SIGHTLENCE — Haptics for Computer Games

by

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ISRN: LIU–IDA/KOGVET–A–12/002–SE
For my family
To think of designing as ‘problem-solving’ is to use a rather dead metaphor for a lively process and to forget that design is not so much a matter of adjusting the status quo as of realising new possibilities and discovering our reactions to them. To make or invent something new is to change not only one’s surroundings but to change oneself and the way one perceives: it is to change reality a little. For this reason it is, I believe, a mistake to begin designing by thinking only of the problem, as we call it, and to leave thinking of how it is to be solved to later stages.

(Jones, 1992, p. XXIX)
SUMMARY

Games in general and computer games in particular have now become a mainstream activity for young people in the industrialized nations. Sadly, people's interaction with computer artifacts and games are mainly still limited to the visual and auditory modalities. This constrains the richness of our interaction with those artifacts, it constrains the possibilities of using those artifacts to communicate and build relations with others, and it excludes some people from using them at all.

This thesis answers the questions of whether it's possible to use haptics as a single modality for conveying information in computer games, if it's possible to translate the standard interfaces of existing computer games into haptic interfaces, and if it can be accomplished with the technology used in the gamepads of current generation game consoles. It also contains a theoretical foundation for using haptics in game design and a new design method for analyzing the requirements of computer game interface modalities.

A computer game prototype called Sightlence was developed in order to answer these questions. The prototype was developed in four iterative cycles of design, development, and evaluative play sessions. Four groups of people participated in the play sessions: graduate students, and teachers, specializing in games; people who are deafblind; people from the general population; and pupils from a national special needs school in Sweden for children with deafness or impaired hearing combined with severe learning disabilities, or congenital deafblindness. The prototypes were tested with usability techniques for measuring performance and learnability. The usability tests showed that Sightlence can be successfully learned by people from the general population while the pupils with cognitive development disorders from the special needs school would need additional support in the game in order to learn to handle the increased abstraction caused by the haptic interface.

The thesis ends with discussion of the designed and developed artifact Sightlence. The discussion touches on the design process, the usability testing, and possible future research and development relevant for making haptics a fruitful tool and medium for designers and people.
ACKNOWLEDGMENTS

I want to begin by thanking Dr. Mattias Arvola for taking the time to act as my supervisor for this master’s thesis and making sure I walked in the right direction to begin with instead of ending up in an intellectual cul-de-sac by mistake.

I also want to thank Eva Linde for taking on the task of reviewing this thesis and being its opposition during my defense of it. Saying that your feedback has been valuable is a clear understatement.

Getting the opportunity to expose your work to a wider circle of professionals is a rare thing in general for a thesis. Therefore I want to thank Ulf Hagen and Jon Manker for inviting me to Södertörn University to present my work at their seminar series on games. I also want to thank Dr. Miguel Sicart for giving me the opportunity to showcase an early prototype of this game at the IT University of Copenhagen’s Play Day.

David Brohede, in the role of organizer of the lecture series P2P at Linköping University, deserves thanks for inviting me to talk about computer games, Sightlence, and design for deafblind people at P2P; I had a blast and learned a lot by doing that. The students that arrange the Swedish Game Awards, in Stockholm, every year should have many thanks for putting in all those volunteer hours that result in a fantastic game development competition for students. Sightlence was nominated for Best Serious Game at the Swedish Game Awards, which made me very glad and I’m grateful for getting the opportunity to showcase Sightlence for such a large audience.

Without the support and encouragement of my family my studies would have been immensely harder and for that I’m always grateful. For the same reason I want to send my warmest thoughts to my grandfather who sadly did not get to see this thesis in its final form. You always took an interest in my life, showed endless enthusiasm for my education, and I miss you so much.
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1 INTRODUCTION

Games in various forms have been an integral part of human societies for millennia. They might be unique for a particular population, be stable game systems regardless of where they are found, change over time or exist under different names and variations across cultures. Games can be considered a childish activity as with tic-tac-toe or the subject of national interest and pride as in the case of Chess during the Cold War. Chess is one of the oldest European games, though its predecessors originate from India during the 6th century, and was given much of its current form around the 15th century (Hooper & Whyld, 1992, pp. 173-175). Go can trace its history back even further to the Analects of Confucius from 6th century BC. (International Go Federation, 2008). The oldest game currently held in the archives of the British Museum is the Royal Game of Ur (British Museum, n.d.), which is dated to somewhere between 2600 and 2400 BC. During all this time most games were given a physical representation in the form of a board, game pieces, tokens or other objects. It was possible to pick up the pieces and feel them.

The advancement of ever-more complex graphics in computer games has seen a tremendous development during the last 20 years; both in pre-rendered trailers and real-time generated in-game graphics. Sound and music in computer games has a history almost as long as graphics, though drastically increasing investment in sound and music development got off to a later start than computer graphics, and today it’s a substantial budget post in triple A titles as full voice-over, original music score and realistic sound effects are quickly becoming the norm in them. Compared to graphics and sound, haptics is still waiting for its breakthrough in consumer level products. This is not a situation that’s unique to computer games, Tan & Pentland (2005) asserts that “in the general area of human-computer interfaces ... the tactual sense is still underutilized compared with vision and audition.”

The possibility of using haptics in human-computer interaction has been widely ignored for a long time, which is a bit surprising since the skin is the human body’s largest organ; it has a surface area of about 1.8 square meters (m²) and makes up around 17 percent of a human’s total body weight (Montagu, 1978, p. 4). Despite this the only parts of the body being routinely
used in human-computer interaction are the hands and then only for input to computer systems. This lack of interest in the possibilities of haptics is not isolated to computer games and HCI. Research on the human body's sensory organs have primarily concerned itself with vision and hearing (Gallace & Spence, 2010). Even today there is much lacking in our understanding of touch, its connection to cognition and how it interacts with the other senses (Gallace & Spence, 2008). Coppola (as cited in Montagu, 1978, p. 212) even goes so far as to speak of a perceptual prejudice and points out that philosophy, physics and psychology have had an almost exclusive preference for visual evidence when seeking to understand the world.

Despite the lack of a general interest in the human body's skin's perception, research in the area has a long history though not a very rich one. Ernst Heinrich Weber (1996) originally published his work on the subject in a two volume set in 1834 in which he studied both tactile and kinaesthetic perception, which are collectively referred to as haptics. Weber used a Stangelzirkel (bream compass) to measure skin sensitivity; a beam compass is almost like a normal pair of compasses but placed on a straight beam instead of on two beams that are connected in the middle with a hinge. His study was done by placing the two points of the compass on an area of the skin in order to measure how many Paris lines the two points had to be from each other in order for a person to be able to discern if the beam compass was placed horizontally or vertically on the skin. A PARIS LINE is an old measurement equal to circa 2.26 mm (Kölliker, 1850 & 1854). Using this metric, Weber (1996) found that the fingertips had a sensitivity of just one Paris line while the skin on the back varied between 18 and 30 Paris lines in sensitivity. Even though research on the perception of the skin began almost two centuries ago we still know very little about it. This can be a contributing reason for why haptics is underutilized in human-computer interaction as a carrier for conveying meaning.

Haptics has so far not been used in computer games to present information to people in sophisticated manner. A rudimentary possibility for haptics has been present in most game consoles since 1997 with the introduction of the Rumble Pak for the Nintendo 64 (Buchanan, 2008, April 3). The use so far has mostly been limited to crude vibrations in relation to explosions happening in the computer game. Even if the vibrations overall have been limited some games
have made an attempt to incorporate vibrations more clearly into the game. Notable examples include a sequence in *Metal Gear Solid* (Konami, 1998), and in *Rez* (United Game Artists, 2002). In *Metal Gear Solid* the player is instructed in a part of the game to place the gamepad against their body while it vibrates. *Rez* could be bought in Japan together with a *Trance Vibrator* to give a haptic experience of the game. The *Trance Vibrator* went on to become a collector’s item as a result of its limited production volume and by being reviewed at *Game Girl Advance* as a sex toy because of its shape and washable exterior combined with the steady rhythmical vibrations provided by the music game *Rez* (Game+Girl=Advance, 2002, October 26).

1.1 PROBLEM FORMULATION

Games have existed for at least 4500 years and computer games have been around for more than 50 years now. In the beginning games were by and large physical artefacts that could be touched, picked up and held. When games began to be created inside computers this changed and computer games became something you only experienced through vision and hearing as the physical aspect was lost. Some people who had enjoyed playing analogue games now found themselves unable to play computer games as this new medium lacked the necessary tactile and kinesthetic feedback.

This thesis’ primary focus is to answer if it is possible to create a computer game that only uses haptics for information input and output exchange with the person playing the game. In continuation of this the thesis asks if it is possible to translate existing computer games from their original visual or auditive modalities into only using the haptic modality. These two questions are asked through the use of inexpensive and readily available equipment, instead of requiring exotic and expensive hardware, in order to make any positive answers economically viable for as many people as possible.

The thesis secondary focus will be to give a theoretical overview for designers that want to use meaningful touch-based interaction in their games and to give an overview of a demographic that is still ignored by the games industry.
2 BACKGROUND

The goal of this thesis is to construct a game with an interface that allows it to be played even if the player is deprived of sight, hearing and speech. Games and play are often considered special or different compared to other human activities. Therefore this section begins with a discussion of the definition of games in general or computer games in particular in order to allow such a distinction to be made.

There is a broad range of definitions of what games are. They are proposed by hobbyist, professionals and academics alike. Not only are they different in exact wording but they also place different emphasis on what parts of a game they see as most important in defining them as artifacts. To give a sense of the diversity, three such definitions will be presented in the following text. The first one is from Crawford who is one of the pioneers in the commercial games industry and is a professional often referred to by academics. The second is from Salen and Zimmerman’s textbook on computer games where they try to propose a definition inspired by a number of previous writers on the subject; mainly academics but also Crawford. The third definition is by Juul and also rests on the definitions of previous writers; Salen and Zimmerman being among them and also Crawford. These three definitions offer a sort of natural progression from the growth of a professional industry, to academia’s awakening interest for computer games and then an attempt to reconnect computer games with their predecessors.

Crawford has a definition that he himself deems to be a bit too simplistic. Its strength is that it feels close to how a layman would implicitly identify games if asked. The definition concludes that games are made with the purpose of making money, they’re interactive, have goals, competitors, and the competitors are allowed to impede each other’s attempts to win (Crawford, 2003, pp. 6-8).

The academic writers Salen and Zimmerman (2004) choose not to hint on the rationale behind game productions but instead focus on the properties that constitute games as designed artifacts. To shape their definition they gather inspiration from eight previous authors; all but one, Crawford, are academics.
with the oldest source being Huizinga’s seminal work Homo Ludens (Man the Player) from 1938. Huizinga died in captivity during the Second World War for his anti-Nazi convictions. All sources used by Salen and Zimmerman (2003) naturally originate from outside the young field of game studies though most of their sources are today considered part of its canon. Salen and Zimmerman (2004) state with their definition that “a game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome” (pp. 79-80).

Juul (2005) also builds his definition on previous work and include Crawford, Salen and Zimmerman, which is a testament to how young the particular field of game studies is. Juul choose to study traditional games instead of computer games with the hope of creating a classical game model that can be applied in order to understand computer games as well. Previous definitions are split up and sorted into three broad categories by Juul: their relation to the game as formal system, the player and the game, and the game and the rest of the world. They are then reworked into a definition that reads:

A game is a rule-based formal system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels attached to the outcome, and the consequences of the activity are optional and negotiable. (Juul, 2005, p.36)

These three definitions are a good starting point for understanding computer games since they focus on different aspects of games, are acknowledged and referenced in the discussion of computer games and they all build on numerous predecessors. Game studies has so far been more directed towards the study of computer games as isolated artifacts compared to studying computer games as artifacts that mediate interaction between people, and between people and the game’s rules. This can also be seen in the definitions above where the person playing the games are only mentioned in passing and a consideration for her is almost coincidental in the definition. The computer game is here more seen as being defined as a result of its rules or material characteristics rather than through its relationship with its players and their motivation for playing the game. The player as an entity is mentioned in the
definition above but its inclusion stems entirely from an analysis of the game in isolation from an external world and its players, even though the player is held up as important in both academic and professional writing. All three definitions have a focus on games as artifacts in themselves rather than as artifacts that exist in a social context. The need for cultural knowledge in order to understand games and how they are played is lacking in these definitions while the importance of such an understanding in order to successfully participate in the playing of a game has been clearly demonstrated by Hughes (2006, pp. 504-516) and understandable so since games are played by human beings.

This becomes apparent when following the consequences of parts of the statements in the above definitions. This can be seen when Salen and Zimmerman (2004), pp. 79-80) states that “...players engage in artificial conflict...” which raises a number of questions regarding the use of the word artificial. Do they want to devalue games by stating that their impact can only be artificial? Such a conclusion would be hard to draw based on the tone held in the rest of their book. Instead they mean that the conflict itself is artificial. A conflict is a disagreement between at least two parties. Even if it’s in a playful manner there is still has to be an investment in it that creates an experience for the participating people which makes it real. The game as an isolated artifact might not affect its physical surrounding but it will always affects the relationship, in a manner dependent on how it’s played, between the parties playing the game.

Though there is currently no all-encompassing definition of games or computer games this does not have to be a problem. This absent of a stringent definition might simply be an indication that games and computer games are not objects with exact attributes. Other design disciplines have a long tradition of working with a subject matter that has shown resilience against being pinned down. Not even architecture seems to have reached consensus around one definition despite being influenced by engineering and having a very long history of publishing books; Alberti (1988) published De Re Aedificatoria back in the late 15th century where he made an attempt to define the responsibilities of the architect. Alberti’s books were largely based on Vitruvius’ writing (1st century BC/2009). He published some the first known
books of architecture in the first century BC. Alberti can be seen as the new dawn of design writing as there wasn't much published in between those two.

According to de Souza (2005, p. 27) signs are constantly reinterpreted in an unlimited semiosis. This means that even if we try to find a definition of what a game or computer game is our most recent conclusions will lead to further uncertainty in an iterative fashion. Reaching a final definition might therefore be impossible while the pursuit of one is still a fruitful journey since it has the chance of deepening our understanding of that which we are studying.

2.1 THE NORMAL PLAYER ASSUMPTION

As this thesis explores a modality that's currently unused in gaming it's interesting to ask who might use this modality to play games in the future. Who is the player? A question surely often asked by executives and answered by marketing reports. Though an equally interesting and valid question to ask is the inverse: Who is not the player? Nintendo has had a huge success with their Wii game console by drawing in demographics that have previously not bought computer games. Everyone is currently not able to enjoy computer games because the games produced aren’t as diverse as they could be. As making games that can be played by deafblind persons is an inspirational backdrop for this thesis the following section will describe a demographic that computer games has yet to branch out to as the techniques for player output mainly relies on sight and sound.

According to Förbundet Sveriges Dövblinda (2009, January 15 a) there is no certain number of how many deafblind persons there are in Sweden though they estimate that there are around 1300 people under the age of 65 who are deafblind. About 400 of those are estimated to have become deafblind before they had a chance to develop a language. This group is called people with congenital deafblindness.

2.1.1 Forms of deafblindness

A new Nordic definition of deafblindness was agreed upon by the five Nordic countries in 2007 (Förbundet Sveriges Dövblinda, 2009, May 22) that reads:
Deafblindness is a particular disability. Deafblindness is a combination of impairments to the sense of sight and hearing. It limits a person’s activities and restricts full participation to such an extent that society needs to give support with specific services, environmental changes and/or technical solutions. [Author’s translation] (Förbundet Sveriges Dövblinda, 2009, May 22)

Having impairments that result in deafblindness does not have to equal complete loss of the senses of vision or hearing though. A person can be considered deafblind and still have some remaining functionality of the two senses (Rutgersson & Arvola, 2006). People with deafblindness can roughly be divided into two main categories: people who have congenital deafblindness and people who became deafblind later in life (Förbundet Sveriges Dövblinda, 2009, January 15 b & May 22). The group with congenital deafblindness is made up of people who are born with impairments to vision and hearing, and also of people who have lost both vision and hearing before learning a language (ibid.).

The group of deafblind people who get the impairment later in life is made up of three subgroups (Förbundet Sveriges Dövblinda, 2009, January 15 b & May 22). One group consists primarily of people who are deaf or have a hearing impairment and have later in life gotten vision impairment as well. The second group consists primarily of people who are blind or have vision impairment and have later in life gotten a hearing impairment as well. The third group consists of people who have had none of those impairments but got them both later in life.

2.2 THE HUMAN BODY

A part of design is to present information to a person in a way that’s useful and legible for her. Creating such a presentation rests on a foundation of knowledge of the human perceptual system; as haptics is still a novel perceptual modality with few examples for designers to draw on an overview of the perceptual system is presented in this section. Among the human senses, vision is the one that has received the most attention by scientists compared to the other senses. It also takes up the larger part of the discussion
regarding the sense in standard student textbooks (Sternberg, 2003, pp. 108-148). This focus on the visual, and to some extent auditory, senses also holds in the area of human-computer interaction and Tan and Pentland (1997, pp. 84-89) asserts that “the tactual sense is still underutilized compared with vision and audition”.

This heavy focus on vision and auditory compared to haptics might be natural from a cultural perspective where artifacts in the form of, especially, paintings but also in books, and audio recordings have existed for a very long time. This focus can be put in relation to the physiology of the human body since the skin is its largest organ. For a newborn baby the skin is about 2500 cm² and for an adult male it is about 18 000 cm², almost 2 m², large and makes out about 16 to 18 percent of a person’s total body weight (Montagu, 1978, p. 4). It’s a part of the somatosensory system which is a combination of a number of different sensory modalities that register the sense of touch, temperature, body position and pain.

2.2.1 Modalities

In the somatosensory system a distinction is made between tactile, kinesthetic and haptic perception. Haptics is a collective name used to describe the combination of tactile and kinesthetic perception. This differentiation is valuable when reading about proposed techniques for realizing haptic sensations in human-computer interaction. Loomis and Lederman (1986, pp. 1-41) have given the following description of these perceptions:

**TACTILE PERCEPTION**, or **CUTANEOUS STIMULATION** as Loomis and Lederman (1986, pp. 1-41) also calls, it is a perception that arises from stimulation of the skin itself. The sensation of the texture of fabric against your finger, the prick of a needle at the doctor’s office and the cold, wet, feeling of lowering yourself into the ocean are all cutaneous stimulations as they are interpreted by your mind.

**KINESTHETIC PERCEPTION** (Loomis & Lederman, 1986, pp. 1-41) is strongly connected to the concept of proprioception in the human body; it comes from a combination of the Latin word *proprius* which means “one’s own” and the word perception. It’s the perception of one’s own body’s joint’s positions and
their movement. It allows us to close our eyes and maintain a sense of how the parts of our body relate to one another, if they are currently moving or are immobile. Separating kinesthetic perception from tactile perception is hard according to Loomis and Lederman (1986, pp. 1-41) but they give an example concerned with information. Imagine picking up two rods of different size but otherwise identical, one after the other, and holding them by the ends. When holding both rods you will have a tactile perception of the rods as your hands are holding them but since they are identical except for length you gain no additional information from either to distinguish them. Your kinesthetic perception of the two will be different though as a result of your arms being positioned closer or farther away from your torso, giving a possibility to distinguish them from one another even if not being seen.

Haptic perception is the perceived experience of objects and events when significant information about them is integrated simultaneously into a whole from both the tactile and kinesthetic senses. Most of the tactual perceptions and tactually controlled performance is of this kind (Loomis & Lederman, 1986 pp. 1-41). It’s not uncommon that the word haptics is used colloquially to denote both tactile and kinesthetic perception.

### 2.2.2 Receptors

The somatosensory system generates information through three types of receptors: thermo-, chemo-, and mechanoreceptors. Only the mechanoreceptors are relevant to current methods to achieve haptic sensations so this thesis will only concern itself with those. The other two are only mentioned for brevity. In the glabrous skin (skin devoid of hair) four different kinds of mechanoreceptors have been found (Pasquero, 2006). These mechanoreceptors are the **MERKEL CELL**, **MEISSNER CORPUSCLE**, **RUFFINI ENDING** and **PACINIAN CORPUSCLE**. Mechanoreceptors can be divided according to the size of their receptive field and their adaptation rate to stimulus (Pasquero, 2006). Their receptive field can either be of type I, meaning they have small and well-defined boarders, or type II, meaning they have large and poorly-defined boarders. The adaptation rate to stimulus can be either SA (Slowly Adapting) or RA (Rapidly Adapting). See Figure 1 for a categorization:
The receptors sending the information are each functionally simple. They each focus on a single simple perception; the movement of the skin, the indention of the skin or, in the case of case of thermo receptors, temperature changes. The wet, cold, feeling of lowering your hand into a cold lake is therefore not a single, unified perception in itself but rather a complex sensation caused by information from several different receptors, each in it functionally simplistic, that is then integrated in the brain and experienced continuously. The stimulation of the skin's receptors is never ending but often we don’t notice the cutaneous perception of clothes or other objects against our skin because our attention is focused elsewhere.

2.3 SIGNS

Designing the physical information transfer is not enough for facilitating understanding for people; the information must also have a proper form. For Sightlence this means remapping information output from the visual modality to the haptic modality and semiotics provides a useful theoretical framing for conceptualizing this remapping.
People communicate through language. It is used to convey information and meaning to others by using words or signals to represent other concepts. If two individuals are to understand each other they must agree to communicate in such a manner that the sender of information knows, to a fairly certain degree, how that information will be interpreted and understood by the intended receiver. To realize Sightlence it was necessary to invent new signals to represent concepts that the person playing the game unfortunately does not know how to interpret. Successfully playing the game is thus a dual process of learning the rules of the game in order to know which actions to take and of learning the language of the game to know how to interpret its information output. The study of the connection between a word and the object it represents is known as semiotics. It was used in this thesis as a theoretical grounding when designing the game’s words, its output, during the design process.

Charles Sanders Pierce was one of the two original founders of the field of semiotics. He imagined that our language is connected to the world in a way that can be conceptualized as a system of signs; that are in turn composed of three parts: A representamen, an interpretant and an object (Charles, 2007, p. 29). The REPRESENTAMEN is the shape that a particular sign has; this is by some theorists called the sign vehicle (ibid.). The INTERPRETANT is the sense that is made of a sign when it’s observed. The OBJECT is that which lies beyond the sign and is what’s being referred to when the sign is used. Sightlence’s translation can therefore be thought of as a change of the representamen while trying to keep the interpretant intact. The object can be seen as the operations that the computer performs unobserved by person playing the game even though that is a slightly liberal interpretation of Pierce’s original concept.

Pierce was of the opinion that there are only three categories that are interesting for semiotics: FIRSTNESS, SECONDDNESS and THIRDDNESS (Souza, 2005, pp. 46-48). Firstness is used to denote experiences that are consciously experienced of but can’t describe. Secondness is the direct association between two different phenomena, while thirdness is “rationality par excellence” which allows us to formulate reasons around a phenomenon.

A sign, or sign vehicle can be either symbolic, iconic or indexical (Chandler, 2007, p. 36). SYMBOLIC SIGNS have an abstract connection with the object it
refers to and they have to be explicitly learned; an example is our written word for pen and the physical object that we call pen. **ICONIC SIGNS** are signs that resemble the object it refers to in some manner. A drawing of a dog is an example of an iconic sign. **INDEXICAL SIGNS** are directly connected to the object it refers to; smoke is an example of an indexical sign for fire. It doesn't mean that the indexical sign truly has to be connected to the object but rather that it’s perceived to be. A sign is not only a relation that connects a representation with an object, it can also recursively be applied to itself and generate new interpretations that can go on recursively (Souza, 2005, pp. 26-28).

Symbols and icons can come in many different shapes. They don’t necessarily have to be spoken or written in the case of symbols, or pictures and drawings in the case of icons. Earcons have been suggested by Brewster, Wright and Edwards (1992) as a way to create icons made out of sound. Brown, Brewster and Purchase (2005) have suggested that vibrations can be used to convey tactons (tactile icons). Brewster, McGookin and Miller (2006) have done some initial attempts to create icons based on smell. In these articles there is confusion though around concepts and their relation to the theoretical foundation of semiotics. What is being called icons in these articles have more in common with the small pictograms used on buttons in computer programs. In these articles icons should therefore generally be read as symbols instead in order to keep consistency with semiotics.

### 2.4 THE USER INTERFACE

Understanding the recipient and the nature of the information you want to convey is vital for your message but it also requires a medium to pass through; this section therefore presents an overview of hardware techniques used for haptic output and parameters to use when designing information to use those techniques. Conventional user interface design for computer software has mostly focused on the mouse and keyboard as input devices and the monitor as output device for the computer. Other techniques exist but have yet to penetrate the mainstream. Some techniques are on the verge to do so though in the form of like touch interfaces (for example iPhone), motion interfaces (for example Wii) or gesture interfaces (for example Kinect for Xbox 360). Since the focus of this thesis is on haptic design the following pages will focus on different technical solutions for designing haptic sensations.
2.4.1 Techniques to achieve haptic sensations

Research on haptics has focused on roughly four different methods for allowing users to experience haptic sensations while interacting with technology (Hayward & Maclean, 2007). The methods are VIBROTACTILE DEVICES, FORCE FEEDBACK SYSTEMS, DISTRIBUTED TACTILE DISPLAYS and SURFACE DISPLAYS. Though most of the research on, and application of, haptics has been done with vibrotactile devices and force-feedback systems (ibid.).

There are a number of different techniques for each method to create haptic sensations. Based on the differences, possibilities, limitations and cost of the techniques used to create haptic sensations the designer therefore needs to focus on the intended purpose of the imagined artifact and user when selecting the technique to use. For Sightlence this resulted in the decision to use the Xbox 360 gamepads as input, and output, devices as their low cost and widespread use makes the game available to more people than would be possible if expensive, or custom-made, devices were used instead.

2.4.1.1 Vibrotactile devices

The most common method for providing haptics, out of the four, is through vibrotactile devices. It’s also the method that most people have experience of using. It consists of a motor that gives rise to vibrations that the user experience through touch. They are built into mobile phone to give us silent alerts and into gamepads to enhance the experience of events happening on the screen.

2.4.1.2 Force-feedback systems

Through a force-feedback system a sense of force and resistance is conveyed to its user. In teleoperation, where an artifact is used to remotely affect objects, the ideal device is a massless, infinitely rigid stick (Hayward & Maclean, 2007). A force-feedback system simulates the resistance that a user would experience when trying to apply force to a particular object. This is done by having motors apply a counter force to the user’s force in direct proportion to the force the object being simulated would display if the user would attempt to affect it directly. This can be used to both give a user a sensation of a physical object
remote to the user, for example using a robotic hand to lift an egg without crushing it. See Hayward and Maclean (2007) for a further, and more in-depth, explanation of the difficulties involved in achieving this effect and for a large number of references to suitable literature on the subject.

2.4.1.3 Surface displays

There is a conceptual difference between surface displays and force-feedback systems. A force-feedback system simulates the force of an object and delivers that force as output to the user. A surface display is instead used to deliver a sensation of the simulated object’s surface; the reacting force that the user experience is just an implicit result of that object’s behavior (Hirota & Hirose, 1993).

2.4.1.4 Tactile displays

With a tactile display a sensation of touch can be experienced by the user through deformation of the user’s skin. This is achieved by having the display spatially affect an area of the user’s skin. Most tactile displays use small pins to indent the skin on a finger because they are very sensitive relative to other parts of the body. Pasquero (2006) describes in his survey attempts of using other regions instead of the fingers, for example by placing actuators in the mouth or on the back, torso or thighs. Many attempts have also been made to use other techniques than pins; for example heat, air pressure, and materials that change shape or small electrical currents (ibid.). Another example of a tactile display is the Braille displays used by blind people to read texts from newspapers, books and computers. Unfortunately tactile displays are still too expensive to be a widely available HCI technology (Hayward & Maclean, 2007).

2.4.2 Parameters in tactile icon design

As has been previously shown there are a number of methods that can be used to create haptic sensations through mechanical and electrical artifacts. These sensations can be used to simulate the existence of an object by creating a sign of it. Aside from simulation they can also be used to create tactile icons, called tactons by Brewster and Brown (2004), which carry an abstract representation of a concept. Tactile icons can be constructed using several different
parameters, most of them corresponding to parameters of auditory sensations. Brewster and Brown (2004) define these parameters as FREQUENCY, AMPLITUDE, WAVEFORM, DURATION, RHYTHM, BODY LOCATION and SPATIOTEMPORAL PATTERNS. Haptics is subject to habituation as other sensory stimuli so the magnitude of the sensation can be expected to decrease during exposure and recover during absence of stimuli. The recovery period can vary from a few seconds, to minutes depending on the intensity of the stimuli and its duration (Gunther, Davenport, & O’Modhrain, 2002).

2.4.2.1 Frequency

The frequency range available for tacton design is between 20 Hz and 1000 Hz with maximum sensitivity occurring around 250 Hz (Gunther et al., 2002). Frequency is the number of occurrences of a repeating event over a unit of time; in this case 1 second meaning that 20 Hz corresponds to 20 occurrences of the event per second. Gill (as cited in Brewster & Brown, 2004) suggests that this range allows for up to 9 frequency levels to be used. Relative comparisons between frequencies are also easier to make than an isolated absolute identification of one frequency (Brewster, Wright, & Edwards, 1994). Guitar players are known to pick up the phone and listen to its dial tone when tuning their guitar since it gives them a comparison.

2.4.2.2 Amplitude

During oscillation the amplitude denotes the maximum displacement from a zero value. Frequency and amplitude are therefore closely related to each other where frequency denotes the number of occurrences of an event while amplitude denotes the maximum displacement of the occurrences. Suggestions have therefore been made to treat them as a single parameter to simplify design (Brewster & Brown, 2004). Amplitude is in this case used to decide the intensity of the haptic sensation. Sensations above the 55 dB mark should probably be avoided since Verrillo and Gescheider (as cited in Gunther, 2001, p. 17) has found that it’s the threshold for pain. Perception of sensations also decrease in clarity above 28 dB according to Sherrik (1985, pp. 78-83) which might be caused by “signal leakage” if the vibrations affect a too large area.. Gill (as cited in Brewster & Brown, 2004) suggests that four or fewer levels of intensity should be used to keep them perceptually separate from
each other. The number of steps can even be limited to just three for practical reasons since this allows the steps to be understood through absolute identification instead of in relation to each other (Geldard, 1960).

2.4.2.3 Waveform

Different waveforms can be used to create the effect of varying coarseness of the haptic sensations. Four common waveforms are the sine, square, triangle, and saw tooth waveforms. The square waveform is closely related to represent digital information since they are based on ones and zeros where transistors can be either on or off, never in a state between the two. If a sine wave is used for tactile icons it can be altered by modulating it with a sine wave of another frequency to produce a more rough sensation for the user. Geldard (1960) suggest that waveform discrimination should be possible if the basic frequency is low enough. Brown, Brewster and Purchase (2005) assert that the tactile sense is most sensitive to frequencies of 250 Hz. They also confirmed that Gerhardt’s (as cited in Brown, Brewster & Purchase, 2005) finding, in acoustics, that 20 Hz is the lowest modulation frequency that should be used also holds true for haptics. Below 20 Hz a sine wave is perceived acoustically and tactually by humans as separate sensations rather than a continuous one. In their empirical study (ibid.) they also find that human can distinguish between three different sine waves; described as smooth, rough and very rough. Unfortunately the study reached this conclusion by comparing five different stimuli by using a pair-wise Wilcoxon test statistical model. By applying it to two different stimuli in turn compared to applying an analysis of variance to all of them at once they have inflated the probability of making a type one error that’s above what is normally tolerated. In subsequent studies users have been able to differentiate between three different waveforms with a recognition rate of 94% (Hoggan & Brewster, 2007).

2.4.2.4 Duration

A signal’s duration can be used to indicate that two signals should be interpreted differently by the listener. Signals lasting only 0.1 seconds or less are perceived as a sudden taps or jabs while longer vibrations are experienced as continuous waves (Gunther, 2001, p. 59). Geldard (1960) suggests not making signals exceed 2 seconds in duration. He also reports that this range
can be filled with 25 steps ranging from 0.05 to 0.15 seconds in differentiation (ibid.). Even though 25 steps are possible Geldard suggests using only four or five levels and to only use three if the users are not trained (ibid.).

2.4.2.5 Rhythm

When people hold speeches or perform music a suitable rhythm becomes important and the same is true for tactile sensations. By combining vibrations of different duration they can be experienced as rhythm. This can also be used to distinguish tactile icons from each other if they are presented on the same part of the skin (Gunther, 2001, pp. 50-60). Two tactile icons can then be presented at the same time on the same part using rhythm if one uses longer durations with slowly changing amplitude while the other has shorter durations with fast changes (ibid.).

2.4.2.6 Body location

The skin is the largest organ of the human body (Montagu, 1978, p.4) and is receptive to sensor modalities that allow signals to be distributed across the skin's surface area. Therefore signals transmitted through this sense don't need to convey meaning solely through its own properties but can also rely on the spatial placement on the body as a bearer of meaning during interpretation. When placing transducers it's preferable to place them at anatomical joints of the human body as research has shown that on the arms humans are more likely to correctly localize vibrotactile stimulation to the wrist and elbow joint compared to other parts of the arm (Cholewiak & Collins, 2003). The same holds for the abdomen where vibrotactile stimulation close to the naval and spine are more easily correctly identified compared to other parts of the abdomen (Cholewiak, Brill & Schwab, 2004). The hands are highly sensitive to tactile sensations but since they are used for work it might be impractical to place sensors on them.

2.4.2.7 Spatiotemporal patterns

The body location of a certain signal can be expanded with adding duration or movement to it, which creates spatiotemporal patterns. This can be used to create patterns by stimulating several areas of the body sequentially or at the
same time. Brewster and Brown (2004) suggests an idea where a 3x3 array on a person’s back is used to simulate shapes, for example the capital letter l. Several interconnected haptic devices can also be used to simulate motion by having patterns travel from one haptic device to another. When using spatiotemporal patterns to design tactile icons one also needs to consider the effect of communality, which is the similarity between two patterns (Geldard & Sherrick, 1965). If one pattern use transducers labeled 1, 2, 3, while another uses 3, 4, 5 then the similarity between them would be 33% since both use transducer number 3. Increased similarity increases errors when users try to discriminate between two patterns located within the same region of the body. In an interesting comparison between fingers, palm, and thigh on the ability to successfully discriminate between tactile patterns as a function of communality Cholewiak and Collins (1995) got equivalent results from these three regions. The conclusion is that even though the hands are more sensitive to touch this did not improve the ability to discriminate between patterns, based on their communality, compared to the palm or thigh.
3 METHODS

The design strategy used in this thesis consisted of an exploration of the relevant design space through literature review, sketching, analysis of design suggestions with the invented interface translation method, iterative prototype development, and validation of the prototypes through usability testing.

3.1 DESIGN EXPLORATION

The design process in this thesis was informed by the writing of Buxton (2007) and Jones (1992). Jones was an early advocate of a disciplined and educated design strategy to reach successful results. In his book Jones (1992, p. vii) presents a number of suitable methods to use in a design strategy. These are sorted into the three categories of divergence, transformation and convergence. Jones (ibid.) see these three activities as crucial parts of the designer's job in order to successfully form ideas, explore the structure of a problem and to evaluate the results of the design strategy.

Buxton (2007, pp. 66-80) continues this tradition by advocating that the software industry needs to move away from the current ways of designing software and instead embrace a more diverging exploration of ideas through design to get the right design before committing expensive programming resources to development. He also notes a bit cynically that there is never money to do something right from the beginning, but always money to fix it afterwards when it’s broken.

A few initial design criteria were selected to provide a brief to use as a starting point. These were that a game should be developed that could be played even if the person playing is deaf, blind and mute; and it should not require expensive, or custom-made, devices as the goal is to design a computer game that’s as financially accessible as possible for people in order to hopefully spread the idea and realization that haptics can be used alone or in combination with other modalities in computer games.
After the selection of requirements had been made for the design brief the process continued with sketching, and a literature review, being conducted in parallel with each other. Initial sketching concentrated on the possibility of reimagining a number of classic computer games as games that can be played solely based on the sense of touch. The computer games were analyzed using Sicart’s (2008) model of game mechanics, rules and objects, with the addition of listing all the inputs that can be given to the game and the outputs received from it.

When the initial sketches were finished they were sorted based on categories of similarity that cut across the different sketches. Some suitable categories that emerged were the games’ realization of time and the spatial relationship between objects. An attempt has been made by Wang, Levesque, Pasquero and Hayward (2006) to convey the puzzle Memory through physical pictograms by using a custom-built device. The research attempt I’ve seen that closest to the goal of this thesis. It was therefore decided that the game that were to be developed should be based a continuous time instead for contrast. Most triple-A titles today are 3D games. Considering the primitive information output capabilities provided by the Xbox 360 gamepad it was decided that the game should be based on 2D. It was in an attempt to minimize the need for haptic variables to be dedicated to conveying spatial relationships between objects instead of game mechanics, other rules or objects.

As the choice of spatial representation fell on a 2D model the final game design became a reimagining as a classic computer game rather than a game that is novel in both interface and structure; game mechanics, rules and objects. This simplified the usability testing by eliminating uncertainties as problems during testing can be attributed with certainty to the interface rather than to the interface or the structure. Based on the categories identified previously it was decided that the game should have a spatial 2D environment; be temporal in nature, so decisions have to be taken within a time-limit; and be a traditional game. The game that had the potential to best fill these requirements while also being a historically iconic game that would be worthwhile to bring to a new audience was the reimagining of table tennis into a computer game.
When these decisions had been taken sketching was directed towards exploring various ways in which the user interface of the game could be developed. The sketch that was selected for further refinement into a prototype was one where the attempt was to use natural metaphors to convey the outputs of the game. This was the main reason for the substantial changes made to the user-interface between the first and second prototype; it was understood during the first playtest that the outputs used in the first prototype poorly represented the design intention and caused confusion among the people playing the game.

The design process then moved on to the programming and development of the game. This part of the design process took on the appearance of iterative game development that rapidly cycled between design, implementation, self-testing, and then back again rather than a diverging design process as advocated by Buxton (2007, pp. 143-144). This meant that instead of branching out into significantly different directions it moved in quick iterations through design, development, and internal testing. This allowed for rapid changes and quick evaluation of the existing game design, though it limited the possibility for radically new directions of the game design. After the first prototype was finished a playtest was conducted to discover its flaws and strengths. These findings were then incorporated into a second prototype that was tested again in an attempt to see if the changes made between the first and second prototype had the intended effect.

3.2 THE INTERFACE TRANSLATION METHOD

Sightlence is a game that’s reimagining a classic game concept through the use of an alternative novel interface it was therefore necessary to ensure that all relevant information in the game were translated from the visual to the haptic modality. There interface translation method was invented for this purpose and is described below in this section.

Step one was to analyze the sketched game suggestions using Sicart’s (2008) framework that conceptualize games as consisting of rules and game mechanics. This framework gives an overview of the programmed attributes that a particular game exhibits. The player as an active agent is absent from the analysis as the framework chooses to view the game in isolation from
context; though the concept of mechanics gives a concession to the player as the mechanics are concerned with the actions player can take.

Sicart (2008) define game mechanics as “methods invoked by agents, designed for interaction with the game state”. He also wants to make a separation between mechanics and rules, though both are still code, by making an ontological difference between the two based on the position that:

> Game mechanics are concerned with the actual interaction with the game state, while rules provide the possibility space where that interaction is possible, regulating as well the transition between states. In this sense, rules are modeled after agency, while mechanics are modeled for agency. (Sicart, 2008)

Mechanics can then be further subdivided into core, primary and secondary mechanics (Sicart, 2008) though this aspect has been ignored in how the method is applied in this thesis. A concept that has been of great use though is that of context dependent game mechanics (ibid.), which are game mechanics that can only be used within specific contexts. This requires the presence of objects within the game that instantiate these contexts in the game world. This creates a framework with the following distinctions: agents that can be human or an artificial intellect, objects, game mechanics and rules. Figure 2 shows examples from the analysis that were relevant for Sightlence: the up and down arrows indicates that the game mechanic is move, the paddles and ball are noted as objects and the if-statement is a pseudo-code variant the rules.

Step two in the interface translation method was to analyze the information exchange between the person that is playing the game and the computer that is running the games. This was done by analyzing the possibilities that a player has for giving input to the game and the perceptible elements that the game is using to communicate itself through output to the player; while game mechanics and objects are often conveyed by perceptible elements, all game rules are seldom shown. This resulted in the analysis shown in Figure 3 that lists the possibilities for input that the player has and the parts of the game that are conveyed to the player. A distinction should also be made between what I would like to call perceptible elements and perceptible relations, which
in turn should be distinguished between parts of the game that run in the background and are not shown to the player.

Step three consisted of determining the modalities that are going to be used in the game and the capabilities of the technique used to convey the signals of that modality. The only modality used in Sightlence was haptics and those signals were conveyed through the gamepads from the Xbox 360 game console. The Xbox 360’s gamepads have two mechanical motors, each connected to an asymmetrical piece of metal. The gamepads are almost identical in capabilities to the Rumble Pack that Nintendo introduced in 1997 (Buchanan, 2008, April 3); allowing only a limited range perceptible distinct signals. Having an understanding of the relevant human physiology is more important than the used technique though as it only gets is meaning in relation to the human and her play. For haptics this makes intuitive sense as humans, compared to vision and hearing, still have little conscious knowledge of it as a modality for human-computer interaction.

<table>
<thead>
<tr>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVE UP</td>
<td>PADDLE POSITION</td>
</tr>
<tr>
<td>MOVE DOWN</td>
<td>Relative to ball</td>
</tr>
<tr>
<td>PLAY NEW BALL</td>
<td>Hit boarder</td>
</tr>
<tr>
<td></td>
<td>BALL POSITION</td>
</tr>
<tr>
<td></td>
<td>Relative to paddle</td>
</tr>
<tr>
<td></td>
<td>Hit paddle</td>
</tr>
<tr>
<td></td>
<td>Hit boarder</td>
</tr>
<tr>
<td></td>
<td>SCORE POINT</td>
</tr>
</tbody>
</table>

**TABLE 1: EXAMPLE OF INPUT AND OUTPUT ANALYSIS.**
FIGURE 2: EXAMPLE ANALYSIS OF GAME MECHANICS, OBJECTS AND RULES.
Step four consists of tying the previous parts together into a coherent interface design that players can interact with in order to play the game. This consists of selecting suitable metaphors and creating an information space with the necessary perceptible elements and perceptible relations. In order to make a translation that is as close as possible in information richness to the original. The particulars of the interface for Sightlence can be found in the prototypes subsection of the procedures section.

![Flowchart of the Interface Translation Method](image)

**FIGURE 3: FLOWCHART OF THE INTERFACE TRANSLATION METHOD.**

### 3.3 Usability Testing Performance Metrics

Two performance metrics were used in the design process. They were used to measure increases in performance over time and success in correctly identifying signals from the game.

#### 3.3.1 Learnability

Learnability is an essential performance metric to measure if it’s important that users develop a proficiency in using a designed artifact over time (Tullis & Albert, 2008, p. 93). Learnability in this thesis was operationalized as the increase over time between trials in the number of times the person playing the game managed to successfully bounce the ball back towards the computer opponent. All trials were conducted in succession within the same session. The trial was defined as the period between that a ball was launched and a point was scored. Each participant played the game for about 20 minutes: a more successful player therefore completed fewer trials during that time. Trials within the same session is easy to administer since there is no need to schedule a participant for more than one meeting but it doesn’t take memory
loss over time into consideration. This makes it harder to draw certain conclusions of how generalizable the results of these tests are to situations where there might be longer lapses of time between a person’s different play sessions (Tullis & Albert, 2008, p. 94).

Automated tests can be used to collect data during usability studies (Tullis & Albert, 2008, p. 103). Using automated tests to collect metrics during the play of games is a way to collect a lot of information from a play session at a low resource cost. Data gathering becomes cheap but risk exploding in size. Not only from the ease at which one can collect data on a particular topic but also regarding the range of topics that data can be gathered about. Kim et al. (2008) advice that automated data gathering is beneficial but should be combined with careful thought regarding what research questions should be asked in order to improve the design of the game and let those questions guide the collection of data to avoid data overload. Data regarding the learnability metric was collected automatically by the computer as the participants played the game. This was done by having the computer continuously measure the number of times the person playing the game successfully bounced the ball back towards the opponent, the length of time for each trial and the distance (measured in pixels) between the person’s paddle and the ball when the person missed it.

### 3.3.2 Task success

Task success measures how effectively a user is able to complete a given number of tasks and it might be the most commonly used performance metric (Tullis & Albert, 2008, p.64). Binary success was used to measure the task success metric; meaning that a user can either succeed or fail at a given task (Tullis & Albert, 2008, p. 66): The user can’t partially succeed at a task. The purpose of the task success metric was to measure if the people playing the game understood the meaning of the different vibrating symbolic signs used to convey information; an example of a task was “let me know the next time you feel that the ball is traveling towards you”. If the participant took a long time in providing an answer to the question it was asked again but there was no time limit on completing a task. All tasks used to measure task success performance are listed in the results section of this thesis.
3.4 HARDWARE PLATFORM

Each Xbox 360 gamepad has two motors hidden inside that can each spin an asymmetrically shaped piece of metal. One of the motors is used to create a signal that vibrates at high-frequency while the other creates a low-frequency signal. These were used to produce that output that was used by the game to convey meaning to the person playing it.

FIGURE 4: PHOTOGRAPH OF THE XBOX 360 GAMEPAD (AMOS, 2010).
4 EVALUATION AND MODIFICATION OF prototype iterations

The prototype development was done in four iterations. The iterations ended with a usability test of the prototype and they began, except for the first one, with a modification of the prototype based on the result from the previous iteration's usability test. The overarching goal was to improve the end result of Sightlence but the iterations also had individual sub goals with different purposes.

The first iteration was used to develop an initial prototype to eliciting feedback about the game concept from game designers and scholars. During the second iteration Sightlence was showcased to people who are deafblind in order to get their impression of the game. For the third iteration people with hearing and sight were recruited with the purpose of testing player proficiency and learnability of Sightlence. In the fourth and last iteration the game was usability tested together with children from a Swedish special needs school for children with deafness, or impaired hearing, combined with severe learning disabilities or congenital deafblindness.

4.1 FIRST ITERATION: PLAY FEEDBACK FROM GAME DESIGNERS

The purpose of the first prototype evaluation with game designers at the IT University in Copenhagen, Denmark, was to elicit professional criticism before sizable time investments had been made in the game development. The intention was to elicit criticism that could indicate which the game design should move towards in later iterations.

4.1.1 Prototype

Sightlence is a digital rendition of table tennis featuring two paddles, a ball, and a play area of the form that were very popular in the beginning of the era of computer games. When the game starts the two paddles are placed opposite each other, to the left and right of the play area, with the ball placed in the middle. The ball is held in the middle until the person playing the game
presses the A button, then the ball starts to randomly move towards either the player or the computer agent’s paddle.

The goal of the game is to use one’s paddle to bounce the ball against the computer agent’s paddle in the attempt to make it miss the ball. The player is awarded with one point if she is successful. The computer agent has the same goal and score points if the person playing the game misses to catch the ball. When a point is scored another ball is immediately put into play.

The ball can also bounce against the top and bottom boarders of the play area. This is handled in the same manner as bounces against the paddles: if the ball comes toward a boarder or paddle at an angle then it also leaves the boarder or paddle at the same angle.

4.1.1.1 Input

The paddles can be moved up and down within the play area by pressing up or down on the gamepad’s D-pad: a digital pad with four input possibilities arranged in an up, down, left and right configuration. The A button is used to launch the first ball.

4.1.1.2 Output

Sightlence used one gamepad for its output in the first prototype version, and those outputs were mapped to the gamepad’s two motors. Outputs were provided for the position of the ball relative to the position of the paddle on the Y-axis and for bounces of the ball against the paddles. Outputs for the position of the ball relative to the position of the paddle on the Y-axis used the low-frequency motor if the ball was beneath the paddle on the Y-axis and the high-frequency motor if the ball was above it. If the ball and paddle were aligned on the Y-axis the vibrations were silent.

When the ball bounced against either paddle a vibration with a short duration was emitted with the low-frequency motor. When a point was scored the gamepad’s two motors would go off on full strength for three seconds and the ball would reset to the middle of the playfield.
4.1.2 Play feedback participants

To test the first iteration of the game prototype twelve participants were recruited. Ten of them were between the ages of 22 and 26 while two participants were older than 35. The ten younger participants were all postgraduate students at the Master of Science in Information Technology: Media Technology and Games program at the IT University of Copenhagen, Denmark. The two older participants hold doctoral degrees and both have a background as researchers on games. Needless to say they are all avid players of computer games and active participants in the computer game community.

4.1.3 Procedure

Each participant was first welcomed and given a presentation of the game prototype and the haptic controls, with a visual presentation of Sightlence turned on to help explain the reference between game objects and their corresponding haptic signals. They were then given 2 minutes to familiarize themselves with the haptic signals with the visual representation still turned on. After that the visual representation was removed from the participants and only remained visible for the test facilitator. The participants then played the game for 10 minutes while the test facilitator observed the play session and noted down relevant play performance data and spontaneous verbal comments from the participants. The game also collected play performance statistics automatically but the data were not used in this play test as play proficiency wasn’t the focus in this session. Afterwards an open informal interview was held with each participant to discuss the fruitfulness of the game concept, the execution of the current prototype and viable future directions to move Sightlence towards.

4.1.4 Results and analysis

The collected feedback from the play test centered around five topics: they thought that it was an interesting concept that would do well to be realized; there were some concerns that it might be better to use a new game design together with the interface design; everyone except two felt that it was difficult to play the game as they had trouble remembering the intended meaning of the vibrations; it was perceived as a problem that the haptic interface
conveyed less information about the game than the visual interface did; and an important question given to the test facilitator was how people could learn what a game designer intends with the haptic signals.

Those concerns are all valid, most of them were addressed in the later iterations of Sightlence, and they also deserve some elaboration. The game design was kept as it was as it both helped to isolate issues found during the usability testing of future versions and also had a democratic purpose of accessibility. In future game designs that use haptics it would be interesting to design the game around haptics rather than the other way around. It is true that in the first iteration of Sightlence the haptic information output did not attempt to capture all the output of its visual counterpart as it became clear that the Xbox 360 gamepad’s haptic capabilities are limited. This is in part a result of motor inertia during the spin-up and spin-down of the asymmetrically shaped pieces of metal that cause the vibrations which results in signal boundaries that are indistinct and bleed into each other.

Answering the question of how a player learns to understand what the signals mean falls outside of the scope of this thesis but is an interesting one. This thesis has approached the issue through a semiotic framework where the signals are conceptualized as comparable to symbolic icons in the same sense that words are. The question of learning could then be given the same answer as that of language acquisition. It could equally well be formulated as a question about knowledge acquisition in general, which is normally taken as a given and ignored but the question often seems to rise to the fore with Sightlence, it might be that the novel interface experience makes the question into a conscious consideration.

Most of the test participants had trouble playing the first iteration of Sightlence but two persons did pick it up fairly quickly which gives rise to some interesting questions. One person felt that the game was very meditative since you always strived to cancel out the vibrations and keep them silent by positioning the paddle and the ball in line with each other. This person did not feel that he had any difficulty separating the two signals from each other. The other person played the game better than any of the other participants. His explanation for his proficiency was that he had always been a person that feels a need to touch things in order to fully understand them and that it is not
enough for him to just look at something. Together with the results of the two athletes, which are presented below in iteration three, this is something that would be interesting to research further.

4.1.5 Modifications

Based on the received play feedback from the first iteration the following modifications were made to Sightleunce during the second iteration: Another Xbox 360 gamepad was added for the player in order to allow for a wider range of information output by the use of body location; a signal could then use the same parameters but still be used for different meanings depending on if it was conveyed through the hand gamepad or the lap gamepad. This increased the hardware cost for playing the game but it was considered justifiable based on the low cost of a gamepad, and the increased capabilities it allowed, that would still make it affordable to at least most people that currently live in industrialized societies.

More signals were also added as the information output capabilities were increased as a result of the new gamepad. Signals were added to convey the ball’s position along the X-axis in relation to the paddle, when the ball bounced against the walls, when the paddle hit the walls, when a new ball is played, and also the signal was changed for when a point was scored from a continuous signal into a signal that alternated in strength between high and low intensity as many of the players had trouble recognizing the old signal. The ball was also made to freeze in the middle after a point had been scored and held there until the A button was pressed again instead of starting to travel immediately.

4.2 SECOND ITERATION: PLAY SESSION WITH DEAFBLIND PEOPLE

The intentions with the second iteration’s play session was to let people who are deafblind play the game, provide feedback on it and getting the opportunity to ask them about their current experience of games. The play session took place during an annual meeting of the local Västerbottens chapter of the association for Sweden’s deafblind. Time was in short supply as the play session had to be squeezed in among the other items on their agenda. The play session was conducted despite the time limitations as it was an opportunity to
at least showcase the game and get some feedback from a demographic that’s very important for Sightlence.

4.2.1 Prototype

The rules, game mechanics and objects used in Sightlence remained unchanged between the first and second iterations. There was a minor change made to the input possibilities offered to the player. The most substantial changes made were to how, and in what manner, the output information was given to the person playing the game. These changes dramatically increased the expressiveness of Sightlence’s output capabilities.

4.2.1.1 Input

The person playing the game still use the D-pad’s up and down directions in order to move the paddle. The change was in how the scoring of points is handled. Instead of rewarding a point and restarting the game as soon as a ball goes beyond the game screen the ball is instead held frozen in the middle of the screen after a point is scored until the player presses the A button. The paddles are reset at the same time to the middle of the screen along the Y-axis.

4.2.1.2 Output

The most substantial change for the second test version, as previously mentioned, was the decision to include a second gamepad to handle the output signals from the game. Because of this change the gamepads in the following description will be referred to as the primary or hand gamepad, and as the secondary or lap gamepad. The decision was to split up the output from the game across the two gamepads to separate the output related to the paddle and the ball from each other in order to ease recognition of the signals for the players.

The hand gamepad provides the output that’s related to the paddle. The high-frequency motor is used for output telling the user if the ball is above or below the paddle along the Y-coordinate. If it’s below the paddle it gives off a constant high-frequency signal with low intensity and if it’s above the paddle it gives off a high-intensity signal. The low-frequency motor on the primary,
hand, gamepad is used to indicate when the ball is bouncing against the paddles. A high intensity low-frequency signal is used when the ball bounces against the player’s paddle and a low-intensity signal is used when it bounces against the computer agent’s paddle. If the player’s paddle hits the floor or ceiling boundaries of the game area the hand gamepad gives of a continuous low-frequency vibration.

The secondary, lap, gamepad provides the output that’s related to the ball. The high-frequency motor is used to indicate the position of the ball relative to the player’s paddle along the X-axis. As the distance between the two decreases, relative to one’s own paddle, the high-frequency signal increases in intensity. When the distance increases as the ball travel towards the computer agent’s paddle the intensity decreases to indicate that the ball is far away. The low-frequency motor is used to indicate bounces of the ball against the floor and ceiling boundaries of the game screen. When it bounces against the floor boundary a signal with low-frequency and low-intensity is emitted from the gamepad lap and when the ball bounces against the ceiling boundary of the screen a signal with low-frequency and high-intensity is emitted.

Both the primary and secondary gamepads start to vibrate on both their motors when a point is scored by either the human person playing the game or the computer agent and alternate between turning them on and off with 0.5 second intervals for a duration of 2.5 seconds. The motors vibrate with full force for the person that scores the point and with less force for the person that loses the point. After the duration of the 2.5 seconds have ended the controllers go silent.

4.2.2 Evaluation participants

The annual meeting, of the local Västerbotten chapter of the association for Sweden’s deafblind, was attended by circa 25 people; half of them being interpreters and half being people who are classified as deafblind. Because of the time and facility constraints the play session was conducted as a town hall meeting with everyone present in the same room. The game was actively played by five people with deafblindness, one woman and four men, and additionally by one interpreter. Their age was guessed to be between 30 and 70 as there was no time to conduct individual interviews or have them fill in
questionnaires. More people were interested in testing Sightlence but unfortunately time ran out before they could all try the game.

4.2.3 Procedure

The play session began with the play facilitator giving a five minute “town hall” presentation about games in general, the computer game Sightlence that they were about to try, an explanation of the purpose of the play session, their role if they want to participate, that participating was voluntary and also much appreciated. The presentation was ended by thanking everyone for being given the opportunity to visit their annual meeting in order to show Sightlence. The presentation was translated to the deafblind participants by their respective personal interpreter.

After the initial presentation the people that wanted to participate got an opportunity to volunteer and a cue was arranged. Then one at a time they got to sit down in front of the computer and receive instructions on how the game worked and how the gamepads functioned. Instructions from the test facilitator and questions from the play participant were translated by the personal interpreters. The interpreters were also aided, when needed, by the present head interpreter that oversaw the activity in general. The visual representation of the game was turned on during the presentation and the subsequent play sessions for the benefit of the interpreters in order to help them make the translations as well as possible.

When the instructions for Sightlence had been given the person got to play the game. There was no set time limit to how long they could play but each play session went on for around 5-10 minutes before they gave the controllers to the next person in line. As it was a play session showcase of Sightlence, and not a regular usability test, help and prompts were given during the each person’s play session in order to help them get a feel of the game as quickly as possible due to the severe time limitation of the event.

4.2.4 Results and analysis

Communicating through an interpreter was a new and interesting experience but proved challenging during the play session as it took longer to explain the
instructions for Sightlence and the natural flow of being able to ask and answer questions became hindered. One of the interpreters came up with an interesting explanation of Sightlence for people that cannot see it. She stood behind the person playing the game and mimicked the game’s two paddles by holding her hands on their back to indicate the paddles and she also drew the ball’s movement across the playing field; effectively creating a spatiotemporal haptic imitation on their backs that mimicked the movements in the game.

The participants said they enjoyed playing Sightlence even though it was challenging with such a short amount of time combined with the fact that none of them had ever played computer games before in their entire life so just holding the gamepad was a new experience for them. The most fascinating moment for me in the play session was when two of the older men stood in a corner after they had played the game, they held each other’s hands and used them to retell the movements of the ball to each other; while having a look on their faces reminiscent of that of 15 year olds huddling together after a game of StarCraft to retell the exciting parts of the match to each other.

Deafblind people in Sweden have a right to government support in order to live independent lives. Having access to an interpreter is a part of that and for this play session they were available to help with translations and explanations of the game. This right does not extend to 24 hour support though and they are not as available as people with deafblindness would want them to be. The current iteration of Sightlence needs an interpreter as its menus and tutorials that use text but lack the functionality to output them to a Braille reader. Such readers are not supported by the Xbox 360 XNA development library provided by Microsoft and in this thesis project there were no funds available to buy a reader to implement and test it. There will hopefully be resources available to include such functionality in a future iteration of Sightlence, even though it is not supported by the Xbox 360’s operating system, since interpreters are not always available; even if they were it’s not a design intention that people with deafblindness should have to depend on others to start Sightlence for them.

4.2.5 Modifications

During the play session it was observed that participants in general had problems with moving the paddle smoothly across the play area. This is
understandable since the D-pad on the Xbox 360 gamepad is a digital button which means that it’s either on or off. It was therefore decided that the movement of the paddle should be changed to the analogue left stick where the player can adjust the movement gradually between 0 and 1 depending on how far from the center the stick is moved.

The D-pad’s up and down directions are more distinct and clearer than the analogue stick’s impression of 360 degree movement. The D-pad therefore better corresponds to the possible paddle movements in Sightlence but as the D-pad is apparently harder to use proficiently it was decided that playability was more important and therefore the gamepad’s input settings were changed. The vibration boundary box for the paddles was also changed, which is further explained in the output section under the third iteration.

4.3 THIRD ITERATION: USABILITY TEST WITH AVERAGE PEOPLE

In its third iteration, Sightlence had matured to such a level that it was appropriate to conduct usability testing in order to verify its functionality. The usability testing was done together with people that had played table tennis computer games before; this was done to hopefully isolate the origin of any potential problems to Sightlence’s interface rather than being unsure if they could be attributed to the game’s rule system instead.

The purpose of testing the third iteration of Sightlence was to test if an improvement in proficiency could be noted over time among the people that played the game, and to test if the participants could recognize the vibrations that Sightlence used to convey meaning. Recognizing signals and using them proficiently are interconnected but were still tested separately since a person can have an understanding of what should be done without succeeding in doing it.

4.3.1 Prototype

There were no changes made to Sightlence’s rule system between the second and third iteration. Changes were made to how input is given to Sightlence by changing the control of the paddles’ up and down movement from the D-pad to the analogue stick. The output signals were not changed but the boundary
box for when output related to the ball, and its relative position to the paddle along the Y-axis, was made smaller than the actual paddle; to avoid situations with last second misses by the player.

4.3.1.1 Output

The signal remains silent if the ball is kept between two thirds of the distance from the center of the paddle to the top or bottom of it on the Y-axis: see Figure 5 for visualization. This is to avoid situations where the signal is silent because the ball is within the boundaries but coming in at such a steep angle that it passes right by the edge, avoiding the paddle and scoring a point for the computer.

FIGURE 5: SKETCH OF THE VIBRATION BOUNDARIES ON THE PLAYER’S PADDLE.
4.3.2 Evaluation participants

For the third test iteration 14 participants were recruited. The results for five of the participants were subsequently excluded from the analysis because of problems with the data gathering: one was excluded because of unfortunate interruptions, two because their respective total playtime was less than 15 minutes, and two because of technical problems with the hardware. Eight of the remaining nine test participants were between 18 and 30 years of age, three women and five men, while one was a man older than 50. All of them were familiar with table tennis computer games. All participants use computers on a daily basis in their work and privately at home. One participant was studying towards a PhD, four were currently studying at university, two have completed advanced vocational education, one was attending high school, and one had a senior military education and career. Four of the participants played games more often than a couple of times every week, two played at least once every week, two played “almost never” and one played daily but always the same game; a computer game shipped with Windows XP called Harpan (Microsoft, 2001; Eng. Solitaire).

4.3.3 Procedure

The participants were welcomed and thanked for agreeing to volunteer to test Sightlence before being given a description of the game and instruction on how to play it. The test participants were then given two minutes to orient themselves to the interface by playing the game, with both the haptic and the visual modalities present and asking questions about it. After the orientation phase the test participants moved on to the first play test where they were instructed to play the game for 20 minutes, with only the haptic modality present, and try to do their best to bounce back the ball towards the computer opponent as many times as possible. If they missed a ball they were instructed to put another ball back into play and then continue to play the game to the best of their ability. The test facilitator observed a monitor, with a graphical representation of the game, of the player’s play session in order to observe the participants’ play style. Verbal behavior during play was also observed and recorded by note taking.
After playing Sightlence for 20 minutes the test participants got a short break while the game was restarted for a second test phase. In the second phase of the usability test the participants were asked to identify all the different vibrations by answering questions of the form: “say when you feel that the ball is traveling towards you”. For the second phase the test participants were instructed that it didn’t matter how many times the ball went outside of play field as this phase was only focused on the meaning of the vibrations and that the phase did not have a time limit as the first phase had had. Most participants still took around the same amount of time, 20 minutes, to finish this part of the test. After the second phase was finished a short informal debriefing was held where the participants got an opportunity to ask questions and they were also asked about how they had felt about playing the game, if any parts had been hard and if they had suggestions on how to change the game in order to make it better. The usability test was wrapped up with the participants being thanked for taking the time to participate and for helping to make Sightlence a better game.
4.3.4 Results and analysis of play proficiency

The diagram in Figure 6 shows a number of interesting results. A negative interpretation of the diagram would be that out of the total of 201 played balls, 85 (42 %) were lost without the player managing to bounce them back a single time. If the 45 times that the players managed to bounce the ball back once are considered lucky shots, caused by the player unknowingly and accidentally having the paddle in the right position, this number would increase to 130 (65 %).

A positive interpretation on the other hand is that in 116 (58 %) of the times the player managed to bounce the ball back at least once while using a novel computer game interface modality that they have had less than 20 minutes of experience with. Since the usability testing conducted for this thesis consisted of a single play session it’s impossible to say anything about a potential increase in proficiency over several play sessions. Regardless of potential increases in proficiency the current success rates should not be seen in the light of traditional usability tests where an accomplishment rate of 42 % would be atrocious as failure in computer games are an integral part of what makes them enjoyable for the people that play them (Juul, 2009).

The diagram also shows two outliers that are interesting for this thesis the players that, once each, managed to bounce back the ball 11 times in a row without missing. Those two results show that there is a possibility that computer games with haptic interfaces can be played well, which gives hopes for the future with regards to these interface’s learnability.
FIGURE 6: DIAGRAM OF PLAYERS’ PROFICIENCY IN PLAYING SIGHTLINE.
4.3.5 Results and analysis of haptic signal recognition

Looking at the diagram for the first test in Figure 6 depicting the players’ success in bouncing back the approaching ball it’s clear that players do not become fully proficient after only 20 minutes. This is not surprising since the task was to learn to handle a computer interface modality that’s completely new to them. Successfully playing Sightlence requires two things: recognizing what the different signals represent and acting successfully on those signals. The second test was devised to find if people could successfully recognize the different signals regardless of their ability to play well. There are some interesting results in the diagram for the second test in Figure 7.

The first is that people are successful at distinguishing most of the signals; despite using a completely new interface modality. From the diagram it’s clear that there were two types of signals, four different tactile icons, that the players had trouble distinguishing; those were when the ball bounced against the paddles or against the walls. They are not only interesting as a consequence of being hard to learn but also for a reason that is not apparent in the diagram. The responses that the players gave instead of the correct signal were those signals opposite: Instead of answering that the ball bounced against their paddle they would report that it bounced against their opponent’s paddle. The opposite counterpart to a signal is identical in all regards except for the amplitude (strength). This mistake is not completely surprising since human perception of tactile signals is better at recognizing relative differences in values rather than absolute values.

Recognition was worst when the player was trying to decide which paddle, and second worst for which wall, the ball wall it was bouncing against. As the signals related to the paddle are conveyed through the hand gamepad the answer cannot be one of sensitivity since the hands are more sensitive than the lap, which receives the signals for when the ball is bouncing against the walls. The difference in successful recognition likely depends on time. These two types of signals have a longer time delay between them compared to the other signals. The playing field is also an elongated rectangle with a longer X-axis than Y-axis. This is consistent with the results as the second worst results are for the ball bounces against the wall along the Y-axis, and worst when the ball bounces against the paddle along the X-axis.
Figure 7: Diagram of players' recognition of sightline's haptic signals.
4.3.6 Modifications

After the usability testing in the third iteration the software engine that handled the vibrations was completely rewritten in order to make it more efficient and to make it easier in the future to add or modify vibrations. The previous engine required that the designer did a lot of analysis and testing whenever a vibration was added or modified to ensure that the new vibration did not disrupt any other vibrations. However, this engine rewrite did not change how the signals are experienced by the person playing the game. The menu system was redone according to typographic theory to make it more understandable and aesthetically pleasing while adding some new information about the game. A screenshot of the new menu can be seen below in Figure 8.

![Sightlence Menu](image)

FIGURE 8: SCREENSHOT OF SIGHTLENCE’S NEW MENU SYSTEM.
The first three iterations had both a visual and a haptic modality. After the third iteration the interface translation method was applied to the audio modality in order to see if it was a useful method for translating interfaces into sound as well. Refining and testing this method for translating modalities falls outside the scope of this thesis and will instead be explored in future work.

Lastly, the usability test uncovered that the test participants had problem with two types of signals. They did not have trouble identifying the signal itself but couldn’t distinguish which of the two versions that were being transmitted. To only separate the two versions by amplitude is not enough if there is a long time delay between them. A new signal will therefore be implemented that contains a change in rhythm as well as in amplitude; so that the direction of the change can be felt in the signals as well. This will eliminate the need to keep the other version in work memory in order to be able to make a comparison between the two.

4.4 FOURTH ITERATION: USABILITY TEST AT A SPECIAL NEEDS SCHOOL

With the fourth iteration of Sightlence the intention was to extend the usability testing to include people with deafblindness. A crucial difference between the two groups, aside from the difference in sensor availability, is that people who are deafblind have not played table tennis computer games before. The tasks in this usability test were the same as for the first one: to test if an improvement in proficiency could be noted over time, and if the participants gained an understanding of the vibrations that Sightlence use to convey meaning. The usability test session took place at a national special needs school in Sweden for children with deafness, or impaired hearing, combined with severe learning disabilities or congenital deafblindness.

4.4.1 Prototype

There were no changes made to the game’s rule system or to the way input is handled between the third and fourth iteration. Even though a change is necessary in the future for the four signals, for when the ball bounces against the walls or paddles, they were kept as they were in order to keep the two usability tests consistent with each other. The audio based modality was also deactivated for the same reason even though it had been implemented.
4.4.2 Evaluation participants

The fourth iteration of Sightlence was tested by four children from a national special needs school in Sweden for children with deafness, or impaired hearing, combined with severe learning disabilities or congenital deafblindness.

4.4.3 Procedure

The initial idea for the usability testing in the fourth iteration was to follow the same procedure as the usability testing in the third iteration with the addition of an initial interview. The usability test was also presented to the first test participant in that manner. It quickly became clear that such an approach would not be possible and would yield no interesting results as the participants could not play the game. The school’s IT pedagogue believed that the level of concentration required to listen to the instructions for such a long time, and the level of abstraction required to play the game, were outside what the children could currently perform at. I therefore decided to instead start each session with an interview focused on how the children currently spend their leisure time. After that the participant and test facilitator sat down and played the game together with a focus on observing what the children were struggling with. Each session took 30 minutes and was concluded with the children being thanked for taking the time to help make Sightlence better.

4.4.4 Results and analysis

The usability testing at the national special needs school unfortunately did not yield any useful analyzable quantitative data. The pupils at the school had various forms of cognitive development disorders, which proved to make it impossible to collect the intended data. The explanation that I’m currently entertaining to be the most plausible one is that they were unable to play the game as a result of the combination of a short play session (20 minutes) and the game’s level of abstraction. Sightlence relies on a human perceptual sense in an unfamiliar way and is difficult to grasp even without a cognitive development disorder. The school’s IT pedagogue’s explanation of their approach to learning is that they ground every new learning experience in earlier experiences that are in close proximity to the new in a more rigorous
manner than is needed for children without cognitive development disorders (personal communication, April 27, 2011). If that grounding can be provided it might be possible to design computer games, based on haptics, that they can master first in order to build up to Sightlence’s level of complexity and hopefully also move beyond that game.

4.4.5 Modifications

After the fourth iteration of Sightlence a tutorial mode was added to the game in preparation for public release. A screenshot of the tutorial mode can be seen in Figure 9 below. When the player moves the selector cursor over one of the six small thumbnails it is enlarged on the large square to the right. Each square shows a stylistic, looping, version of a single significant movement in the game together with its visual, audio, and haptic feedback present.

![Sightlence Tutorial Mode](image)

**FIGURE 9**: SCREENSHOT OF SIGHTLENCE’S NEW TUTORIAL.
5 DISCUSSION

There are a few things that I want to touch upon as the parting words of this thesis and in the light of attempting to apply a novel technique to a new domain. It quickly became obvious that there are large areas within design, research and development of haptic techniques for computer games that are still unexplored. I believe thought that there is a possible market for these techniques. Before elaborating on these parts I want to return to the actual prototype developed for this thesis and discuss some particulars of the game itself, the testing of it and the process that resulted in Sightlence.

5.1 REFLECTIONS ON THE DESIGN PROCESS AND THE GAME

It felt reasonable to use an existing rule system in this project as it made it easier to draw conclusions about the players' proficiency in playing the game. If I had decided to design both a completely new game concept and a completely new interface it would have been harder to know if any uncovered problems during testing depended on the interface itself or on ambiguities in the rules. As I selected a well-known game concept it's easier to draw the conclusion that any difficulties in playing the game are caused by the interface design or by limitations in the hardware that's used for the interface rather than the game concept. Selecting an existing game concept proved that it's possible to make translations of computer games from a graphical modality to a haptic one. This shows that at least a part of our computer game history can be made available for people who have been unable to experience them until now.

There were some difficulties with the testing of the prototypes because of the time requirements. Based on the testing of the first prototype it seemed to take around 20 minutes before participants managed to gain a proficiency in playing the game. Combined with introduction, test trial and questions afterwards each test pushed up to, and above, 40 minutes in length, which felt like a long time to require a participant’s cooperation without compensation. As a result of the time demanded from each participant it felt unreasonable to ask them to sit in for more than one session, which meant that a longitudinal study with the intention to measure learning over time wasn’t possible.
5.2 ELABORATION ON THE RESULTS

The initial idea for the usability test was to make a within group comparative study of play proficiency at the beginning and the end of the play session. The plan was also to do a statistical comparison between people with sight and hearing, and with deafblind people. As a result of the previously mentioned problems with gathering statistically useful qualitative data from the children at the special needs school this plan had to be abandoned for the purposes of this particular thesis, though future studies will be conducted.

For the within group design the comparative study was ultimately changed into a descriptive study that shows the actual player performance but leaves statistical models for a later time. The primary reason was that the combined effects of a novel interface technique and a total play time of only 20 minutes per player. If the play sessions were to be fruitfully tested they would probably have had to be divided into smaller parts that were compared against each other as the performance on an individual ball would not say much since so many went out without a single successful bounce. Two choices would be to split the session into two 10 minutes parts, or into four 5 minutes parts, were only the first and last five minutes were used. Play proficiency during the first part would most likely be abysmal and any improvement at all would then be statistically significant if the sample had been large enough, which wouldn’t have made for exciting results. Testing for an increase in proficiency is still very interesting as it allows conclusions to be drawn regarding the usefulness of haptics as a modality in computer games in the long run. For this it would be wiser to compare results over several sessions so players have time to get used to the interface. Recruiting participants for a longitudinal study was avoided for this thesis as there were no monetary resources available that could be used compensate the participants for their time.

An interesting observation was done while the data was being transformed into a usable form and that was that many participants had their single highest scores happening somewhere in the middle of their play session. One possible reason might be that test fatigue began to set in half way through and canceled out the increasing proficiency, another might be that the players felt that they had performed really well after a particularly good ball and turned less attentive to the game after that.
There is also an interesting correlation between the two players that scored that highest number of consecutive bounces and that is that they are both athletes. This is of course just two people so I will be careful about drawing any conclusions. I will instead suggest two explanations that could be used for future hypotheses: Athletes might be more used to consciously listening to the their bodies in a way that’s relevant for haptic perception; or that people that are athletes are often thinner than the average person, which could mean that they are less insulated from the vibrations in the gamepads or that their skin’s mechanoreceptors are packed tighter as the skin is less stretched.

5.3 FUTURE DESIGN NEEDS

Sightlence is a reimagining of a timeless classic from the history of computer games. It has a number of features that makes it an interesting candidate to redesign: spatial movement and relations between objects and agents need for “hand-eye” coordination, and it also has time-limited actions. It is still only one game, part of one genre, and in 2D. It would be beneficial to explore more games designed with haptic interfaces in order to see the possibilities and limitations when using haptics to design games both in the form of entirely new games and as conversions of older games. Older games are suitable for conversion since they often have only a few game mechanics which means that the distinction between different outputs can be made coarser and as a result easier to realize on the gamepad hardware that’s available today. It also allows a wider audience to experience the cultural history of computer games; a culture that is currently inaccessible for many.

If more than a handful of games are going to be designed with haptics language will become an important issue for designers to tackle. No man is an island and neither is a game. Games have through the years, especially within genres, built continuously on the progress of its forbearers. This creates not only expectations but also familiarity and learning that carry across different games. This would not be the case if game designers were not knowledgeable of game design conventions and choose to use them consistently. Conventions of language use have to be established both for the benefit of users and for the benefit of designers if haptics is going to become a standard modality when developing games as that language can carry over between different games. This would create consistency for the player as she’s experiences new games.
Sightlence had some hardware limitations placed on it from the start. The idea was to create a game that would be easily available and affordable, which constrained the options on what hardware technology Sightlence could use; the Xbox 360 gamepad is quite lacking in its ability to convey complex haptics. If games with a great deal of haptic complexity are going to work I believe that we need more advanced haptic techniques to be integrated into the gamepads. Game console developers are the people that must make that move to ensure more inclusive games as they are the gatekeepers of the hardware. Games developers can start developing games with the technology that currently exists but to achieve more advanced game design, more sophisticated techniques have to be made available and they have to have a large market penetration to be interesting for most developers. One can compare the Nintendo Wii Controller with the Sony EyeToy. The former is the standard input device used for the console so every developer has to take it into account while the latter is a gimmick with scant market penetration. More than 10.5 million units of the Sony EyeToy (Kim, 2008) have been sold but this should be compared to the PlayStation 2 console itself, which has sold over 150 million units (Sony Computer Entertainment Inc., 2011). The Sony EyeToy does thus not become a natural consideration in every game development project. This is the reason for why I don’t see this development happening in the PC space as it has very many hardware suppliers.

Producing more advanced hardware and putting it into the hands of users isn’t enough even if goes some of the distance. Tools of production also have to be created for use in the design process. For Sightlence all interactions had to be created at the level of code, which is a needless obstacle that creates a higher barrier of entry for interested designers. Quickly changing the game in order to conduct rapid prototyping becomes difficult when all changes have to be made by terminating the game, altering the code-base and then recompiling it before the game can be run again. It would therefore be beneficial to see middleware created that would allow for alterations to be made while the game is running. If this would be combined with standard graphical interface techniques like instant feedback, drag and drop, and similar capabilities it would make for a tool that would greatly increase the opportunities for designers that want to create interfaces based on haptics.
Developing games that can be played by deafblind people isn’t to target the world’s biggest demographic but to present some interesting possibilities aside from bringing computer games to an entirely new audience. A small independent developer could occupy a niche that is currently free from global publishing companies, other independent game development companies and even hobbyists.

Successfully developing games that transfer information based on haptics open up opportunities for traditional game development as well. Traditional game development companies have for a long time made heavy investments into computer graphics. A few years back sound has started to receive increased attention and investment. This has led to dramatically increased complexity and fidelity in graphics and sound. As a result information in games is currently conveyed through the visual and auditory senses while the tactile and kinaesthetic senses are underutilized in comparison. Games that successfully use haptics prove that it can be used as a stand-alone modality for information transfer, or as a complement to current modalities. With haptics, games would get another information channel available to them that is currently not overloaded. These are considerations aside from the possibility of offering current discerning players a new kind of game experience that they haven’t had the possibility to experience before.

5.5 FUTURE RESEARCH

There are several areas of haptics that needs to be research, not the least in the area of tactile and kinesthetic perception and their link to cognition. The focus here more narrowly discuss haptics closely related to computer games. This thesis shows that people can play Sightlence and they can successfully identify the different vibrations in Sightlence as having different meanings. Since this thesis choose to only use technology that is readily available to a large number of people the hardware choice was limited to the current generation game consoles’ gamepads that only feature limited information transfer via tactile perception. Mainstream commercial games don’t use information transfer through kinesthetic perception. Further research in these areas can hopefully encourage future directions for hardware development that can lead to widely available gamepads that are both cheap to buy and an improvement over current gamepads.
General directions regarding haptic parameters to use, and their ranges, could be found through literature review. Fully exploring this space in relation to computer games, using standard game gamepads, would give a map with the boarders filled in for game designers to use. Studies on the precise time requirement needed to learn and recognize haptic signals would aid in how tutorials and progression in games should be spaced to give players a suitable learning curve. Kinesthetic and tactile perception is under-researched compared to hearing and sight. If more computer games would use haptics to convey game mechanics, rules, objects and agents those computer games could be appropriated by researchers to provide a polished treatment to use when doing studies on haptics and its relation with the other senses and with cognition. Instead of forcing researchers to construct their own hardware and software specific for the purpose they could use artifacts that already exist as a natural part of people’s lives that they willingly interact and spend a lot of time with. This would give researchers artifacts and test participants that could be used to conduct longitudinal studies. These results could then in turn be incorporated into the development of computer games. This would create a favorable situation that academia and industry would mutually benefit from.

The interface translation method has also been applied to sound in order to see if it’s useful for translating interfaces into other modalities than haptics. Sightlence has now been outfitted with an interface based entirely on sound so a player can choose which modalities to turn on while playing. There wasn’t room to explore this issue further in this thesis but the initial results looks promising for future research.
Humans have always strived to better themselves in mind, body, and life. We strive to accomplish more and reach further than those that came before us. The construction of artifacts, in all their forms, has been a part of that journey throughout our history. We have used them to augment and complement our being; to strengthen what we have and add what we don’t. By equating human-computer interaction with sight and sound we have diminished that relationship to only a part of our body’s full perception. It places limitations on some of us and ignores those that cannot see and that cannot hear. Artifacts help us flourish when we can express ourselves and when we can reach out and touch other people through them.

If we create artifacts that make communication possible in better ways, and in new ways, then we have created the possibility for valuable relations between humans. For aren’t we humans, even as a species, impaired for the environmental, cultural and personal challenges and demands that are placed upon us by others and ourselves? Don’t we always strive to break free from the boundaries that try to hold back our true capability? If so, is it really a question of normal or impaired, or is it a matter of the human race and her close relation to her artifacts? Carlyle certainly believed so and expressed it, more eloquently than I could ever hope to do, four centuries ago:

Man is a Tool-using animal. Weak in himself, and of small stature, he stands on a basis, at most for the flattest-soled, of some half-square foot, insecurely enough; has to straddle out his legs, lest the very wind supplant him. Feeblest of bipeds! Three quintals are a crushing load for him; the steer of the meadow tosses him aloft, like a waste rag. Nevertheless he can use Tools, can devise Tools: with these the granite mountain melts into light dust before him; he kneads glowing iron, as if it were soft paste; seas are his smooth highway, winds and fire his unwearying steeds. Nowhere do you find him without Tools: without Tools he is nothing, with Tools he is all.

(Carlyle, 1831, p. 25)
BIBLIOGRAPHY


Buxton, B. (2007). *Sketching user experiences: getting the design right and the right design*. San Francisco, USA: Morgan Kaufmann.


