devices and displays has an inherent usability problem caused by the gaps and bezels between the displays. The problem is further magnified by the small physical screen size of portable devices. Thus, an interesting research approach is to explore how the physical space falling between the devices' displays can be used to extend the game space. In this paper, we explore how to utilize the invisible and non-interactive space between the displays to increase challenge, imagination and surprise in games.

The rest of the paper is organized as follows. We review existing work related to social collocated games, multi-display systems, and theoretical foundations of human perception of partially visible objects. We then introduce our two game concepts, *Tennis* and *Maze*, and explain their underlying design principles. Next, we describe the evaluation method, followed by the results of the evaluation regarding both games. Finally, we discuss the overall findings, our conclusions and the open questions for future work.

RELATED WORK

Theoretical Background
Theories of amodal completion suggest that the human visual system completes parts of an object even when it is partially occluded. Global models suggest that figure completion is based on symmetry or regularity, whereas local models hypothesize that figure completion is based on continuation [12]. Studies suggest that in humans, amodal shape completion occurs in 75-200 msecs, although, the time appears to be dependent on the size of the occluded region [9].

In game design, it is a common method to hide some information from the players. Occluding visual information

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is utilized for example in the *fog of war* design pattern [3], in which only nearby regions are clearly visible. Another common example is the Memory card game, where players try to turn over pairs of matching cards. Thus, we can expect that players are familiar with the uncertainty of dealing with hidden visual information.

Existing Systems

Previous attempts to create social settings for digital games are based on interactive tabletop surfaces or augmented reality (AR) systems. Interactive tabletop systems, such as the STARS platform introduced by Magerkurth et al. [8], are fixed device installations and thus limit the available gaming contexts. Social factors in handheld AR games are studied by Xu et al. [14]. Their experiment shows that a shared physical game board can increase the social presence in handheld AR games. We aim to create a social game space by combining the displays of multiple portable devices, thus eliminating the need for additional game board.

Stitching is a common method in multi-monitor PC setups. In stitching, the mouse cursor warps between the monitors, ignoring the bezels and thus disrupting the relationship between motor and visual spaces. Mouse Ether was proposed as a solution, matching the visual and the motor spaces by allowing the mouse pointer to move in the off-screen space between the monitors [1]. The drawback is that the pointer is invisible to the user in the off-screen space [10]. OneSpace is a similar method for displaying images across multiple monitors without being distorted. Both Mouse Ether and OneSpace require manual calibration to calculate a geometric model reflecting the physical distance between the monitors. Our design is similar to OneSpace, and we use the notion of *displayless space* as defined in [10] to refer to the physical space between the displays.

Halo [2] and Wedge [4] are techniques for visualizing off-screen objects in small-screens devices. Halo is a circular shape and relies on the global models of amodal completion, whereas Wedge is a triangular shape following the local models. Halo has been successfully applied in multi-monitor settings to improve Mouse Ether [10]. Therefore, it would be suitable for our setup to visualize targets between the displays of the portable devices.

Nintendo DS is a dual-screen handheld gaming system with a clamshell form factor and a circa 3 cm wide gap between the two screens (depending on the model). Game designers have three options to handle the gap between the displays. Most of the games for Nintendo DS use the displays to show different information. The second option is to ignore the bezel and present the view to the game world as stitched. The third option is to extend the game world to the displayless space, similarly as in OneSpace [11]. This third option has rarely been used and there are no formal studies of how players perceive it.

Hinckley et al. [5] discuss the design space of dual-screen device postures for private, personal, and social use. Their device prototype, The Codex, is a dual-screen tablet computer that can be oriented in eleven different postures. Our design is similar to the “flat on table” posture for two users. For our study, the interesting findings in [5] were that two screens seem to provide a separation of thought and the collaborative possibilities between the two-display setup were perceived as desirable. The authors did not consider the advantages and disadvantages of the space between displays.

Hinckley et al. [6] proposed an interaction technique for combining mobile devices by using pen gestures that span multiple touch displays. The sizes of the bezels are taken into account when recognizing gestures and the spatial relationship between two devices. However, the authors did not study the use of the virtual space beneath the bezels.

Kortuem et al. [7] presented a sensor node system for calculating relative positions of multiple mobile devices in a peer-to-peer fashion. They discuss various use cases and visualization methods for the system, but do not consider combining the devices into a shared multi-display system.

These previous designs and study findings can be applied in design of multi-device games with a displayless space.

GAME PROTOTYPES

Device Setup

Both games, Tennis and Maze, were implemented on Nokia N810 handheld computer equipped with a touch-screen with the physical dimensions of 9.0 x 5.5 cm and resolution of 800 x 480 pixels. The games were controlled using a stylus. The width of the bezel on the top of the display is 0.7 cm. The minimum vertical distance between the displays of two devices is 1.8 cm, as the outer cover and buttons require some additional space. This corresponds to 157.1 pixels using the same vertical pixel density as the N810 display.

Figure 1: Menu to configure the distance between the displays to 120, 240 or 360 pixels.

Both games were designed so that the distance between the devices can be configured to one of three predefined distances. A distance configuration menu was used to select the distance and to position the devices accordingly (see Figure 1). The configuration menu shows two triangles spanning over both displays, allowing the right distance to be configured by placing the devices so that the triangles seem to be continuous. Similar triangle-based calibration was used in Mouse Ether and OneSpace [11].

The Maze game was based on tiles sized 80x60 pixels, and required the distance between displays to be a multiple of the tile height. Therefore, we selected the distances as 120, 240 and 360 pixels. The minimum distance of 120 pixels was selected according to the bezel width of 0.7 cm (1.4 cm = 122.2 pixels), which caused a perceivable but not distracting 4 mm error in the actual minimum distance of 1.8 cm (see Figure 1a).

Tennis Game

The primary design goal was to challenge players' ability to estimate ball trajectories over the space between the displays. Each player controls a racket by using a stylus to point the touch screen. The players try to hit the ball and make the opponent to miss it. The speed of the ball is initially 75% of the speed of the racket, and gradually increases until one of the players misses the ball.

The game field covers both the displays and the area between the displays. The field contains obstacles that cause the ball to bounce and change direction. The obstacles are either invisible or partially visible continuing to the area between the displays (see Figure 2). This requires players to form a mental model of the obstacles based on the visible areas, and update that model according to any unexpected behavior of the ball between the displays. Therefore, the game is supposed to challenge players' spatial perception and memory.

Figure 2: Tennis played with 360 pixels between the displays.

Maze Game

The Maze game was designed to use the displays as two scrolling windows to view a shared map. The objective of the game is to work together to navigate through a maze to a goal. The players' positions are indicated with red circles, which can be moved by pointing towards the target with the stylus (see Figure 3). A black line inside the red circle indicates the direction of the goal. The displays scroll together according to the movement of both players, ensuring that both players are always visible in their own display.

Figure 3: Maze played with 360 pixels between the displays.

Due to synchronized scrolling, the distance between the two views to the game map is always the same as the physical distance between the displays. This also restricts the movement of the players. As the views show 10 tiles horizontally, the maximum horizontal distance between the players is 9. As the views show 8 tiles vertically and there are 2, 4 or 6 tiles between the displays, the vertical distance between the players is always 3-17, 5-19 or 7-21, depending on the distance settings.

The maze continues through the displayless space, but any part of the maze can be viewed by moving towards it. Both displays can be used to memorize the maze. 5 different wall textures were used to help players to identify and follow how the walls continue through the displayless space.

EVALUATION

We evaluated the game prototypes to explore how the displayless space affects the game experience. Our primary research questions were:

1. How does displayless space facilitate social interaction?
2. How is challenge introduced by the displayless space experienced by players?
3. In what ways does the displayless space stimulate players' imagination?
4. Do fully or partially occluded objects create positive surprises in the game?
5. In what ways does the displayless space affect the visual immersion to the game world?

A qualitative study was conducted to answer these questions. The following sections describe the study setup.

Participants

Total of 14 participants were recruited to form 7 pairs of two players. Pairs were selected so that the players knew each other beforehand, as these types of games are typically played with friends. Participants were 26-36 years old males with some prior experience with playing games with mobile devices.

Study Design

Two pilot sessions were arranged, both with two participants (P1 – P4). In pilot sessions, both games had only one level due to time restrictions in implementation work. On basis of feedback from the pilots, the Tennis game was modified to be faster and include audio feedback.

Figure 4: The test setup. The players were facing each other.

The actual evaluation study consisted of five sessions with two participants each (P5 – P14). All pairs played both games with two distance settings, 120 pixels and 360 pixels. Two levels were used in both games. The order of games, levels, and distance settings were randomized. Figure 4 illustrates the test setup.

Data Collection

Semi-structured pair interviews were used after each play session. The questions were mainly related to the displayless space and our research questions, but also in problems and improvement ideas. After playing each game with the both distance settings for approximately 10-15 minutes, a questionnaire was used to rate the fun factor, the challenge level, and the amount of social interaction in the game, and to compare the distance settings according these aspects. After the Tennis sessions, we asked the participants to draw what they imagined to exist in the invisible area of the level.

RESULTS

Tennis Game

Social Interaction

We identified three main topics for the verbal communication during the gameplay. The most frequent topic was the rules and behavior of the game, as this was the first time they tried out the game.

Another common topic of discussion was the displayless space, particularly while playing with the longer distance. It seemed to provoke discussion when the ball entered the visible game area from an unexpected part of the screen. The players speculated and discussed what in the invisible area made the ball to change its trajectory. The following quote is from group 5:

> **P10**: *"Something very mystic is happening there in the middle."*

> **P11:** *"Yep, there is some bar like this."* [Gestures to show the obstacle between the devices]

The third common topic was friendly bragging and trash talking, indicating that the social setting supported the competitive gameplay. A good example is commentary by P10:

> **P10:** *"Damn,* [he] *approaches the net. Hey that's a tough one. I'll send it right back. No! How did you get it?* […] *Owned!*"

The participants used pointing and gestures to support verbal communication, for example when discussing about ball trajectories. The playing distance was considered small enough to follow the actions and intentions of the other player, but some players speculated that a notably larger distance might hinder the social presence. Players in group 4 stated that the distance was small enough to follow the other player, although P7 was a bit concerned about the large distance setting:

> **Small distance, P7:** *"I can well follow the other's play."* **P8:** *"The devices were still so close each other there."* **P7:** *"Yes, in this like easy level they were quite well close to each other so that you can like see the other's intensions. But if it was a bit further away, you could do this."* [Covers the display with his hand]

> **Large distance, P7**: *"I couldn't follow as well the other player's actions, I concentrated more on my own display. But I could clearly see where it came from* [where the other player struck the ball]. **P8:** *"I was watching so that I kind of saw where you struck* [the ball]. *But maybe* [because of] *that in-between* [space]*, those obstacles and that distance, I had to be a bit more focused."* **P7:** *"Lets say that I saw the other's intentions.* [But] *if it was something like this* [indicates with hand a larger distance], *then it would be a notch more difficult."*

The participants appreciated the social interaction in the game. In the questionnaire results (see Figure 5), 9 out of 10 participants agreed or strongly agreed with the proposed statement that the game involved social interaction. Half of the participants also stated that the game involved more social interaction when played with the larger gap, whereas the other half stated that there was no difference. Overall, the playing situation was perceived socially rich. None of the participants felt that the situation would be socially uncomfortable or intrusive. One participant compared the situation to typical console setting:

> **P3:** *"There is more social presence here than in a Playstation game, where you sit next each other but look at the TV."*

One of the participants, however, stated that the tennis game did not encourage social interaction:

> **P4:** *"This type of pong game doesn't present that many situations for making comments to the other player."*

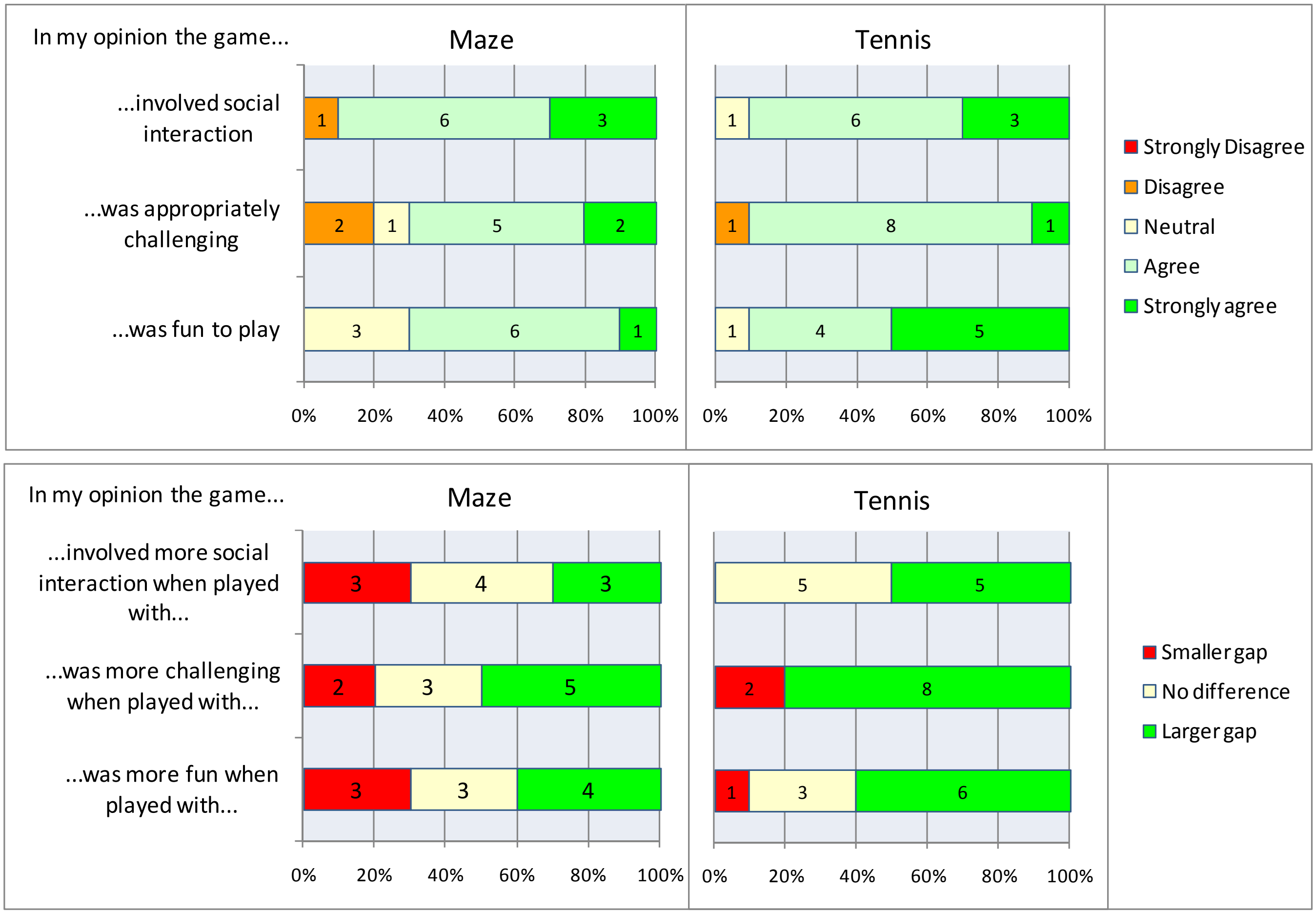

Figure 5: Questionnaire results

Challenge

Overall, the participants considered the game as appropriately challenging. 8 out of 10 participants agreed that the game was challenging. 8 participants also stated that the game was more challenging when played with the larger distance between the devices. Surprisingly, two remaining participants stated the opposite. Based on the interviews, increasing the distance produced an interesting paradox: increasing the distance makes it more difficult to predict the ball trajectories but gives more reaction time. This paradox was illustrated by discussion in group 6:

> **P12:** *"Well, sure it is more challenging when there is more unknown area."* **P11:** *"Well this again feels to move a bit faster when the distance is shorter."* **P12:** *"Yeah, it is true that it* [the ball] *comes rather quickly from there. In my opinion it caused more surprises that there were unknown things in the middle, than that it came quickly."*

In the pilot stage, playing the same field at different distances, there was less challenge provided by unpredictability as the players knew the game area from the previous game session. This was stated by participants in both pilot sessions.

> **P1:** *"This is supposed to be more difficult level since the gap is wider, but we have more time to react, so it is actually easier. We can plan and have plenty of time."*

Initially, the players needed to concentrate on defense and getting the ball to the opponent's side without hitting an obstacle. Some participants felt frustrated if the ball bounced back from an invisible obstacle. As the game progressed, the participants were able to learn the invisible obstacles and take advantage of them in the attack play. However, some uncertainty remained during the entire game session, as discussed by the players in group 4:

> **P8:** *"I think that those* [obstacles] *had more disadvantage like to myself. It* [the ball] *could like bounce back."*

> **P7:** *"For me it bounced back at least once. Scored an own goal. It takes a while to know that there is some obstacle in-between."*

> **P8:** *"Then when it was like a bit uncertain where they* [the obstacles] *are and what they are, and where they there all the time. Would need to play for some time to…* [find that out]*."*

A few participants expressed that they would prefer to see the entire game level before the game starts. This would create a challenge of memorizing the obstacles, while decreasing the challenge of learning them during the game.

Imagination

Based on the sketching task, the participants were able to form fairly accurate models of the level obstacles. In the pilot sessions we used a simplified level, similar to what was sketched by P4 in group 2 (see Figure 6b). The participants in group 2 followed directly the local and global completion strategies:

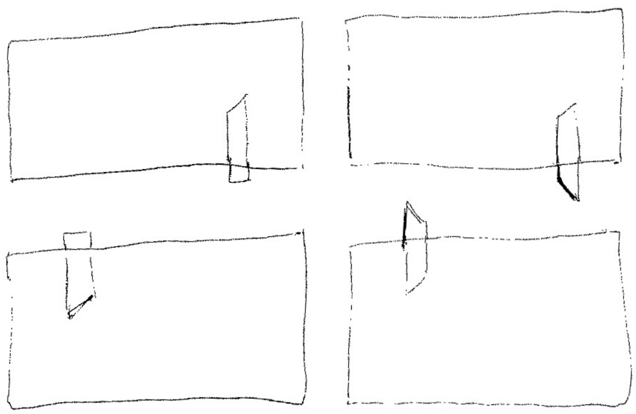

Figure 6: Sketches from the pilot session seem to follow the principles of amodal completion.

As we used more irregular obstacles in the design of the levels used in the actual tests, the participants needed to use more imagination to perceive the game level based on observed ball trajectories and sound feedback. Some participants still managed to form a detailed mental model of the obstacles. For instance, P10 in group 5 was able to draw the diagonal edges of level 1 correctly, based on a specific situation in a game (see Figure 7):

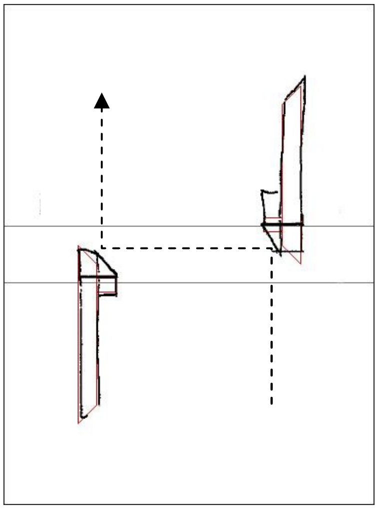

Figure 7: Correctly perceived diagonal edges. The dotted arrow indicates how the ball bounced from the edges.

P10: *"It was something like this because it* [the ball] *sometimes bounced like from here to there."* [gestures the imagined trajectory of the ball]

Following the global completion principle, most participants assumed that the obstacles were symmetric around the diagonal axes. Whereas this was true for the level 1, the center obstacle in level 2 was not horizontally centered. This was noticed only by participants P6 and P8 (see Figure 8).

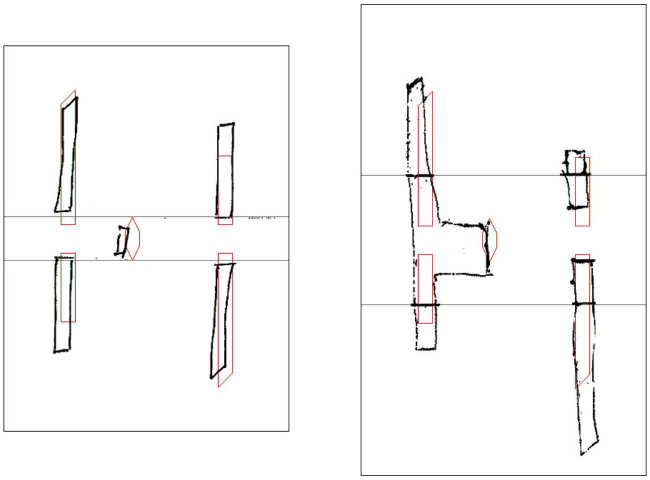

Figure 8: Only two study participants perceived correctly the asymmetrically located hidden obstacle.

All participants noticed the discontinuation in the level 2 obstacles. This kind of a hole in a presumably continuous obstacle was easily detected, when the ball traversed through the obstacle. Participant P6 noticed the discontinuation only in one of the obstacles, as shown in his sketching in Figure 8b.

Some of the sketches were less accurate and more imaginative in nature, especially when the game was played with the larger gap between the devices (see Figure 9). Some participants even speculated that the hidden obstacles might have changed during the game.

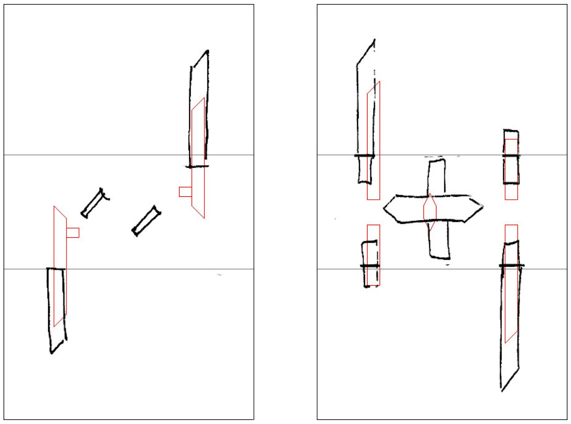

Figure 9: Examples of more imaginative sketches.

Surprises

The initial reaction to the ball bouncing back from an invisible obstacle seemed to be dislike. Particularly, a failure caused by an unexpected surprise was initially considered unfair. On the other hand, some players obtained enjoyment from the misfortune of the opponent.

> **P3:** *"The ball bounced back from the invisible area… It is a bad thing if you lose the game because of that."*

> **P11:** *"When surprises happen to the friend, then it is quite good. It could be a selectable option what lies there* [in the invisible area]."

> **P9:** *"Maybe it was a bad thing* [the surprises]. *Not after you have learned that, yeah, it* [the ball] *can apparently come back from there like that."*

As the game progressed, the players seemed to begin to appreciate the element of surprise, as it made the game more interesting. The invisible space alone was not considered interesting, but the fact that it contained something mystic and unexpected.

> **P7:** *"I think it was a good thing to have something there in-between, that like brought a bit more to the game. A bit more surprises like, oh yeah, there was that thing… When it has been taken into consideration that the ball moves like in the air between* [the screens]*, then you can't see it and it takes a while to see where it comes from.* […] *I think that was good. You have to guess where the ball enters* [the field]. *Then there are those obstacles in-between and they can change its* [the ball's] *direction."*

As expected, increasing the gap between the devices was considered to create more surprises in the game. Players in group 3 stated that due to this, the game was more fun to play with the larger gap. They explained that the surprises made the game more exciting and competitive:

> **P5:** *"I think it was a good thing, because it felt that it changes at some stage. So that occasionally it went through the middle, but at other times it didn't. It brought some excitement to the game."* **P6:** *"I agree. Having an element of uncertainty and like an appropriate factor of unfairness generate some competitive spirit and such like in table hockey."*

Audio-Visual Immersion

None of the participants expressed that they felt the game area was split into two separate fields. The drawings produced by the participants suggest that the game space was perceived as cohesive.

The sound the ball made at impact seemed to help the participants (e.g., P11) to follow the ball trajectory through the displayless space. The sound was absent in the pilots and it seemed more difficult for the participants to perceive what occurred in the displayless space.

Maze Game

Social Interaction

We found that navigating through the maze required coordination between the players. The social interaction ranged from casual conversation to one player rather directly telling the other player what to do.

> **P7:** *"Through discussion* [we coordinated moving], *I said at least a couple of times: "wait, I will move through here"."*

Not surprisingly, the required coordination was proportional to the difficulty level:

> **P7:** *"First I mostly followed my own* [display] *but then it had to be coordinated. Otherwise we wouldn't have reached the goal at all."*

> **P12:** "[…] *if there were quite few options where to go, then you would need to more plan with your friend so that you could get there* [where you want]*."*

Problems in communication occurred from failing to perceive how the two views to the maze were related:

> **P9:** *"I also said to* [P10] *that "go up", when I of course meant go down. But I understood it immediately afterwards that you have to in principle say the opposite."*

Participants acknowledged that they glanced the other's display at least occasionally. Some of the participants noted that they communicated also non-verbally, for example by showing with their eyes the direction of desired movement to the other player.

Other findings

Increasing the distance between the devices seemed to have less effect on the perceived challenge than what the level design had. Those who played level 1 at longer distance felt it easier than level 2 at close distance.

Even a small gap seemed to create a challenge of remembering how the maze continues between the displays. However, it cannot be said if increasing the gap actually increased the challenge further.

> **P9:** "*For example when I have occasionally played with Nintendo DS* […] *there is a gap between the displays, but it doesn't matter because they are in a way connected. That feels to be the case here as well… I presume they* [the displays] *continue. This obviously increases the difficulty level, but* […] *it is somewhat strange… so that are we now at all in the same area* [or not]*."*

Most participants felt that there was not enough benefit from following both displays and remembering invisible parts of the maze. One participant, however, presumed that this was one of the objectives of the game;

> **P1:** *"I think that's one of the points of the game that you should remember those* [the previously seen parts]. *It*

would be so easier if you would see the [entire] *map, but that would not be the point."*

Many participants had problems of initially perceiving the game area as cohesive.

P3: *"At first I thought that the other display was a mirror image* [of my display]*."*

P10: *"At least for me it took a little while to perceive that this was really the same map."*

The following statement from one of the participants in group 4 seems to support the hypothesis of strategy of continuation when perceiving the invisible area:

P7: *"But after I started to take benefit of the colors* [of the maze walls] *it was possible to see that these* [two displays] *are like the same area."*

There were mixed opinions between the participants on whether increasing the distance between the displays disrupted the sense of cohesive space:

P6: *"I think that now we had two separate fields, rather than one shared field."* **P5:** *"I didn't feel like that."* **P6:** *"There was no longer commonness between the fields."*

P11: *"I didn't quite perceive that they were in principle the same space there when the gap was longer. Mostly it was that the other's movement influenced my view."*

Unlike the Tennis game, the Maze game had not been designed to provide surprises. However, many of the participants considered surprises to be important. Thus, they offered several ideas on how to get more surprises and challenge, including a time limit, checkpoints, a door that opens only once, having the labyrinth changing shape, and having monsters.

P5: *"The game was easy as such. But there could be a time limit. Or to have monsters. Now it was like riding a train - no excitement."*

DISCUSSION

Challenge Types

As demonstrated by these games, the displayless space can be used to create various types of challenges. In the Tennis game, the first task was to estimate how the visible obstacles continue in the displayless space. The participants seemed to start according to the local and global completion strategies [12], assuming that the obstacles are symmetric or end right after the edge of the display. The next challenge was to predict the trajectory of the ball assuming that it was not impacted by any obstacles. Whenever the ball hit an obstacle, the players needed to prepare for the changed trajectory and update their mental models of the hidden obstacles. During the play session, there was a continuous challenge of learning and remembering the hidden obstacles. Overall, all these challenges were highly time-critical and the speed was more important than accuracy.

As the players move in the Maze game, the displayless space hides parts of the map that were previously visible. The challenge was to remember those parts, but most players ignored this challenge as they were able to navigate the maze by looking exclusively at their own display. However, some players in the Tennis game stated that they would prefer seeing the whole stage before the game starts, and then try to remember the obstacles during the game. This suggests that the players would appreciate the challenge of remembering already seen things.

Most players in the Tennis game tried to avoid the obstacles, rather than using them to make unpredictable shots. This indicates that the participants perceived the challenge as against the game, rather than against the opponent. This is explained by the fact that the ball often bounced back from an obstacle, sometimes causing the player to miss the ball. This could be changed by removing horizontal obstacles that cause the ball to bounce back.

In general, coping with partially or entirely invisible objects is cognitively demanding and requires constant concentration. If the challenge becomes too difficult or the benefit is not seen as worth the effort, players start focusing only on their own display. This can reduce the social factors of the game. One approach to avoid this problem is phasing that allows players to concentrate on one thing at a time, similarly as in the Tennis game.

Imagination and Surprises

As can be seen from figures 5 to 7, in the Tennis game, the participants were able to form quite accurate models of the hidden obstacles. However, there was some mismatch in the size and the shape of the obstacles. Particularly, most participants overestimated the size of the obstacles. This can be explained by error propagation in the player's mental model. If a ball hits the same obstacle multiple times, errors in the points of impact cause the perceived size of the obstacle to increase. Once a mental model is established, it may take multiple observations to change or reject the model. Some participants trusted their mental models to the extent that they believed that the obstacles had dynamically changed during the game.

The Maze game did not have similar phenomenon, as parts of the level were hidden only temporarily. Permanently hidden objects can create positive surprises, making a game more exciting. However, excessive amount of hidden details may break the mental models and frustrate the players. A few small obstacles were enough to create surprises in the Tennis game. Using symmetry in level design decreases the cognitive load of memorizing the level's appearance. As shown in level 2 of Tennis game, having an asymmetric element in a seemingly symmetric game level increases the potential for surprise.

Social Elements

Social interaction during the play sessions was strongly connected to challenge, imagination and surprises. In the

Tennis game, players discussed the hidden obstacles and unexpected trajectories of the ball. In the Maze game, increasing the challenge required more coordination.

In comparison to typical mobile or console game settings, the game setup was better suited for social interaction. As the players were facing each other, they were able to see each others' actions and intentions, as well as gestures, facial expressions and other non-verbal cues. The face to face situation caused some confusion regarding directions and coordinate axes, but this was not considered as a problem.

Distance between the devices was relatively small in all sessions and was not considered to hinder the social presence. In fact, the questionnaire results indicate that increasing the distance in the Tennis game actually increased the amount of social interaction. Most likely explanation is that the increased amount of surprises provoked discussion. However, there are two alternative hypotheses. Firstly, the phase of the game depends on the distance, as the ball traverses through the displayless space with a constant speed. Thus, increasing the distance slows down the phase, allowing more time for observing the other player. Secondly, participants were seated at a constant distance from each other. Therefore, increasing the distance between the devices decreased the distance between a player and his own device. This may help following the opponent's display and his nonverbal cues simultaneously. These hypotheses need to be tested in future experiments.

Improvements to the Maze Game

The Maze game failed in motivating players to follow both displays and to memorize how the maze continues through the displayless space. The participants were able to navigate the maze by relying mainly on their own display, and there was not enough benefit in constantly following both displays. Participants also felt that the game lacked challenge. The illusion of a coherent space got broken when played with the larger distance between the devices.

These problems can be addressed by encouraging players to follow each other's actions, along with a proper feedback and reward mechanism. We designed and implemented a new version, where players need to follow each other's steps to reach the goal. Evaluating the new version is a topic for future work.

CONCLUSIONS

In this paper, we have explored the new design space of collocated multiplayer games for portable devices. We implemented and evaluated two multiplayer games called Tennis and Maze. The games are played on two devices so that both displays together provide a unified view to the game world. The physical distance between the devices is taken into account so that the game world continues through the displayless space between the devices.

To evaluate the games and examine how the displayless space is experienced by the players, we arranged a qualitative study with 14 participants. Results of our study show that the displayless space can be used to increase challenge, create positive surprises, stimulate imagination, and provoke social interaction in games. If the game is not appropriately designed, even a small increase in the gap between the devices may break the illusion of a coherent space.

Our study contributes to understanding player perceptions of the relationship between physical space and game space, and provides insight for designing games that utilize this design space.

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