The Sightlence Game: Designing a Haptic Computer Game Interface

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ABSTRACT

The haptic modality is currently underutilized and poorly understood as a design material in game design. There are few computer games to draw on for inspiration during design explorations. This design case study explores how to use the haptic modality as a design material for computer game interfaces that requires neither graphics nor audio. The idea behind the case study is that a better understanding of haptic computer game interfaces can increase interface innovation and accessibility by giving game designers a third modality to work with together with graphics and audio. The design problem was approached through design explorations, development of an interface translation method, iterative game development of a haptic translation of Pong, and playtests with 34 people comprised of game design students and professors, adults with and without deafblindness, and children with deafblindness and congenital cognitive disabilities. The results show that computer games can be designed with haptic interfaces that only require standard gamepads rather than expensive or custom-made hardware. This also holds for computer games with time-critical features and complex interfaces with concurrent haptic signals.

Keywords

case study, deafblindess, design, game design, gamepad, haptics, interface, usability

INTRODUCTION

Haptics has been available as an interface modality in game consoles since Nintendo introduced the *Rumble Pack* in 1997 (Buchanan, 2008, April 3). If the haptic modality is used in a game it is mostly in a cursory manner as an enhancement to feedback primarily presented in another modality. While haptics is an umbrella term that encompasses both kinaesthetic and cutaneous perception Pasquero (2006) it's used here to primarily refer to cutaneous, touch, perception unless explicitly stated for simplicity and colloquial conformity. In *Halo: Combat Evolved* (Bungie, 2001) it is used to complement the graphics and audio when a weapon is fired. Haptics is currently underutilized in computer interaction compared to graphics and audio (Tan & Pentland, 2005). The skin offer game designers a largely ignored opportunity for design explorations since the skin is the body's largest organ (Montagu, 1978, p. 4) and has interesting unique properties.

While haptics is currently underutilised there are a few notable exceptions where the modality has been used in a more integral manner in computer games. *Haptic Battle Pong* (Morris, Joshi & Salisbury, 2004) combines a graphic and kinaesthetic haptic interface to create a version of *Pong* (Atari Inc., 1972) focusing on physics where the players control their paddle with a Phantom stylus. *Blind Hero* (Yuan & Folmer, 2008) combines an

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audio and tactile haptic interface using a custom made haptic glove to create a guitar game that's playable without graphics. Wang, Levesque, Pasquero and Hayward (2006) created a game of *Memory* that uses a custom-made tactile display as interface. Gutschmidt, Schiewe, Zinke and Jürgensen (2010) created a *Sudoku* game with a tactile haptic interface based on a custom-made Braille display. *Fallout 3* (Bethesda Game Studios, 2008) combines graphics, audio, and tactile haptics in its lock pick minigames and the modalities depend on each other to enhance the interface experience. *VI-Bowling* (Morelli, Foley & Folmer, 2010) made an audio and haptic interface translation of the *Wii Sports* bowling game (Nintendo, 2006). Computer games that are playable with only a haptic interface, for example the memory game of Wang, Levesque, Pasquero, and Hayward (2006), tend to run on either custom-made or expensive hardware devices, and they are also not time-critical. Computer games that only rely on standard gamepads for its haptic interface, for example VI-Bowling and Fallout 3, tend to combine the haptics with other modalities, and also only use one or a few haptic signals.

The design challenge in this case study has been to design a computer game that only relies on standard game console gamepads, that has a more complex haptic interface with several concurrent haptic signals, and that also feature time-critical game challenges, while still being playable without graphics or audio. It is valuable to explore haptics as a game design material as it expands the interface repertoire for computer games with a third modality that can be used to create new gameplay experiences, while also inviting currently excluded people to play.

HAPTIC DEVICES

Research and development of haptic interfaces devices can be roughly divided into four categories: vibrotactile devices, force-feedback systems, tactile displays, and surface displays (Hayward & Maclean, 2007). The two types of haptic devices most commonly found in today's consumer electronics vibrotactile devices and force-feedback systems. Vibrotactile devices are more prolific since they are imbedded in mobile phones, and gamepads. Vibrotactile devices usually consist of an electrical motor that rotates an asymmetrically shaped weight, which causes vibrations. Force-feedback systems work through force input, which simulate resistance by applying a counter-force that the person feels when they try to affect an object. Force-feedback systems in computer game devices are commonly found in steering wheel devices for racing games.

Haptic Parameters

Brewster and Brown (2004) suggest that haptic signals can be used to carry abstract linguistic representations. Designing haptic signals is similar to designing audio signals, with the addition of a couple of unique parameters. The common parameters are frequency, amplitude, waveform, duration, and rhythm while the unique are body location, and spatiotemporal patterns (ibid.). People eventually habituate to haptic signals so sensation decreases with prolonged exposure. The recovery period varies from seconds to minutes depending on signal intensity and duration (Gunther, Davenport, & O'Modhrain, 2002).

Frequency is the number of occurrences of a repeating event over a unit of time measured in hertz; 20 Hz corresponds to 20 occurrences during 1 second. Humans can perceive frequencies between 20 Hz and 1000 Hz, and are most sensitive to frequencies around 250 Hz (Gunther et al., 2002). Humans are better at comparing relative differences between haptic signals rather than identifying absolute frequencies (Brewster, Wright, &

Edwards, 1992). Gill (as cited in Brewster & Brown, 2004) states that humans can differentiate between 9 frequency levels at most.

Amplitude denotes the maximum displacement from a neutral zero value during oscillation. It affects the perceived loudness or strength of a signal. The pain threshold for haptic signals is 55 dB according to Verrillo and Gescheider (as cited in Gunther, 2001, p. 17). Haptic signals start to show signal leakage above 28 dB (Sherrik (1985, pp. 78-83). Geldard (1960) suggests that a designer should only use three different amplitude strengths for haptic signals for humans to be able to identify them absolutely.

Waveform can be changed to give haptic signals different coarseness. Humans can differentiate between three absolute waveforms (Hoggan & Brewster, 2007). Four common waveforms are the sine, square, triangle, and saw tooth waveforms.

Duration is the length of a haptic signal measured in seconds. Signals are perceived as sudden taps if they are less than 0.1 seconds and as continuous signals if they are longer (Gunther, 2001, p.59). Geldard (1960) suggests that haptic signals should not exceed 2 seconds in duration, and also to use 5 or less absolute durations in interface design.

Rhythm is created when haptic signals change in frequency, amplitude, or waveform over its duration. This allows for greater differentiation between haptic signals.

Body location can be used to distribute haptic signals across the skin's surface area. It is best to place haptic devices at anatomical joins since research shows that humans are better at locating haptic signals correctly when they occur at joints compared to other body locations (Cholewiak & Collins, 2003). The same holds true for the navel and spine compared to the rest of the abdomen (Cholewiak, Brill & Schwab, 2004).

Spatiotemporal patterns are made up of haptic signals that change body location over their duration. This can be used to create patterns by sequentially stimulating several areas of the body. When designing spatiotemporal patterns it becomes important to consider their commonality, which is the similarity between two patterns that share one or more haptic devices (Geldard & Sherrick, 1965).

Semiotic Framing of Haptic Signals

The design of the haptic signals took a semiotic approach, which proved valuable. It is also appropriate as the game's code, and subsequent presentation, as an interface for player interaction fits into the structure of semiotics. Pierce's semiotic model was used instead of Saussure's as it conformed better to both project needs, and to computer game code. Peirce model holds that language and its connection to an external world can be conceptualised as a system of signs (Chandler, 2007, p. 29). For this design project it was assumed that the notion of language is modality independent. Each sign consisting of three parts: a representamen, an interpretant and an object (ibid.). The representamen is the signs particular shape, the interpretant is the sense made of the sign, and the object exists beyond the sign and is its referent (ibid. p.36).

The design approach also considers computer game code to be equivalent to sign objects while representamens form the user interface. Designing a successful modality translation therefore consists of understanding the sign objects well enough to successfully design new representamens in another interface modality while keeping the interpretants intact. The Xbox 360 gamepads have imprecise vibrotactile devices. This makes it necessary to design haptic modality translations with only symbolic signs that correspond to words in spoken languages. Iconic and indexical signs would be hard to design on an Xbox 360 gamepad because of technological limitations.

DESIGN PROCESS

The design process was organized to be explorative and with divergent, transformative, and converging activities (Buxton, 2007; Jones, 1992, p. viii). This allowed for the exploration of divergent ideas, structuring of the problem space, and evaluation of outcomes to arrive at a suitable design before spending development resources. A couple of initial criteria were decided for the design process. The first was that the computer game should be playable without graphics and audio. The second was that it should require neither expensive nor custom-made haptic devices. This led to an early decision to use Xbox 360 gamepads since they contain two vibrotactile devices.

The initial sketching concentrated on imagining what the interfaces of classical computer games from genres like platformers, shooters, sports, and fighting games could feel like as haptic interfaces instead. The games were analysed using Sicart’s (2008) model of game mechanics, rules, and objects. Agents were also added to his model, as they seem implicit. The possible inputs to, and feedback from, the computer games were also analysed. This exploration indicated that the spatiotemporal relationships between a game’s objects would be interesting to explore further. New ideas for computer games were also sketched but it became clear that designing both a new game interface and a new game structure would lead to methodological problems during play testing. It would not be possible to say for certain if confusion when playing the computer game is caused by the haptic interface or the structure of the computer game. It was therefore decided that a classic computer game would be redesigned with a haptic interface.

Based on the early sketch explorations it was decided that the computer game should have a 2D environment and few objects, it should have time-constraints to give decision making a time limit, and it should also be an iconic and historically important computer game in order to make it accessible to a new audience. The computer game that best fit these criteria was Pong. The design process then moved on to development and changed into an iterative game development with rapid cycles between design, implementation, and testing. The novel interface translation method was an important part of this iterative development.

Interface Translation Method

The computer game translates the interface of the classic computer game Pong into a haptic interface. It was therefore important to ensure that all relevant information in the original interface was translated into the haptic interface. An interface translation method was created for this purpose. An overview is given in figure 1 below.

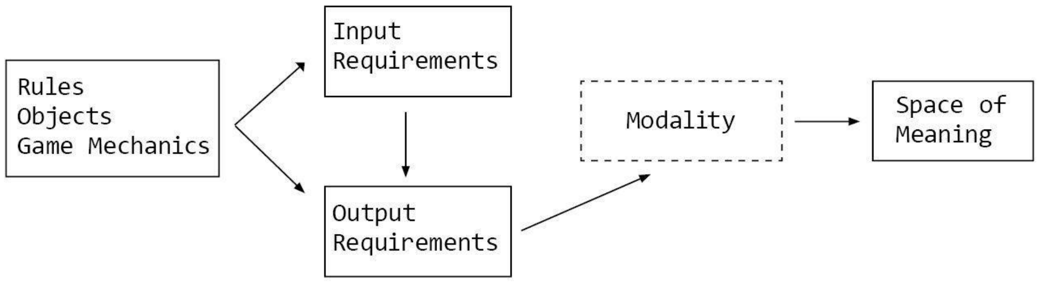

Figure 1: Flowchart of the Interface Translation Method.

The first step is to analyse the game using Sicart's (2008) framework by articulating the game mechanics, rules, and objects of the game. Sicart defines game mechanics as "*methods invoked by the agents, designed for interaction with the game state*". This definition also shows his distinction between game mechanics and other parts of the computer game's code. For the method this distinction was ignored in favour of another distinction in how the interface makes the game mechanics, rules, objects, and agents accessible to the player.

The second step is to analyse the interaction between the player and the computer game in the form of input and feedback. Game mechanics and objects are often presented as perceptual elements. The input and feedback for Pong are presented in table 1.

Input	**Output**
Move player's paddle up	Ball position relative to the player's paddle on the Y-axis
Move player's paddle down	Ball position relative to the player's paddle on the X-axis
Play a new ball	Ball bounces against the game's upper or lower boundary
	Ball bounces against a player's paddle
	Paddle hits the game's upper or lower boundary
	Player scores a point

Table 1: Controller input and feedback output for Pong.

The third step is to decide on the modalities that are going to be used for the computer game interface and the capabilities of the hardware used to mediate it. In this case study the vibrotactile devices in the Xbox 360 gamepads used to give haptic feedback to the player. The computer game uses the original graphic interface from Pong but only needs the haptic modality to be played.

The fourth step is to tie the previous parts together into a coherent interface design that players can interact with to play the computer game. This involves creating suitable interface metaphors if necessary, and designing a rich information space that communicates all necessary perceptible elements and their relations

Usability Testing Performance Metrics

Two performance metrics, learnability and task success, were measured during second iteration of the play tests. Learnability was measured to identify player proficiency increases over time (Tullis & Albert, 2008, p. 93). It was operationalized as the number of times in a row that a player managed to successfully intercept the game's ball and bounce it back towards the computer opponent. Automated tests were used to collect this data during play. Task success measurements were used to evaluate how well players managed to recognize haptic signals in given tasks (Tullis & Albert, 2008, p. 64). They were evaluated with a binary success criterion to avoid grey areas of partial successes. An example of a task was to identify a ball moving towards the player.

GAME OVERVIEW

The classic computer game Pong was released in 1972 by Atari Inc. and is now a beloved classic in computer game history. The Sightlence version is an attempt to give Pong a new haptic interface. The haptic interface is communicated to each player through two Xbox 360 Wireless Controller for Windows because of gamepads limited capabilities.

The Sightlence version leaves the basic rules intact and primarily remains a two-player game where the players take turns bouncing the ball between them until one player fails to catch the ball. It is difficult for people to play the game solely with the haptic interface because of limitations in the Xbox 360 gamepad's vibrotactile devices, and their unfamiliarity with the haptic modality as a computer game interface. A few changes were therefore made to make the challenge easier.

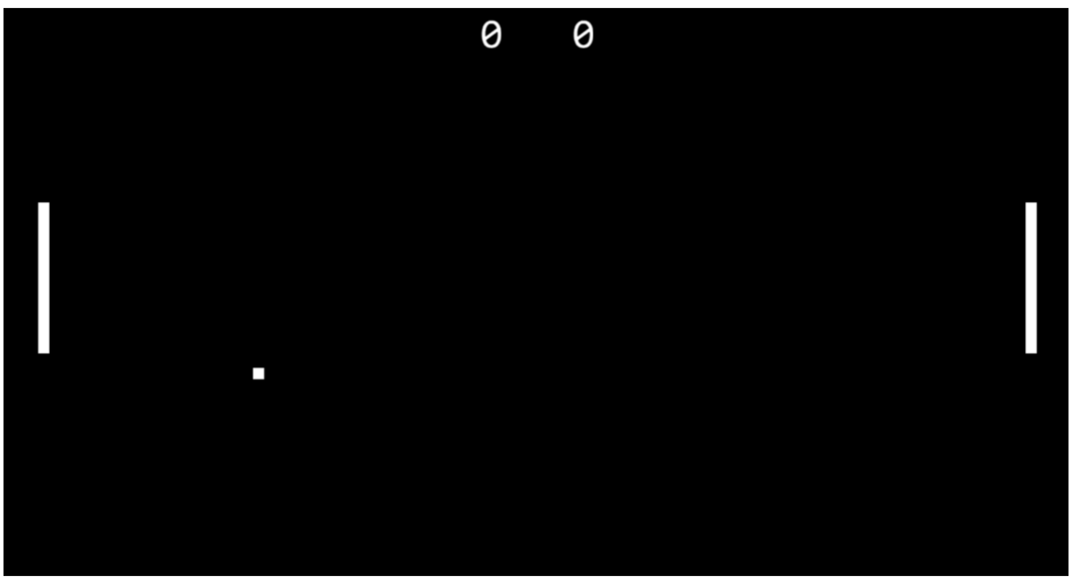

Figure 2: Screenshot of in-game play.

The paddles were made taller to make it easier to catch the ball. The ball's angles when bouncing against the paddle were set to 45 degrees instead of being calculated as a function of where the ball hit the paddle. The speed of the ball was also decreased compared to the original game. The ball then speeds up with 10 percentages for each paddle bounce. These changes make the game relatively easy to play with the graphical interface turned on during the first few bounces but it is still challenging when played with the haptic interface because of players' unfamiliarity with the interface modality.

PLAY TESTING

Once the design concept had been formulated in the exploration phase to find the right design the work continued with four iterative design and development cycles. This phase focused on refining and getting the design right. Each cycle consisted of design, development, play testing, and evaluation. The evaluation was then used as input to the design exploration in the next cycle. The play test in each iterative cycle had different foci and participants. The groups that participated in the play tests were, in chronological order: (1) game design students and academics; (2) adults with deafblindness; (3) adults with average vision and hearing; and (4) children with both deafblindness and congenital cognitive impairment.

The First Play Test

The purpose of the first playtest was to elicit criticism on the design concept and the first prototype. Ten postgraduate game design students and two professors participated in the play test. The sessions consisted of a play-through, and a subsequent critique discussion.

Each participant was given a presentation of the computer game prototype and a demonstration of its haptic interface. Both the haptic and the graphic interfaces were turned on during the demonstration to make it easier for the participants to understand the connection between the game objects, their interaction, and their corresponding haptic signals. The participants were then given a couple of minutes to familiarize themselves with the haptic signals before the graphic interface was turned off. Then they played the computer game for ten minutes with only the haptic interface to the best of their ability. After each session there was an open-ended informal critique discussion of the prototype.

Results

The participants in the play test found that the haptic interface concept for computer games was worthwhile. They also raised concerns that can be grouped into three topics. The first concern was the choice to translate the interface an existing computer game rather than designing both a new rule set together with a haptic interface. It would clearly be a valuable exploration for future game design projects. For this particular project however, the choice to work with an existing computer game was made for methodological reasons in order to isolate playability issues to the interface itself rather than possible confusions around the game rules. Another concern was that difficulty of remembering the meaning of different haptic signals. The vibrotactile devices in the Xbox 360 gamepads are not particularly precise in themselves and this is compounded with the participants' unfamiliarity with haptic computer game interfaces. Lastly, it was seen as a problem that the haptic interface conveyed less information than its graphical counterpart about the computer game. It was an important problem to correct as it would be hard to claim that a successful interface translation has been done unless both interfaces convey the same information richness.

Modifications

A secondary Xbox 360 gamepad was added for each player in order to increase the haptic interface's information richness. Body location is an available design parameter when creating haptic interfaces and it is therefore possible to use haptic signals on both gamepads that are identical in frequency and amplitude to each other. Four haptic signals were added to convey the position of the ball in relation to the paddle along the X-axis, for when the ball bounces against the upper and lower boundaries of the play area, for when the paddle hits those boundaries, and also for when a new ball is played. The existing haptic signal for when a point is scored was also changed to alternate between high and low amplitude strength for its duration to improve player recognition.

The Second Play Test

Five people participated in the second play test. They were between 30 and 70 years old and had deafblindness. The purpose was to learn about their perception of the game, and their computer game experiences. The play session took place at the annual meeting of a local chapter of the Swedish association for people with deafblindness, FSDB. Because of time constraints the play session was done in a town hall meeting format. More people wanted to play the game than there was time for despite only playing 5-10 minutes each.

Results

The participants stated that they found the computer game enjoyable, despite being very challenging since it was their first time playing computer games. An interesting event took place during the play session that showed some of the potential with haptic interfaces. One of the interpreters placed her hands on the participants back and used them to draw the size and location of the two paddles, and then she mimicked the movements of the ball as it travelled across the play area. In this way she managed to create a spatiotemporal haptic translation of the graphical interface on the players back. A personal anecdote that I feel compelled to share is that of two senior gentlemen that played the game and were afterwards holding each other's hands to show how they had been playing by mimicking the paddles with their hands and then moving their hands together to feel in the air the movement of the ball. Their smiles reminded me of myself as 15-years old when I played StarCraft at LAN parties and afterwards huddled up excitedly with my friends to discuss everything that had happened during the match.

Modifications

The participants had trouble moving the paddle smoothly up and down across because the D-pad on the Xbox 360 gamepad is a digital button, which can only be completely on or off. Paddle control was therefore moved to the left analogue stick so players can gradually adjust the paddle movements between 0 and 1. The boundary hit box for the paddles was also changed so the haptic signals for when the ball is above, or below, the paddle has their onset one sixth of the paddle length earlier than the actual hit box size.

The Third Play Test

The third play test was done with participants that had average vision, and average hearing, when adjusted with aids. The purpose was to measure improvements in play proficiency over time, and haptic signal recognition. The assumption was that participants might be better at correctly identifying haptic signals than they are at proficiently playing the computer game since it is skill-based.

14 participants were initially recruited, but 5 were later excluded. 3 participants were excluded because of unfortunate interruptions, and 2 because of technical problems. The 9 remaining participants were all between 18 and 30 years old, 3 women and 5 men, except 1 man that was 50 years old. All participants were familiar with Pong, and they used computers on a daily basis. 4 of the participants played games at least three times per week, 2 played at least once a week, 2 almost never played games, and 1 played only one game but played it daily. That computer game was Harpan for Windows XP (Microsoft Corporation, 2001; Eng. Solitaire).

The participants were given a presentation of the computer game, and then got to play the game for 2 minutes with both the graphical and haptic interfaces turned on. The participants were then asked to play the computer game with only the haptic interface to the best of their ability for 20 minutes. They were then given a short break. In the second part they were asked to identify the haptic signals used in the game. The questions were given in the form of "*Indicate when you feel that the ball is moving towards you*".

Results

To play the game successfully the player must recognize the haptic signals and respond with appropriate actions. The first part of the play session was designed to measure player proficiency, and the second part was designed to measure haptic signal recognition.

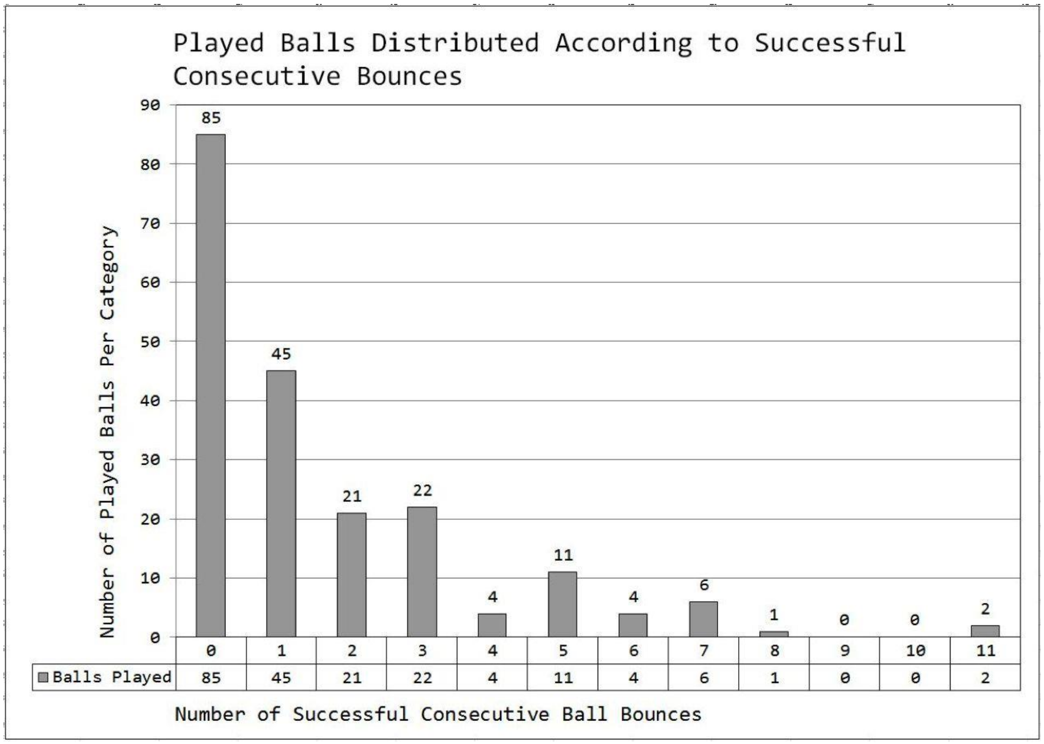

Figure 3: Diagram of players' proficiency in intercepting the ball successfully.

Figure 3 shows that the participants had a hard time playing the game with only the haptic interface. This is not surprising since it's the first time they played with such an interface. Two participants performed significantly better than the rest, and intercepted the ball 11 times each in a row, which gives hope for the learnability of haptic interfaces.

Out of the total of 201 played balls, 85 (42%) of them were not successfully intercepted a single time. This is not a particularly high number but it also means that it took the participants less than 25 minutes to learn a completely new interface well enough to catch 116 (58%) of the balls at least once. Participants seemed to undergo a shift in their understanding of the haptic interface after about 20 to 25 minutes of playtime. They reported a sense of "getting it" and finally being able to discriminate the signals from each other. This indicates that a further longitudinal study with repeat play sessions could reveal further learning effects.

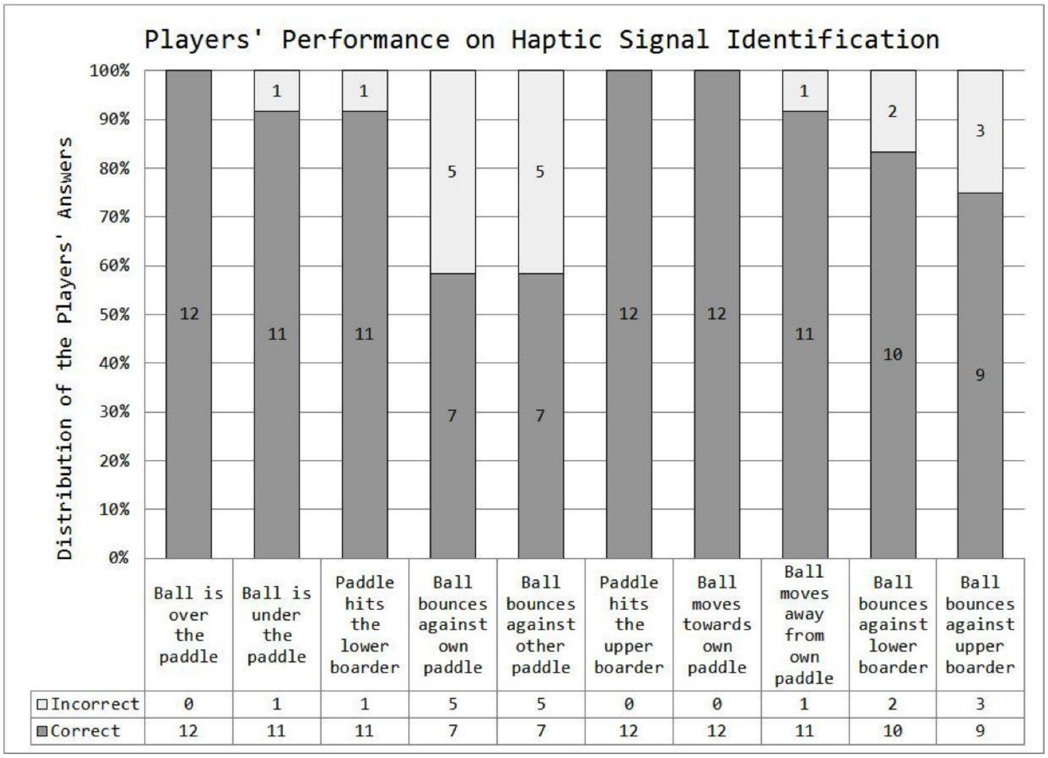

Figure 4: Players' proficiency in haptic signal recognition.

Figure 4 shows that the participants were better at identifying the different haptic signals than they were at using those signals to play the computer game. Two signal pairs are interesting because of their commonality and the mistake people made when identifying them. Those signals where when the ball bounced against the paddles (bar four and five from the left), and when it bounced against the upper and lower boundaries of the play area (last two bars from the left). In both cases the participants didn’t have trouble recognising the signal as being about those two interactions but they did have trouble recognizing which of the two paddles the ball was bouncing against, and which of the two boundaries it was bouncing against.

Figure 4 shows that recognition was worse for the paddle bounce, than for the boundary bounces. This cannot be explained by haptic sensitivity of different areas of the skin since the paddle interaction was transmitted through the gamepad that they held in their hands while the interaction for when the ball bounced against the upper and lower boundaries was transmitted through the gamepad in their lap. If haptic sensitivity was involved the results should be better for the hand gamepad instead of worse. It is probably a question of signal decay over time. The play area is rectangular and it takes longer for the ball to travel across its length than for it to travel across. This is consistent with earlier research stating that people are better at recognising haptic signals rather than recalling them, and that people are better at recognising relative values compared to absolute values (Brewster, Wright, & Edwards, 1992). This should be taken into consideration when designing haptic computer game interfaces in the future. A solution could be to give haptic signals a slight duration change in their intensity to give them a relative difference rather than an absolute value.

Modifications

After the third iteration the engine for handling the haptic signals was completely rewritten in order to save the designer time when analysing and testing haptic signals to make sure they did not disrupt the other haptic signals. This was an important design discovery since it showed a need for design tools appropriate for haptic interface design.

The Fourth Play Test

The fourth play test was done at a Swedish school for children that have a combination of deafblindness and congenital cognitive impairments. The initial idea was to follow the same procedure as the third play test with the addition of an initial interview with the children. It quickly became apparent though that the children could not play Sightlence. In retrospect, it should not have been a surprise since the game was not designed with scaffolding to support people with cognitive impairments. The play session was still valuable since it showed how inclusive a game design must be to be truly accessible.

Results

The school's IT pedagogue believed that the game's instructions were currently too long, and the game's abstraction level was currently too high, for the children's current proficiency. Extra scaffolding, support, and playtime might make the game accessible them. It's a design hypothesis worth exploring in the future to make the game more accessible, and to gain further insights about game accessibility.

Modifications

A tutorial was added for the game's haptic signals. See figure 6 below for a screenshot of the tutorial mode. Each thumbnail presents a stylistic looping version of a significant interaction between objects together with its graphical, audio, and haptic feedback.

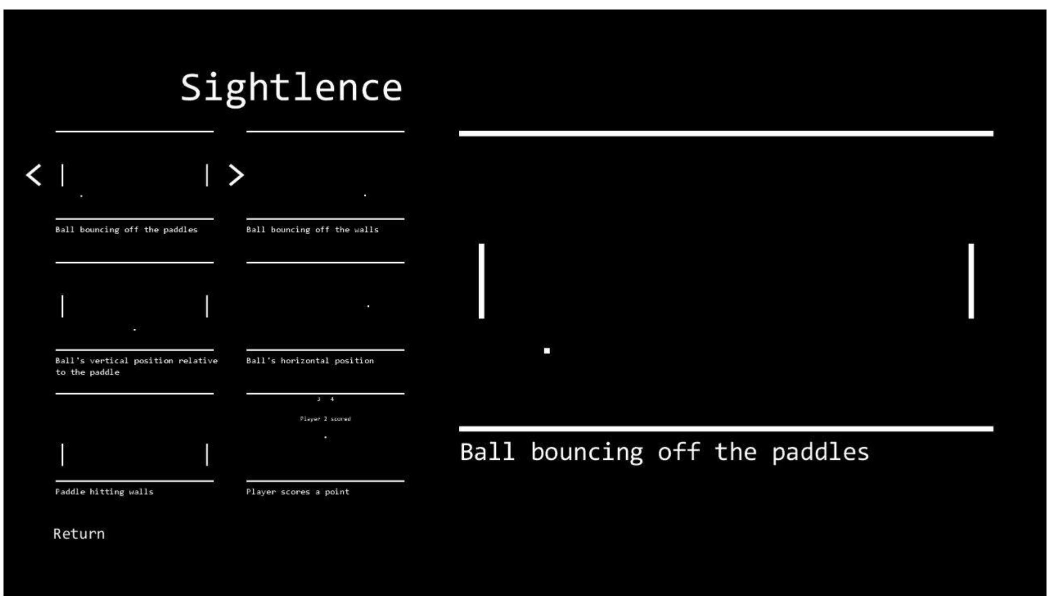

Figure 5: Screenshot of the tutorial system in Sightlence.

CONCLUSIONS

In figure 3 and 4 it can be seen that it's possible to design haptic interfaces for computer games that are playable without graphics and audio while still only using the vibrotactile devices found in readily available and inexpensive standard gamepads like the Xbox 360 Wireless Controller. This can even be used to create complex interfaces with several concurrent haptic signals. Through the use of haptic interfaces computer games can be made available to people that are currently excluded from playing them. From play session together with the people with deafblindess it's clear that they could be interested in playing computer games if they were accessible. There are limitations though since children with congenital cognitive disabilities and deafblindness were unable to play the game in its current state. While haptic interfaces could be combined with other interface modalities in order to make them playable by children with deafblindness and congenital cognitive disabilities the increased abstraction level would require extra scaffolding.

FUTURE RESEARCH

The current iterations of the Sightlence computer game project have focused on using the haptic modality as a design material in computer game development. There are several strands left untouched though that would be fruitful for future explorations. The latest iteration has primarily seen efforts put into building interfaces with the graphical and haptic modalities. Audio games and the audio modality have been around for quite some time as interfaces. It would be interesting to explore the three together in a more systematic manner in order to see how the graphical, audio, and haptic modalities can be used together to complement each other in computer games where each builds on its particular set of properties and strengths. From a design perspective this would allow us to answer questions about how game rules and player interaction can be conveyed through different interface modalities, and how they affect the experiential meaning making, and play proficiency of players. Such design explorations would be the beginning of building an interface agnostic approach to game design. From a user experience perspective we should conduct more studies using both formal self-report questionnaires and physiological measurements on how isolated or combined interface modalities give rise to gameplay experiences. Further explorations of these topics would allow us to design more appropriate tools for computer game design.

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