Introducing Product Experience into Assistive Technology

Jens Ager Sørensen, 201205392

Simon Møller Christensen, 201205400

Simon Hammerholt Madsen, 201205391

Master's Thesis, IT Product Development

June 2017

Advisor: Ole Caprani

AARHUS UNIVERSITY

DEPARTMENT OF COMPUTER SCIENCE

Preface

This thesis was written in the period from the 1st of February 2017 to the 15th of June 2017, at the Department of Computer Science, at the University of Aarhus.

We attended an education event in February 2016, as representatives for the IT Product Development education. At the event, we had brought along some projects that we had carried out during the course of our education, to showcase what kind of work an IT Product Developer does. At the event, we were approached by a project manager from the company Applikator. He explained that the company had created an Assistive Technology called Touch & Play, which was a large touch screen interface, designed to stimulate both physical and cognitive faculties of elderly users, as well as users with impairments. Though Touch & Play had become quite popular, they had experienced some challenges in the interaction between the users with more severe physical impairments and Touch & Play. In relation to this, he suggested, that our Master's thesis could revolve around attempting to overcome some of these challenges.

In a pilot study and the work conducted for this thesis, we have collaborated with a group of students at an institution, that offers an education to youths with special needs. Both the institution and the students wish to remain anonymous. For this reason, their names have been omitted from this thesis. Through this work we have shifted focus. Instead of only focusing on overcoming the challenges we focus more generally on Product Experience in relation to Assistive Technology.

Several people have contributed during the process of writing this thesis. First of all, we would like to thank our supervisor Ole Caprani, who has guided us through the entire process. Secondly, we would like to thank Eve Hoggan, who has provided us with invaluable input and feedback. Thirdly, we would like to thank Carina Corfitz Christensen for proofreading and helping improve readability of the thesis. Finally, we would like to thank Applikator and the STU Center with whom we collaborated on this thesis.

Jens Ager Sørensen
Simon Møller Christensen
Simon Hammerholt Madsen
Aarhus, June 15, 2017

Abstract

In a pilot study we examined the practical challenges faced by a group of students with severe physical and cognitive impairments, when interacting with a specific Assistive Technology, called Touch & Play. Through this study, it was found that the functional purpose for which the Assistive Technology was built was not what the students found most attractive. Instead the most attractive qualities of Touch & Play were: (1) that it helps the students feel included, (2) that it strengthens the social relationships between the students, and (3) that it allows them to feel heard. These three qualities are connected to the concept of Product Experience, which had not been in focus during the design of Touch & Play. Therefore this thesis presents an investigation of the impact the introduction of a focus on Product Experience has on the usage of Assistive Technology. To form a basis for this thesis, a theoretical inquiry of the relevance of this research is conducted, through related work within both the fields of Assistive Technology, and Human-Computer Interaction in general. Following this, the design process of two Assistive Technology prototypes, built as input devices for Touch & Play, is presented. One focusing solely on extending functional capability, and the other having an additional focus on Product Experience. The two prototypes are then both evaluated on their ability to extend the functional capability of the users, for which it was built, and comparatively analyzed in relation to Product Experience. The results of this evaluation suggest that introducing an additional focus on Product Experience into Assistive Technology has the potential to enhance social interaction, engagement and enjoyment for this specific user group.

Contents

Preface ii

Abstract iii

1 Introduction 2
1.1 Pilot Study: Touch & Play at the STU Center 2
1.2 Research Question and Thesis Structure 4

2 Researching Design for Users with Impairments in Relation to Product Experience 7
2.1 Design for Users with Impairments 7
2.1.1 Assistive Technology 8
2.1.2 Inclusive Design 9
2.2 What is Product Experience? 11
2.2.1 A Historical Overview of the Field of Human-Computer Interaction 11
2.2.2 Product Experience 16
2.3 Relevance of Introducing a Focus on Product Experience when Designing for Users with Impairments 17

3 Understanding the Context 19
3.1 The STU Center 19
3.2 Touch & Play at the STU Center 20
3.3 The Users of Touch & Play at the STU Center 22
3.4 The Pilot Study 23

4 Designing the Assistive Technology Prototypes 25
4.1 Design Methodology for the Developed Assistive Technology Prototypes 25
4.1.1 User-Centered Design in an Assistive Technology Design Process 26
4.1.2 Empirical Methodology based on Ethnography and Ethnomethodology 28
4.1.3 Appropriated Methodology for This Thesis 29
4.2 Usability Challenge Chosen for the Prototypes 30
4.3 Designing the Traditional Assistive Technology Prototype 31

4.3.1 The First Iteration of the Traditional Assistive Technology Prototype . . . 31
4.3.2 Testing the First Iteration of the Traditional Assistive Technology Prototype . . . 34
4.3.3 Second Iteration of the Traditional Assistive Technology Prototype . . . 35
4.3.4 Testing the Second Iteration of the Traditional Assistive Technology Prototype . . . 35
4.4 Designing the Product Experience Inspired Assistive Technology Prototype . . . 36
4.4.1 Conducted Video Observations . . . 36
4.4.2 Reviewing the Raw Video . . . 37
4.4.3 Patterns and Tendencies . . . 38
4.4.4 Guiding the Design Towards a Focus on Product Experience 41
4.4.5 Sketching the Idea . . . 42
4.4.6 The First Iteration of the Product Experience Inspired Assistive Technology Prototype . . . 44
4.4.7 Testing the First Iteration of the Product Experience Inspired Assistive Technology Prototype . . . 51
4.4.8 The Second Iteration of the Product Experience Inspired Assistive Technology Prototype . . . 52
4.4.9 Testing the Second Iteration of the Product Experience Inspired Assistive Technology Prototype . . . 52

5 Findings **53**
5.1 The Degree to Which the Developed Prototypes Overcame the Usability Challenge . . . 54
5.1.1 The Degree to Which the Students with the Most Severe Impairments Were Able to Interact with Touch & Play . 55
5.1.2 The Amount of Times the Students Were Unable to Reach the Desired Part of the Interface . . . 55
5.1.3 The Amount of Time the Employees Assumed Control of Touch & Play Completely . . . 55
5.1.4 Other Areas in Which the Prototypes Improved the Functional Capability of the Students . . . 56
5.2 The Product Experience Inspired Assistive Technology Prototype Enhanced Engagement for the Students . . . 58
5.2.1 The Time It Took for the Students to Appropriate the Prototypes . . . 58
5.2.2 The Amount of Interaction That Occurred with the Prototypes . . . 59
5.2.3 The Students' Levels of Concentration . . . 61
5.2.4 The Amount of Time the Employees Assumed Control of Touch & Play Completely . . . 62
5.3 The Product Experience Inspired Assistive Technology Prototype Facilitated a Higher Degree of Social Interaction for the Students . . . 63

5.4 The Product Experience Inspired Assistive Technology Prototype Created a More Enjoyable Experience in General for the Students . . . 64
5.5 Summary of the Findings . . . 65

6 Discussion **66**
6.1 Answering the Research Question . . . 66
6.2 Reviewing the Problem-Solving Capacity of This Research . . . 67
6.2.1 Research Validation Methodology . . . 67
6.2.2 The Significance and Effectiveness of the Research . . . 68
6.2.3 The Efficiency of Introducing a Focus on Product Experience into the Design Process . . . 69
6.2.4 Transferability of the Findings . . . 69
6.2.5 Limitations and Overall Confidence of the Findings . . . 70
6.3 Potential for Future Work . . . 72
6.4 Summary of the Discussion . . . 73

7 Conclusion **74**

Bibliography **81**

Appendix **82**

Chapter 1

Introduction

The main focus of this thesis is an investigation into how Product Experience qualities [18] can be introduced into technologies for people with impairments. This investigation was inspired by a pilot study [36], in which we explored the challenges a group of students with severe mental and physical impairments experienced when interacting with an existing Assistive Technology [4] called Touch & Play [2]. Touch & Play, along with the students who participated in the pilot study, will also be the focus of this thesis.

1.1 Pilot Study: Touch & Play at the STU Center

As mentioned, the pilot study revolved around an Assistive Technology called Touch & Play. Through a background interview with a project manager from Applikator, it was described that Touch & Play was originally designed in response to a request from a group of Danish municipalities who wanted a large touchscreen interface that could handle some scrapes, bumps and hits. This resulted in a large touch-screen interface, that uses infrared light to detect touch, and a tailorable GUI that contains a number of applications designed to stimulate both physical and mental faculties through games, images, movieclips and music. A transcription of relevant parts of the interview with the project manager from Applikator can be found in the appendix.

The institution in which the pilot study was conducted is a learning institution offering a youth education known in Denmark as an STU (Særligt Tilrettelagt Ungdomsuddannelse), which translates to Specially Planned Youth Education, which is an education for youths with special needs [42]. The section of the STU Center in which Touch & Play is located is attended by the students with the most severe degree of impairment. Out of the seven students that attended the STU Center in this section, five agreed to participate in the study. The students are all between 16 and 30 years of age and their diagnoses are diverse, but all students have both physical and cognitive impairments, as well as very limited fine motor skills. Their ability to speak ranges from a very limited vocabulary

Figure 1. Screenshot taken from a video recorded at a testing session, to show the scale of Touch & Play. The image shows one of the researchers besides the Touch & Play interface.

to complete inability to express themselves verbally. Finally, the majority of the students are confined to manual or power wheelchairs.

To uncover the practical challenges these students faced when interacting with Touch & Play, we conducted a series of data gathering activities at the STU Center, consisting of passive video observations of Touch & Play in use, focus group interviews [6] with the employees at the STU Center, and a Cultural Probe study [48, p. 490-491] using disposable cameras.

Through the focus group interview we found, that Touch & Play is used as a tool to teach communication and motor skills at the STU Center (transcriptions of relevant parts of the focus group interview can be found in the appendix). Therefore, we attempted, during interviews with the employees at the STU Center, to uncover to what extent Touch & Play helped the students develop their communication and motor skills. Through this, we found a mismatch between the official reason for using Touch & Play at the STU Center, and the way in which the employees and students actually use it. What the employees and students found to be the most attractive qualities of Touch & Play, was not its capacity to facilitate teaching of communication and motor skills, but instead:

- that it helps the students feel included
- that it strengthens the social relationships between the students
- that it allows them to feel heard

These three qualities are not related to Touch & Play's capacity to facilitate teaching, but are instead related to what Desmet & Hekkert call the Three Types of Product Experience: (1) Emotional Experience, (2) Aesthetic Experience and (3) Experience of Meaning [18]. This seemed salient, as Product Experience had not been an area of interest in the design of Touch & Play. This led us to question how the usage would change if Product Experience had actually been a point of focus when designing Touch & Play.

1.2 Research Question and Thesis Structure

For this thesis the following research question has been chosen:

How can the introduction of a focus on Product Experience impact the usage of Assistive Technology?

Creating an entirely new version of Touch & Play, with an additional focus on Product Experience, is neither feasible within the timeframe of this thesis, nor in the interest of the company Applikator. Therefore, to answer this question, this thesis will present the design, development and comparative evaluation of two prototypes built as input devices for Touch & Play. The prototypes built for this thesis will both be Assistive Technology prototypes focusing on solving a specific usability challenge that the students encounter when interacting with Touch & Play, but they will be built with different foci. One prototype will be built as a traditional Assistive Technology, focusing primarily on extending the functional capability of the students, whereas the other prototype will be built to still extend functional capability, but with special attention paid to the Product Experience. The prototypes will be evaluated on the degree to which they solve the usability challenge intended, as well as comparatively analyzed in relation to Product Experience. In Figure 2 you can see an image of both the prototype designed as a traditional Assistive Technology prototype, and the prototype designed with special attention paid to Product Experience.

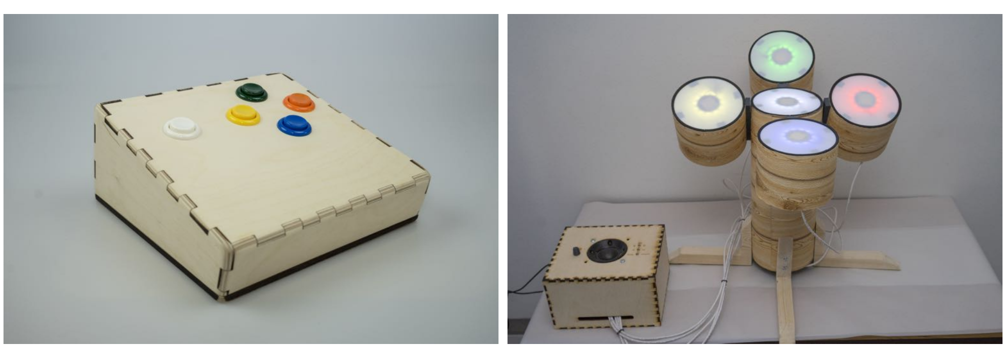

Figure 2. The two prototypes developed for this thesis. On the left, the traditional Assistive Technology prototype is shown, and on the right, the Product Experience inspired Assistive Technology prototype.

To further legitimize our research question and to aid us in our design process, we have defined a series of subquestions. These subquestions will additionally act as a frame for the overall structure of the thesis, whilst also guiding the method used for the conducted research throughout the process. The first three subquestions form the theoretical foundation for the thesis. The fourth subquestion investigates the institution, the users, and Touch & Play, along with the findings from the pilot study, to understand the context wherein the work for this thesis was conducted. Lastly, the fifth and sixth subquestions investigate what changes occur, when introducing an additional focus on Product Experience into Assistive Technology, via the development and evaluation of the two previously mentioned prototypes.

The subquestions are as follows:

1. How is technology currently designed for users with impairments?
2. What is Product Experience and how is it used in a design process?
3. Would it be beneficial to introduce a focus on Product Experience into Assistive Technology?
4. How is Touch & Play currently used at the STU Center and how could this usage be improved?
5. How can an Assistive Technology design process be structured to incorporate a focus on Product Experience?
6. How does the usage differ, when using a traditional Assistive Technology input device, compared to when using one, with an additional focus on Product Experience?

The first subquestion will be answered in section 2.1, in which the current practices, within the fields that are concerned with designing technologies for users with impairments, are introduced. Both the underlying ideologies, as well as definitions and work within the field will be presented, in order to give an understanding of how technology is currently designed within these fields.

The second subquestion will be answered in section 2.2, in which a historical overview of Human-Computer Interaction will be provided. This is done in order to demonstrate what the concept of Experience is in relation to Human-Computer Interaction, and why it has become one of the main areas of interest within this field. Following this, Desmet & Hekkert's Framework of Product Experience is unfolded to give a more concrete definition of Experience, and to introduce what they call The Three Types of Product Experience [18].

The third subquestion will be approached from a theoretical and reflective point of view, in section 2.3. In this section work that has acknowledged the need for the introduction of a focus on the concept of experience within design for users with impairments will be presented.

The fourth subquestion will be answered in chapter 3, which will provide contextual insight into the institution wherein the evaluations for this thesis was conducted, the Assistive Technology Touch & Play, around which this thesis revolves, and the users for whom the prototypes were developed and with whom they were evaluated. This chapter will furthermore briefly present the pilot study along with the results from that study.

The fifth subquestion, "How can an Assistive Technology design process be structured to incorporate a focus on Product Experience?", will be answered in chapter 4, where the design methodology used for both the traditional Assistive Technology prototype and the Product Experience inspired Assistive Technology prototype will be presented, as well as the design process for both prototypes.

The sixth subquestion will be answered in chapter 5, through a comparative analysis of the interaction occurring between the users and Touch & Play, when using the two prototypes. This analysis will be based on observations of the testing sessions, video analyses of interaction with Touch & Play using the two prototypes, and interviews with the employees at the STU Center.

The thesis will conclude with a discussion of the methodological choices made during the process, as well as the validity and generalizability of our results in relation to Oulasvirta & Hornbæk's concept of Problem Solving Capacity [44].

Chapter 2

Researching Design for Users with Impairments in Relation to Product Experience

This chapter is written as an overview of the different fields investigated, and drawn upon, in this thesis. First, Assistive Technology and Inclusive Design is presented, giving an explanation of what the two concepts encompass. Afterwards, a historical overview of Human-Computer Interaction as a field is presented in combination with a description of the concept of Product Experience. Lastly, a discussion of the relevance, of introducing a focus on Product Experience in design for users with impairments, is presented, based on related work.

2.1 Design for Users with Impairments

This section will describe and discuss different approaches to designing for users with impairments, including examples of work done within the fields. The different approaches to designing for users with impairments are split into two main subsections, called Assistive Technology and Inclusive Design. Both Assistive Technology and Inclusive Design are used as umbrella-terms for a multitude of different fields and subfields. The Assistive Technology umbrella-term covers all the fields and subfields that have, as a primary purpose, the design of technology specifically for people with impairments, whereas Inclusive Design covers all the fields that advocate designing in ways that do not exclude anyone, regardless of ability.

2.1.1 Assistive Technology

The field of Assistive Technology (henceforth referred to as AT) and subfields such as Adaptive Technology and Rehabilitative Technology/Design, are branches within the field of Human-Computer Interaction, that strive towards making technology that is specifically designed for people with impairments. Within the field of AT, different definitions are advocated, in both academia and industry. Assistive Technology Industry Association (ATIA) defines an AT as *"... any item, piece of equipment, software program, or product system that is used to increase, maintain, or improve the functional capabilities of persons with disabilities."* [4]. Shinohara & Wobbrock [50] and Scherer [49], who are all researchers within the field of AT, use the definition from the Technical Assistance to the States Act [43], when defining AT: *"... any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain or improve functional capabilities of individuals with disabilities"*. Another researcher within the field, Karen Forgrave, cites Lewis when defining AT's two purposes: *"to build on individual strengths, and to compensate for their disabilities to enable them to better perform a given task."* [21, p. 122].

In order to design products that are specifically tailored to improve the functional capability of users with impairments, an AT design process necessitates a study of the specific requirements the users have. This is usually done by utilizing the design methodology User-Centered Design, as also mentioned by Marion Hersh in her article regarding the design and evaluation of AT products and devices:

"User-centred design is considered to be best practice, particularly in systems that involve human-computer interaction or software. It has been shown to lead to more usable systems and to save time in large projects. It is particularly important in the case of assistive products, since their end-users may have very precise requirements and the fact that designers of assistive products are generally not themselves disabled or elderly and are therefore unlikely to be aware of these requirements without the involvement of end-users." [30]

Some AT research focuses specifically on allowing persons with impairments to interact with computers. Some examples of this type of AT are the LF-ASD Brain Computer Interface (BCI) [10, 38] that utilizes EEG-data to make human-computer interaction possible for paralyzed users; EdgeWrite [62] aimed at making text entry to a computer more effective for power wheelchair users; and the Camera Mouse [24] which, by using video tracking, allows a user with paralysis to control a computer by movement of, for example, the pupils.

Other AT research focuses on utilizing different interaction modalities, like Keates et al. [33] who investigated how force feedback can assist users with impairments in day-to-day point-and-click tasks; Forgrave [21] who investigated voice recognition as input, but also speech as output, to help students with impairments communicate and learn; and Carrington et al. [11] who, through

Participatory Design workshops, investigated how power wheelchair users would prefer to interact with technology, and listed preferred input and output techniques and technologies.

What the aforementioned definitions and research have in common, is a primary interest in increasing or improving the functional capabilities of persons with impairments, by allowing them to perform a given task, and a focus on usability goals such as efficiency, effectiveness, safety and learnability [48, p. 20].

Because of these shared characteristics, the definition of AT that will be used throughout this thesis is the definition used by ATIA presented above, i.e. *"... any item, piece of equipment, software program, or product system that is used to increase, maintain, or improve the functional capabilities of persons with disabilities."* This definition is used, as it encapsulates the functional, task-oriented focus, that we have come to understand as being at the center of AT.

2.1.2 Inclusive Design

In contrast to AT, Inclusive Design, and similar fields such as Design for All, Universal Design/Access, Accessible Technology/Computing and Transgenerational Design, do not concern themselves with design for people with impairments. Instead these fields focus on designing in ways that do not exclude anyone, regardless of ability [15].

This idea of designing in ways that attempt to avoid discrimination was inspired by a series of acts presented by the UK, the US and the EU among others, meant to minimize and stop discrimination against people with impairments. Roger Coleman has written a brief about Inclusive Design [15], in which he mentions a few examples of these acts and legislations, e.g. the US Americans with Disabilities Act (1990, US), the Australian Disability Discrimination Act (1991, Australia) and the Disability Discrimination Act (1995, UK).

In his brief, Coleman lists a glossary of terms for Inclusive Design and the like, which includes both a definition of Inclusive Design and the names and definitions of the other approaches. Most importantly he defines Inclusive Design as:

"A process-driven approach by designers and industry to ensure that products and services address the needs of the widest possible consumer base, regardless of age or ability. Emphasis is placed on working with 'critical users' to stretch design briefs." [15, p. 22]

This definition goes well with Norman's description of Inclusive Design, where focus is on ensuring that the design caters to the widest possible user base.

"Designing for people with special needs is often called inclusive- or universal design. Those names are fitting, for it is often the case that everyone benefits." [41, p. 246]

There are different approaches to accomplishing the goal of addressing the widest possible user base. However, one approach that seems pervasive throughout all the fields, is to make designs highly modular and flexible, in order to allow the individual user to customize it, to fit his or her needs and abilities [32] [41, p. 443-447].

For example, Pattison & Stedmon present a range of mobile phones, developed with the Inclusive Design principles in mind [45]. One of these phones is the TS41 'Bone-Phone', which is based on technology that transmits sound via the skull. This phone was designed to include older people and people with hearing impairments, but it also became popular among young businessmen, who are working on the go. The Bone-Phone can be seen in Figure 3.

Figure 3. The TS41 Bone-Phone, which can transmit sound via the bone of the skull.

Even though Inclusive Design differs from AT, both fields concern themselves primarily with the pursuit of allowing users to perform tasks they were previously unable to, or struggled to, accomplish. By focusing on making designs that can be customized to any user, regardless of ability, Inclusive Design focuses on increasing or improving the functional capabilities of persons with impairments, as well as persons without.

Therefore, the definition of Inclusive Design and similar fields used throughout this thesis, is the one presented above by Coleman, i.e. *"A process-driven approach by designers and industry to ensure that products and services address the needs of the widest possible consumer base, regardless of age or ability. Emphasis is placed on working with 'critical users' to stretch design briefs."* Furthermore, we emphasize, that the main focus of Inclusive Design and similar fields is highly functional and task-oriented, as is also the case with AT.

2.2 What is Product Experience?

This section will provide a historical overview of the field of Human-Computer Interaction, in order to demonstrate what the concept of Experience is in relation to Human-Computer Interaction, and why it has become one of the main areas of interest within this field. Following this Desmet & Hekkert's Framework of Product Experience is unfolded to give a more concrete definition of experience in relation to Human-Computer Interaction, and to introduce what they call The Three Types of Product Experience.

2.2.1 A Historical Overview of the Field of Human-Computer Interaction

Human-Computer Interaction (Henceforth referred to as HCI) is a field of research, that is concerned, as the name suggests, with the interaction that occurs between humans and computers [12]. There is a general consensus within the HCI community, that the field of HCI has gone through three phases, commonly referred to as waves, paradigms or eras (hereafter referred to as waves), since its emergence in the early 1980's [26, 12, 8, 47, 9]. Each of these waves represents a shift in, what Harrison et al. [26] refers to as centers and margins. In their terminology centers refer to what is currently at the center of HCI research, and margins refers to what is marginalized as a result of the shift in centers. The primary shifts in centers from wave to wave, revolves around the users that interact, the purpose of interaction, and the contexts and devices in which, and on which, the interaction takes place [26, 12, 8, 47, 39].

The First Wave of Human-Computer Interaction

In the 1970's the only users of computers were information technology professionals and dedicated hobbyists, but the advent of personal computing in the late 1970's, allowed for everyone to be a potential user of computing technology [12]. This necessitated a more 'user-friendly' way of interacting with computers than the previously used command line interface, and thus the field of HCI was born in the early 1980's [12, 39, 5].

Initially HCI was a specialty area within computer science, embracing cognitive science and human factors engineering [12]. This wave of HCI was primarily concerned with what Harrison et al. [26] call Man-Machine Coupling, and the goal of work within this wave was to optimize the fit between humans and machines. Though the advent of personal computing allowed for everyone to be a potential user of computing technology, the bulk of computer users were still workers, and most systems were productivity applications such as text editors and spreadsheets designed for use at the desktop [12]. Much of the work within HCI was therefore oriented towards optimizing the workflow between the user and the system. One of the ways in which this was done was by creating and using mental models and rigid guidelines to design interfaces, that would make it easy for the user to both learn, use, and remember the interface [12].

Figure 4. The Xerox 8010 Information System (Xerox Star) is an example of first wave HCI, featuring the first commercially available GUI operating system [48, p. 55-57].

The Second Wave of Human-Computer Interaction

The transition from the first to the second wave in the late 1980's, is characterized by Bannon as "From human factors to human actors". In his article Bannon [5] criticizes the first wave of HCI for being too system-centric and portraying the user as naive or stupid, and just another component in the system. There are different opinions as to what makes up the specific centers and margins of the second wave [26, 8], but the most widespread view seems to be that identified by Bannon [5] and agreed upon by Bødker [9, 8]. In this view, HCI was still focused on the workplace, but both the way in which the user was viewed, and the interactions and activities that were in focus at the workplace, were dramatically different compared to the first wave [5]. Firstly, the user was no longer seen as a naive component in the system, but rather as a competent practitioner, who should be actively involved throughout an iterative design process. Secondly the messy context of multi-tasking and both work related and non-work related social interactions, that take place within a work-setting, should be taken into account in the design of a system. Thirdly the focus from the first wave, on interaction between a single person and a single computer, was broadened to incorporate other constellations of interacting agents, thereby supporting the notions of cooperation and coordination through computing. Finally there was a push for research to be dragged out of the laboratory, and into the environment wherein the technology was being used [5]. This included mostly abandoning the rigid guidelines and formalized methods used throughout the first wave, for proactive methods such as a variety of participatory design workshops, prototyping and contextual inquiries [8].

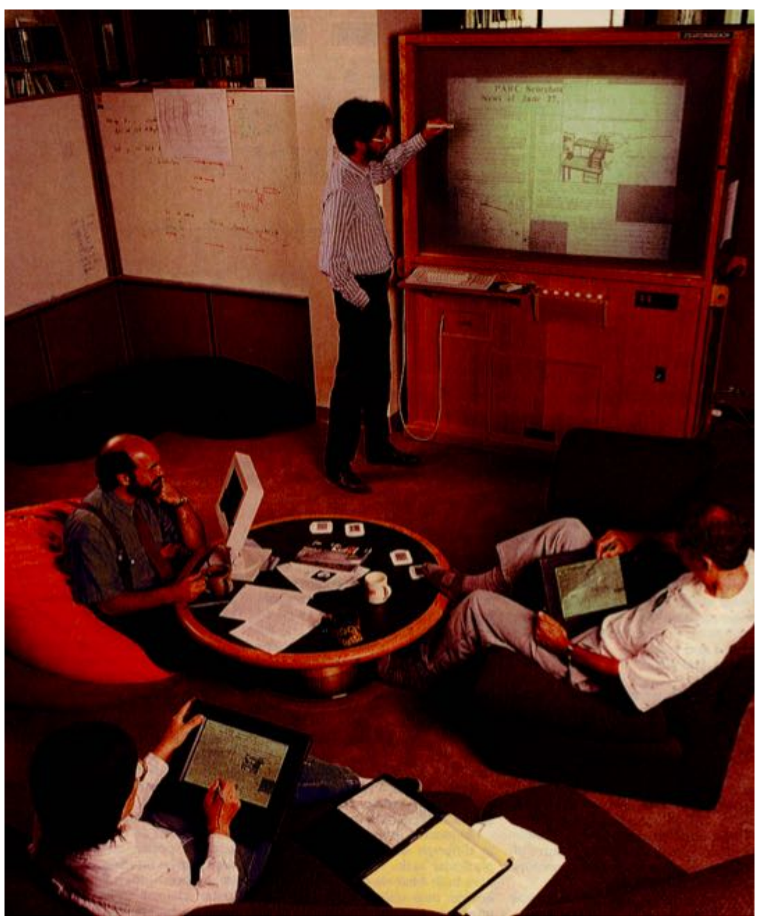

Figure 5. Mark Weiser's Tabs, Pads and Boards, an early CSCW tool, is an example of second wave HCl [56].

The Third Wave of Human-Computer Interaction

As the computing devices began increasingly being used in the private and public spheres in the 1990's [39], new aspects of human life were included in the field of HCI, which led to the third wave [8, 39]. The opinions regarding the specific shifts in centers and margins of the third wave are divided, but some areas of focus are agreed upon; as computers were no longer solely work machines, aspects of human life such as aesthetics, emotion and experience became areas of focus within HCI. As Bødker describes it:

"the focus of the third wave, to some extent, seems to be defined in terms of what the second wave is not: non-work, non-purposeful, non-rational, etc. Conceptually and theoretically, the third wave HCI focuses on the cultural level (e.g. through aesthetics, expansion of the cognitive to the emotional, or a pragmatic/cultural-historical focus on experience)" [8, p. 1-2].

These new areas of focus within the field, known collectively as Experience, necessitated new methodological approaches, that would allow researchers to more deeply understand the users, beyond the tasks they are trying to accomplish, and the patterns of actions they execute to do so. In relation to this Bødker highlights Cultural Probes, as a way for designers to seek inspiration from use [8, p. 2].

Figure 6. As an example of third wave HCI, Aarhus by Light, was a social experiment with an interactive media facade at the Concert Hall in Aarhus, Denmark [13].

Since the introduction of the third wave of HCI, a lot of research has been done within the area of Experience [18, 39, 63, 9, 12, 8, 14, 29, 17, 13]. One example can be seen in Figure 6.

Much of this research is grounded in McCarthy & Wright's thoughts on technology as an experience [39], in which they define the Four Threads of Experience. These are (1) The Sensual Thread, (2) The Emotional Thread, (3) The Compositional Thread and (4) The Spatio-Temporal Thread. The Sensual Thread states, that if technology can stimulate the senses of the users properly, the barrier between user and technology could be broken down completely. The Emotional Thread states, that depending on the individual user, a range of emotions based on the socio-cultural background of said user, will be playing a role in how the technology is experienced. This means that different users might experience the technology differently. The Compositional Thread revolves around the aesthetics of the experience:

"When we are immersed in experience, the elements of experience so interpenetrate each other that we lose our sense of the separation of self, objects and events." [39, p. 90-91]

McCarthy & Wright describes this as an aesthetic experience, an experience that you lose yourself in, and an experience that stands out from the ordinary everyday experiences. This immersion is dependent on the first and the second thread, which in turn means that the level of immersion can differ from user to user. The immersion described in The Compositional Thread leads on to the last thread, the Spatio-Temporal Thread, which describes how the user might completely lose sense of time and place, when he or she is immersed in the experience. These threads represent only a small part of the reflections of McCarthy & Wright, but they provide a brief perspective on how to perceive the experience related to technology. In short, these four threads can be used to get a basic understanding of the completely immersive aesthetic experience with technology, that breaks down barriers between user and technology, while also completely changing the user's perception of time and place, creating an experience that stands out from the prosaic experiences of everyday life.

While McCarthy & Wright provide an overview of what an experience with technology can be, they do not provide specific design guidelines. Many researchers address experiences with technology, but few suggest concrete frameworks or guidelines to design for these. Therefore, we looked to Desmet & Hekkert, who, in their well-cited article Framework of Product Experience [18], describe how the previously mentioned research in the field, has led to a *multitude of experiential concepts that, to some extent, differ in terms of described affective phenomena, theoretical backgrounds, research purposes, and design possibilities* [18, p. 57]. The purpose of this article is to create a *general framework of product experience that provides a structure that facilitates comparisons between experiential concepts* [18, p. 57]. Therefore we have chosen to base our work with experience on their framework [18], and use it as a starting point for our design process.

2.2.2 Product Experience

In their paper, Framework of Product Experience, Desmet & Hekkert define Product Experience (Henceforth referred to as PE) as *a change in core affect that is attributed to human-product interaction* [18, p. 59]. In this definition, core affect refers to core affect theory introduced by Russell [18] in 1980, describing the combined experience of affect and physiological arousal. He moves on to describe that PE can be categorized into three different types: Experience of Meaning, Aesthetic Experience and Emotional Experience. Desmet & Hekkert then refine their definition of PE to include the three types as follows:

"[PE is] the entire set of affects that is elicited by the interaction between a user and a product, including the degree to which all our senses are gratified (aesthetic experience), the meanings we attach to the product (experience of meaning) and the feelings and emotions that are elicited (emotional experience)"[18, p. 59]

These three types of PE are then exemplified, through the following story:

"One of the authors recently purchased a Chinese teacup during a visit to China. An example of an aesthetic experience is the enjoyment he experiences from hearing the sound produced by the fragile porcelain lid when it is placed on the mug. He is attached to the cup, because it is a memento that represents his visit to China, in which the attachment is an experience of meaning. An example of the third level of product experience, that is, an emotional experience, is the satisfaction he experienced when he found that the size of the cup perfectly matches his tea drinking needs."[18, p. 59]

To elaborate on the story, Aesthetic Experience relates to the perceptual experience, in this example the sound the cup produces, but could also be the visual appearance. Experience of Meaning is here exemplified with his attachment to the cup, because it is a memento from a visit to China, but is generally related to the meanings that are attached to products, for example metaphors can be used to create Experience of Meaning. Emotional Experience closely relates to the demands and requirements we have to products. In the example he is satisfied by the amount of liquid the cup can contain, but it can also be an Emotional Experience to be happy about a low price on a well functioning product.

The specific use of PE in this thesis, is unfolded during the description of the Design Process, with references and explanations from the underlying literature.

2.3 Relevance of Introducing a Focus on Product Experience when Designing for Users with Impairments

As can be seen from the description of the field of HCI and PE, in relation to the description of how designs for users with impairments are done now, there is a clear difference. It seems that AT and Inclusive Design are stuck in the early waves of HCI, with little to no thought of Product Experience in the design process. The purposes of AT and Inclusive Design seem to be mainly, if not only, functional, even though the arguments for focusing on PE in the field of HCI, i.e. computing devices increasingly being used in the public and private spheres, are just as applicable for AT as they are for HCI in general. As the fields were reviewed, some related work revolving around the same thoughts as this thesis addresses, were found.

Hedvall has written an explorative paper on how accessibility in general (i.e. AT, Inclusive Design etc.) has not evolved in the same tempo as the field of HCI [28]. He presents the three phases, or waves, of the HCI field and argues that accessibility is stuck in the first wave. Hedvall writes that accessibility is currently based on a view of technology and of human beings that was more relevant 25 years ago than it is today. According to Hedvall's interpretation of the first wave and accessibility, accessibility is still based on the large-scale, predictability and rule management of the first wave. To Hedvall, this means that, in current accessibility research, the individual (i.e. the user with impairments) is an un-situated passive robot without desires or idiosyncratic whims. He suggests that the accessibility field should move on to a 'version 2.0', which can be done through inspiration from the newer waves of HCI. Hedvall squeezes several related fields together, e.g. ubiquitous computing, tangible interaction, augmented reality, pervasive computing, enactive computing, etc., under his umbrella term Mixed Reality. He argues that it is important, that researchers and designers draw inspiration from HCI and move accessibility into the second and third waves, with the coming of the Era of Mixed Reality. This is because the lifeworld of users becomes entangled with technology, and the holistic view of the later waves of HCI can help accessibility fit into this world.

Like Hedvall, Frauenberger questions the ability of AT to consider all parts of the lifeworld of the user [22]. He asks if it, as of now, can consider the physical, the biological, the psychological, the psychosocial and emotional, the socio-economic, the cultural and the normative at the same time in meaningful ways. He continues by arguing that the increasing pervasiveness of technologies, means that it consequently becomes more difficult to solve an isolated problem, as its solution always interacts with many other aspects of our life. He argues that the problem lies in the biological determinism and social constructionist societal views on disabilities and users with impairments. Instead, researchers and designers should look to a critical realist perspective, which takes the whole lifeworld of the user into perspective, and which succeeds at breaking down the stigmatizing barriers of AT design, in contrast to the previous views.

Additionally, Frauenberger suggests that the third wave of HCI is appropriate in the critical realist perspective, as it recognizes the need for a situated value driven and participatory approach. In the third wave, he more specifically suggests User-Sensitive Inclusive Design as the closest approach embodying a critical realist agenda. Especially the strong emphasis on Participatory Design, which makes the designers consider the whole person, not simply their physical characteristics, gives User-Sensitive Inclusive Design credibility as a critical realist approach. He concludes his paper with the project Outside the Box, in which he tested his claims about the critical realist perspective and the need for third wave HCI with Participatory Design. By conducting a design process strongly influenced by Participatory Design, in cooperation with autistic children, he claims to have achieved a design process that does not reduce the users to what they struggle with, but a process that instead takes their every need and wellbeing into consideration.

While reviewing the field, no immediate examples of research that is specifically trying to bring AT or Inclusive Design into the later waves of HCI was found, besides the example of Outside the Box by Frauenberger. An example of research investigating how the use of technology in the form of a robot could be emotionally beneficial to people in a nursing home, was found. The research was not specifically directed towards investigating how the later waves of HCI could be transferred to AT and Inclusive Design, but it gives a hint of what could potentially be achieved, if done so.

This indirect research was conducted by Wada et al. [55] over a period of a few years, and it investigated how an interactive seal robot can be emotionally beneficial to people. They mention animal-assisted therapy (AAT), as having three documented positive effects on people: (1) Psychological effect (e.g. relaxation, motivation), (2) Physiological effect (e.g. improvement of vital signs) and (3) Social effect (e.g. stimulation of communication among patients and caregivers). The goal of their research is to investigate whether these qualities can be translated into Robot-assisted Therapy (RAT), which is meant as a hygienic way of bringing AAT into hospitals and nursing homes. To conduct their investigations, they introduced the robot seal Paro in a nursing home, which over time showed radical improvements in the mental and physical states of the elderly. In another instance, Paro seemed to have an improving effect for young people with autism. A nurse said that Paro had a rehabilitative function as well as a mental effect, on the children. They conclude the paper by saying that interaction with Paro improved the mood of users, while even countering depression.

To sum up this chapter, there seems to be a wish and need to move AT and Inclusive Design towards a more modern HCI view. Though this wish is relatively new and unexplored, there is research that touches upon the wish for a focus on PE in technology designed for vulnerable users. This wish and need is why we deem further research in this specific field, and the research of this thesis, relevant.

Chapter 3

Understanding the Context

This section will provide contextual insight into the institution where the evaluations for this thesis were conducted, the AT Touch & Play, and the users with whom the prototypes were evaluated. Furthermore, this section will provide a brief introduction to the pilot study, conducted as a precursor to this thesis, as well as the main findings from that study. The information presented in this chapter was obtained through a combination of findings uncovered during the pilot study, and a PACT analysis [7, p. 26-49], conducted as part of this thesis. The full PACT analysis can be found in the appendix.

3.1 The STU Center

An STU Center is a learning institution offering a youth education known in Denmark as an STU (Særligt Tilrettelagt Ungdomsuddannelse), which translates to Specially Planned Youth Education. An STU is an education, that is specifically structured to fit with each individual's personal wishes and capabilities. STU's are offered to youths with special needs, such as youths with severe motor disabilities, youths who are multi-handicapped, youths with autism or youths with ADHD. The duration of an STU is calculated to be three years, but can be extended by up to two years. Furthermore an individual enrolling in an STU must have finished 9 years of school and be below 25 years of age [42].

The specific STU Center, around which this thesis revolves (throughout this thesis referred to as the STU Center), is divided into three different sections. The section of the STU Center with whom we collaborated, in both the pilot study and this thesis, is attended by the students with the most severe degree of impairment.

At the STU Center, the Touch & Play interface is located in an approximately 40 square meter room used both as a classroom and a common area. This means that the environment is used for social activities, and can often be quite noisy.

3.2 Touch & Play at the STU Center

Touch & Play was originally designed in response to a request from a group of Danish municipalities, that wanted a large touchscreen interface, that could handle some scrapes, bumps and hits. This resulted in a touch-screen interface, that uses infrared light to detect touch, and a tailorable GUI [58] that contains a number of applications designed to stimulate both physical and mental faculties through games, images, movieclips and music. At the STU Center, Touch & Play is run as a web application in the Google Chrome web browser, on a 110 inch screen, as seen in Figure 7. Furthermore it is run on a NUC (Next Unit of Computing) [60] with Windows 8 as an operating system.

Figure 7. The Touch & Play system in situ at the STU Center. A researcher is included in the photo, to give a sense of scale. Furthermore, a guitar can be seen to the left of Touch & Play, which is one of many instruments in the classroom.

The applications, as explained by the project manager during the interview, are developed by Applikator based on their "Three S"-concept; The applications should be "Sunde, Sociale og Sjove", which translates to "Healthy, Social and Fun". Some of the applications also give access to external websites, for example a video-application that plays videos from YouTube. The Touch & Play GUI features customizable profiles for each user, and allows administrators in the system, this normally being the staff at the center or the school, to allow or remove access to certain applications in the system.

Touch & Play was designed and built with two very different user groups in mind. One of the user groups is users with impairments, and the other is elderly users. This resulted in Applikator developing the hard- and software for Touch & Play as one product, but with two different objectives: Development and Settlement (From Danish: Udvikling og Afvikling). Development was targeted at users with impairments, who should evolve and learn when using the system; and Settlement was for the elderly, who should have a system that allows them to be social, share memories and watch videos, without the need for elements of learning. The abovementioned information was gathered from the background interview with the project manager from Applikator, and can also be found transcribed in the appendix.

As the STU Center is a learning institution for youths with special needs, the objective of Touch & Play at the STU Center is Development. According to the employees, Touch & Play is officially used as a tool to teach communication and motor skills at the STU Center. This is done in sessions of approximately 45 minutes, where three students interact with Touch & Play, and one or two employees facilitate the interaction. In these sessions, the students take turns choosing and engaging with one of the applications, while the others spectate. When a student cannot interact with the system by themselves, the employees function as intermediaries, interacting with the system on the student's behalf.

As previously mentioned, Touch & Play contains a number of applications used to play games, display images, watch movieclips and listen to music. At the STU Center, the applications most used are games and a video-application that plays videos from YouTube. The games used are primarily cognitively or physically demanding. The cognitively demanding games are games such as puzzles or memory-type games where the students have to match, for example, a sound with a specific animal. Examples of physically demanding games are a balloon-popping game, a game of target shooting, that resembles darts, and a game in which the goal is to click on a mouse that pops up in different places on the screen. Throughout the observation sessions at the STU Center, it was observed that more than half of each session was spent using the video-application to watch music videos. Furthermore, at the first observation at the STU Center in the pilot study, it was observed that a lot of different applications were used. As the study progressed, and more observations were conducted, the amount of applications used grew smaller, and the amount of music videos watched grew larger.

Another important function of Touch & Play at the STU Center is its use during their morning gatherings, in which students would share something they had experienced since the day before. This was usually done by sharing pictures, videos or stories about their experience, often using an employee or a family member as a mediator.

3.3 The Users of Touch & Play at the STU Center

Below is a list, provided by the STU Center, of the students in the section that have agreed to participate in this study, and what they have been diagnosed with. The provided list did not include specific ages, but all students are within the age limits of an STU education. In the timespan between our pilot study and this thesis, one student who participated in the pilot study graduated, and a new student enrolled in the STU Center and agreed to participate in the study. The student who graduated between the pilot study and the thesis will, in Figure 8 be denoted Student X, and the new student denoted Student 5.

Student	Diagnosis
Student 1	Diagnosed with moderate to severe retardation of unknown origin. Student 1 can only say very few words, and usually communicates by making sounds, gestures or by pointing. Student 1 uses a wheelchair when he has to cover greater distances, and he has trouble with fine motor skills.
Student 2	Diagnosed with Cerebral Palsy and a general mental retardation. Student 2 can communicate "yes" and "no" with his eyes. Student 2 is bound to a wheelchair and needs assistance in all daily tasks.
Student 3	Diagnosed with Spastic Tetraplegic Cerebral Palsy and Microcephaly. Student 3 communicates using sounds, facial expressions and body language. Student 3 is bound to a wheelchair, and has widespread paralysis and contractures in both upper- and lower extremities.
Student 4	Diagnosed with Down Syndrome and an innate brain deformity resulting in severe mental retardation and decreased vision. Student 4 communicates by making sounds and can use a limited vocabulary. Student 4 is able to walk, but has trouble with fine motor skills.
Student 5	Diagnosed with Down Syndrome. Student 5 communicates using a small amount of verbal language and understands short and simple sentences. Student 5 is fully mobile with relatively well developed fine motor skills.
Student X	Diagnosed with general retardation of unknown origin, Epilepsy, and Spastic Diplegia with varying tonus and weakness of the lower extremities. Student X communicates using a limited vocabulary, sounds, gestures and facial expressions and by pointing. Student X is bound to a wheelchair and has trouble with fine motor skills.

Figure 8. The Students and their diagnoses.

All of the students have cognitive impairments, a very limited attention span, and very limited communication skills. Furthermore, apart from Student 5, all of the abovementioned students have trouble with fine motor skills and some degree of physical impairment, mostly in terms of mobility. Finally, based on findings from navigating menus in a GUI and observing a game similar to "Memory", the students seem to have below average memory.

3.4 The Pilot Study

The pilot study functioned as a precursor to this thesis, and revolved around the same Assistive Technology, institution and students as this thesis does. The purpose of the study was to explore which challenges the students faced, when interacting with Touch & Play. This included both collecting data about the context in which Touch & Play was used, including the STU Center, the students, and Touch & Play itself, and observing the users interacting with Touch & Play, to uncover specific elements of the interaction in which the students struggled. Furthermore, as neither of the researchers had any experience with working with users with impairments, another goal of the study was to investigate which methods were most effective for empirical data gathering and evaluation with this particular user group.

The study was initiated with an initial data gathering phase, focusing primarily on gathering information about the context in which Touch & Play was used. This was followed by a series of increasingly more passive observations, which were also video recorded, in order to uncover which challenges the students faced when interacting with Touch & Play. The reason for making the observations increasingly more passive was to investigate the Hawthorne effect [48, p. 641] in relation to these particular users i.e. the effect visible presence of researchers and video recording equipment had on the students and employees. This was done in order to evaluate which method would be most suitable for empirical data gathering and evaluation with this particular user group. Finally a Cultural Probe study was conducted with the employees, using disposable cameras, in order to gain insight into the students' interaction with Touch & Play, as seen through the eyes of the employees.

The result of the study was a series of findings in relation to both which methodological approaches would be most effective with this group of users, and which challenges the students faced when using Touch & Play. In relation to methodological approaches, the main findings were that the students were easily distracted by the presence of researchers and visible videorecording equipment, but that the Hawthorne effect could be substantially diminished by using non-noticeable videorecording equipment, and having no researchers present during the sessions. Furthermore, as the students have very limited communicative skills, a large part of the empirical data collected during the study was based on expert accounts from the employees at the STU Center. This strategy of data gathering seemed highly viable with regards to both additional data gathering, as well as evaluation with this particular user group.

In relation to empirical findings regarding which challenges the students faced, when interacting with Touch & Play, the findings are divided into two categories; practical challenges and experiential findings. The practical challenges, are functional complications that arise in the interaction with the interface, on account of the students' impairments. The two main practical challenges uncovered during the pilot study were:

1. Due to most of the students either being bound to a wheelchair or having limited gross motor skills, the dimensions and vertical position of the touchscreen, made it difficult or impossible for the students to use it by themselves
2. Due to limited fine motor skills, the students had a tendency to navigate to unwanted parts of the interface, due to multiple unintentional taps

In relation to the first of these challenges, the students and employees at the STU Center, had attempted to create a workaround to solve this problem, in the form of a foam rod that could be used when attempting to reach the top part of the screen. This workaround did reduce the problem slightly, but did not eliminate it completely. A photo of the foam rod used as a workaround can be seen in figure 9.

Figure 9. The foam rod used as a workaround to alleviate one of the practical challenges the students faced, when interacting with Touch & Play.

The second genre, experiential findings, relates to the students' and the employees' experience when using the interface. Through our interviews with the employees, our observations of the interaction with Touch & Play, and the Cultural Probe study conducted with the employees, we found a mismatch between the official reason for using Touch & Play at the STU Center, and the actual utilization, and reasoning of the employees. What the employees and students found to be the most attractive qualities of Touch & Play, was not its capacity to facilitate teaching of communication and motor skills, but instead: (1) that it helps the students feel included, (2) that it strengthens the social relationships between the students, and (3) that it allows them to feel heard.

Chapter 4

Designing the Assistive Technology Prototypes

This chapter describes the process of designing both the traditional AT prototype, and the PE inspired AT prototype. First the methodology with which the two prototypes are designed is described, drawing inspiration from related work, as well as findings from the pilot study. Afterwards, the specific usability challenge chosen to address with the two prototypes is presented along with a specification of the requirements for the two prototypes, based on the challenge chosen as well as the specific context in which the prototypes are to be used. Finally, the design processes for both prototypes are presented along with the reasoning behind the design decisions.

4.1 Design Methodology for the Developed Assistive Technology Prototypes

This section will present the design methodology chosen for the two developed prototypes. First, the traditional way of conducting an Assistive Technology design process, e.g. User-Centered Design, is presented. Afterwards, the concepts of ethnography and ethnomethodology are unfolded, as these are normally used to include users in a User-Centered Design process. Furthermore, potential strengths and weaknesses of using ethnography and ethnomethodology in relation to our user group will be discussed. Finally, the appropriated methodology, chosen for the two prototypes developed for this thesis, is described, based on the two previous sections.

As previously mentioned, redesigning the entire Touch & Play touch input functionality to follow the ideology, ethics and guidelines of Inclusive Design is not within the scope of this thesis, nor is it in the interest of the company Applikator. Furthermore, since the specific usability challenge chosen is entirely based on observed needs for these specific users, in this specific context, building tailored input devices was deemed the most appropriate approach. Since this approach means building devices made especially for these students, the prototypes will be Assistive Technologies, and therefore the design methodologies will be presented in regards to AT.

4.1.1 User-Centered Design in an Assistive Technology Design Process

As previously mentioned, User-Centered Design is considered to be the best design methodology, when designing AT. Abras et al. describe User-Centered Design (henceforth UCD) as *"a broad term to describe design processes in which end-users influence how a design takes shape"* [1, p. 1]. They argue that there is a range of ways the user can help shape the design, but the primary focus should be, that the users are somehow involved. This involvement can vary from being a part of gathering requirements, to being an active part of the design development, throughout the entire process. Figure 10 suggests possible ways to include users in the design process, and indicates at which stage of the process, the method should be used.

Technique	Purpose	Stage of the Design Cycle
Background Interviews and questionnaires	Collecting data related to the needs and expectations of users; evaluation of design alternatives, prototypes and the final artifact	At the beginning of the design project
Sequence of work interviews and questionnaires	Collecting data related to the sequence of work to be performed with the artifact	Early in the design cycle
Focus groups	Include a wide range of stakeholders to discuss issues and requirements	Early in the design cycle
On-site observation	Collecting information concerning the environment in which the artifact will be used	Early in the design cycle
Role Playing, walkthroughs, and simulations	Evaluation of alternative designs and gaining additional information about user needs and expectations; prototype evaluation	Early and mid-point in the design cycle
Usability testing	Collecting quantities data related to measurable usability criteria	Final stage of the design cycle
Interviews and questionnaires	Collecting qualitative data related to user satisfaction with the artifact	Final stage of the design cycle

Figure 10. Techniques for User-Centered Design, as presented by Abras et al. [1, p. 5-6]

To get an idea of how to shape the User-Centered process, Abras et al. suggest that the designer considers the seven design principles by Don Norman, shown in Figure 11 [1].

1	Use both knowledge in the world and knowledge in the head. By building conceptual models, write manuals that are easily understood and that are written before the design is implemented.
2	Simplify the structure of tasks. Make sure not to overload the short-term memory, or the long term memory of the user. On average the user is able to remember five things at a time. Make sure the task in consistent and provide mental aids for easy retrieval of information from long-term memory. Make sure the user has control over the task.
3	Make things visible: bridge the gulfs of Execution and Evaluation. The user should be able to figure out the use of an object by seeing the right buttons or devices for executing an operation.
4	Get the mappings right. One way to make things understandable is to use graphics.
5	Exploit the power of constraints, both natural and artificial, in order to give the user the feel that there is one thing to do.
6	Design for error. Plan for any possible error that can be made, this way the user will be allowed the option of recovery from any possible error made.
7	When all else fails, standardize. Create an international standard if something cannot be designed without arbitrary mappings.

Figure 11. Don Norman's seven design principles [1, p. 2-3].

They are not strict principles, and the designer can pick and choose, depending on the user and design case, but they can be seen as a suggestive guideline. Additionally Abras et al. argue that it is necessary to think carefully about who the users are, and how to involve them in the design process. In essence, users are the people who, in some way, will use the final product or artifact to accomplish a task or a goal. Furthermore, Eason [1, p. 4] has identified three types of users: Primary, secondary and tertiary. Primary users are the users who actually utilize the designed artifact. Secondary users will occasionally use the artifact or use it through an intermediary. Tertiary users are users who will be affected by the use of the artifact or make decisions about its purchase. Distinguishing between primary and secondary users, is crucial to this project, since communication and interviewing of the primary user is neither viable nor possible. Therefore expert secondary users, the employees, have been interviewed after the testing sessions of the two prototypes. Due to physical limitations of the primary users, the secondary and primary users occasionally swap types. The secondary users thereby, as mediators, become primary users, making their experience and account an important factor.

Depending on what needs have been identified for each type, the users can then be included in whatever part of the process the designers see fit. To include users in the design process, this project utilizes both ethnography and ethnomethodology, which will be elaborated later in this section.

When research involves users in the design process, it means incorporating specific techniques to identify the users, and to get an overview of, and be able to appropriate experiences with, an existing system. This presents some challenges for researchers when working with users with specific impairments such as cognitive, auditory, visual or speech impairments, or a combination of these, as these types of impairments can make it difficult to communicate with the user. Communicating directly with the users in this thesis is not only difficult, if not impossible, but also discouraged by the staff at the STU Center. Therefore, to involve the users in this project, a tailored UCD-inspired methodology was developed, and the following sections describe the different elements of methodologies chosen.

4.1.2 Empirical Methodology based on Ethnography and Ethnomethodology

The following section different branches of methodologies which can be used to incorporate User-Centered Design when designing AT. In the end of this section, our own appropriated methodology is introduced, and arguments for a methodology using aspects of both ethnography and ethnomethodology are presented.

Ethnography

Ethnography is a social research field, drawing on multiple sources of information. The emergence of ethnography marked a major transition in how other cultures are investigated and understood. It shifted from the anthropological understanding of what members of other cultures do, to understanding, through participation in and observation of their daily life, what members of those cultures experience through their actions [63]. The main goal for an ethnographer is to participate in people's daily lives, in order to collect the necessary data needed to shed light on the issues the observed individuals experience [25].

Ethnography is neither a framework nor a specific set of guidelines. Many ethnographers use their own set of specific methods in order to appropriate the thoughts and experiences of the studied subjects [25].

Ethnomethodology

Ethnomethodology is a qualitative research tradition, that has intellectual roots deeply inspired by Alfred Schütz' Social Phenomenology [20, p. 665]. The ethnomethodological focus, much like other qualitative research methodologies, is to understand how meaning is made in everyday social contexts. Ethnomethodology furthermore concentrates on investigating how social actors accomplish everyday tasks, situations and practices; therefore the focus is on how social actors act [20]. Heath and Hindmarsh, quoting Harold Garfinkel, argue that what is rejected in ethnomethodology is *"admittance into analysis of information not obtained through close observation of the 'objective reality of social facts as an ongoing accomplishment of the concerted activities of daily life'"* [20, p. 663]. This closeness deeply relies on a detached analytic stance. Christian Heath therefore pioneered the use of observations through video recordings as the primary method of gathering empirical data, with interviews and documents as the main method for collecting background information. One advantage of video recordings is that researchers are able to review the sessions multiple times, for different stages of analysis. This way of gathering empirical data allows the researcher to, as unobtrusively as possible, observe and do situated analysis based on the video recordings [20, p. 666]. After the observations are recorded, the analytic technique consists of reviewing "key incident" candidate sequences, that include instances or fragments of talk or action, then identifying patterns, regularities and deviant cases based on the candidate sequences. It is argued that this methodology will result in an objective picture of communication and action, in regards to specific tasks and everyday practices [20, p. 666].

4.1.3 Appropriated Methodology for This Thesis

When working with technology made for the user group of this thesis, users with severe cognitive and motor impairments, direct communication with the primary user can be difficult, if not impossible. Therefore strictly following one research methodology and/or tradition can be problematic. The abovementioned branches of methodologies, however, all include aspects which are beneficial to doing empirical and evaluative work with this particular user group. Ethnographic methods will be used throughout our work, with experts within the field of working with people with impairments, namely the employees at the STU Center. The employees are a big part of the students' everyday lives, and often function as mediators for them. Dourish argues that there can be tension between conceptualizing and empathizing in ethnography [63, p. 640], therefore it is probable that we, as researchers, will never be able to fully understand the user. The employees at the STU center were keen to let us know, during the pilot study [36], that their experience and familiarity with the students was attained over a long time. The employees will therefore be crucial to evaluation, where they will be able to perceive and grasp how the student feels about an experience, based on their extensive knowledge about the individual.

During our pilot study an investigation of the Hawthorne effect [48, p. 641], the alteration of behaviour by the subjects of a study due to their awareness of being observed, on this particular user group was conducted [36], as previously mentioned. The results indicated that for empirical work, the ethnomethodological approach of unobtrusive video observation was the best way to gather empirical data and observe the lives of the users, due to the fact that visible cameras or researchers distracted the users. This approach was also strived for during the evaluations of this thesis. To further evaluate the prototypes developed, video analysis [27, p. 61-85] was used to analyze certain themes and patterns in the interaction. Furthermore, all evaluations were followed up with interviews with the employees. The objective of the interviews was to learn more about the employees' reflections on, as well as the students' appropriation of, the prototypes.

4.2 Usability Challenge Chosen for the Prototypes

In order to support a comparative analysis of the two prototypes designed for this thesis, the functionality of the prototypes should be equivalent. Therefore we have chosen one of the two practical challenges found during the pilot study, which both the traditional AT prototype and the PE inspired AT prototype, will attempt to overcome.

The two uncovered practical challenges made it difficult for the students to interact with Touch & Play, on account of their impairments. These two challenges were, as previously mentioned:

1. Due to most of the students either being bound to a wheelchair or having limited gross motor skills, the dimensions and vertical position of the touchscreen made it difficult or impossible for the students to use it by themselves.
2. Due to limited fine motor skills, the students had a tendency to navigate to unwanted parts of the interface, due to multiple unintentional taps.

Both of these challenges are potential candidates for the prototypes developed for this thesis. The second challenge could, however, be overcome by making changes to the existing Touch & Play interface; either tweaking the sensitivity of the touch screen, or adding a delay after a tap. Furthermore, as the students and employees have attempted to overcome the first challenge by using a workaround in the form of a foam rod, the first challenge seems more important to the students and employees at the STU Center. Therefore we have chosen to focus on the first challenge. This challenge will henceforth be referred to as *the usability challenge*.

To overcome the usability challenge, the developed prototypes should allow a user the same functionality as the touch screen does, which is moving the cursor and left-clicking (the Touch & Play interface does not allow for right-click). Furthermore, as the dimensions and vertical position of the touch screen made it difficult for the students to interact with the interface, the prototype should be usable from a seated position. Finally, as all of the students have very limited fine motor skills, the prototype should require as little manual dexterity as possible.

Apart from the above, some requirements arise on account of the context in which the prototypes are to be used. Firstly, the employees explicitly stated, during a conversation that unfortunately was not recorded, that they would prefer if nothing was mounted on the students. Furthermore the prototypes are to be used in a social, turn-taking setting, and would therefore have to be usable by all participants, without the need for time demanding calibration.

The abovementioned requirements will be used as the offset for both prototypes and are clarified in Figure 12:

Minimal requirements for prototypes

1. The prototype should allow for movement of the cursor and left-clicking
2. The prototype should be usable from a seated position
3. The prototype should require as little manual dexterity as possible
4. The prototype should not require being mounted on the user
5. The prototype should be readily usable without calibration

Figure 12. Minimal requirements for both prototypes, based on the usability challenge chosen, and the context wherein the prototypes are to be used.

4.3 Designing the Traditional Assistive Technology Prototype

This section will present the design process for the traditional AT prototype. First the process leading to the concept chosen for the traditional AT design process is presented. Following this the testing sessions for the first and the second iteration of the prototype, as well as preliminary findings, are presented.

4.3.1 The First Iteration of the Traditional Assistive Technology Prototype

The list of requirements presented in the previous section excludes many different types of Assistive Technologies. Taking the types of Assistive Technologies mentioned in section 2.1 as examples, the LF-ASD Brain Computer Interface [38, 10] would require that the prototype was mounted on the students, the Camera Mouse [24] and voice recognition [21] would require calibration for each individual student and EdgeWrite [62] would not allow for manipulation of the cursor. Instead we decided to build an input device that could be operated by hand from a seated position. Using a regular computer mouse or a joystick would require too much manual dexterity from the students, which led us to using easily activatable buttons as input. There are a number of Assistive Technologies already on the market, that function as computer mice and use buttons as input, so instead of reinventing the wheel with an entirely new prototype, we used the BJOY Button AT [3] as inspiration for our design. To achieve similar fidelity of the two prototypes developed for this thesis, we have chosen to build a prototype with a similar design, instead of simply buying the

BJOY Button AT and using that for the testing sessions. An image of the BJOY Button AT can be seen in figure 13.

Figure 13. On the left is the standard model of BJOY Button AT. The BJOY Button AT is customizable, and a more simple version can be chosen, with less buttons. Unfortunately no images of a simple customized BJOY Button AT were available in high quality. Therefore the sketch on the right has been created by the researchers. Furthermore, the web page on which you customize the BJOY Button AT can be found in the appendix.

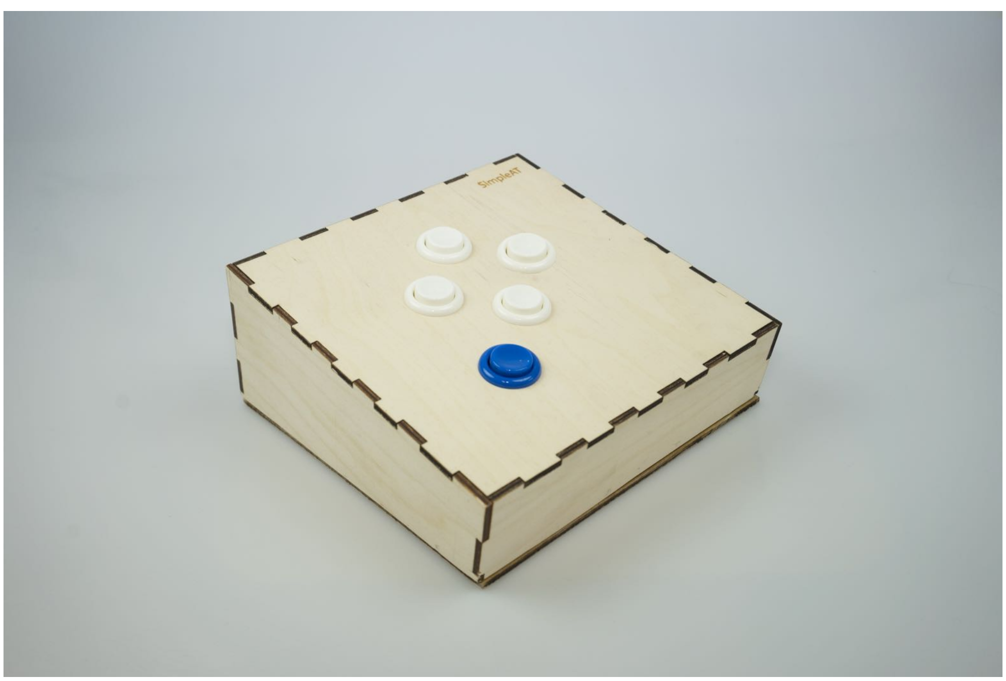

Figure 14. First iteration of the developed AT Prototype. As it can be seen, it is clearly inspired by the BJOY Button shown in Figure 13.

As can be seen from figure 14, the first iteration of the traditional AT prototype was built as a laser-cut [59] wooden box with five buttons on top, used to manipulate the cursor. The wooden box is slightly slanted, such that the buttons are both easily visible and accessible when sitting in front of the prototype. The four white buttons move the cursor in the directions up, down, left and right, and are arranged in a cross, so there is a natural mapping between the placement of the button and the direction to which they are linked. The fifth button represents a left-click, and is blue. The color was chosen to make it stand out from the other buttons, thereby making it clear that it had a different function than the others. The placement of this button was chosen as a combination between inspiration from the BJOY Button AT, and wanting the button to be close enough to the other buttons to be operated using one hand.

The buttons are 35 mm concave momentary pushbuttons, as are also used on the BJOY Button AT, and are connected to a MaKey MaKey [37], in order to make the prototype function as an input device. In essence, a MaKey MaKey is a small prototyping board that is preprogrammed to function as an HID-interface when connected by USB to a computer. The MaKey MaKey features a series of exposed ports that represent buttons on a keyboard, directions for a computer mouse etc., and some exposed ports connected directly to ground. Creating a closed circuit between one of the ports representing for example a button on a keyboard, and a port connected to ground, will make the MaKey MaKey output a keystroke to the computer. This allows the user of a MaKey MaKey to rapidly create prototypes of computer input devices. The electronic components of both the first and the second iteration of the traditional AT prototype can be seen in figure 15.

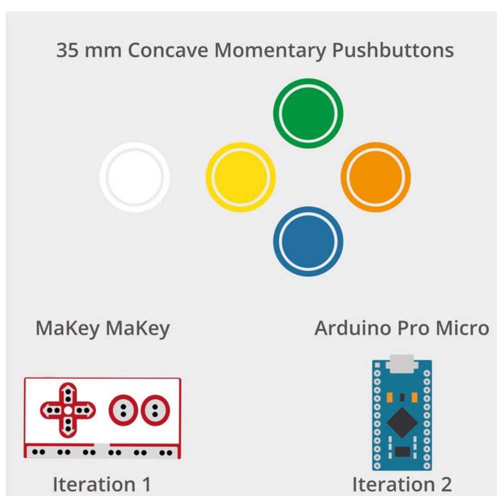

Figure 15. Electronic components in the first and the second iteration of the traditional AT prototype. For simplicity, connections between buttons, and the Arduino or MaKey MaKey, as well as the USB cable connecting the prototype to Touch & Play, are omitted.

A video demonstrating the traditional AT prototype can be found in the appendix.

4.3.2 Testing the First Iteration of the Traditional Assistive Technology Prototype

The first iteration of the traditional AT prototype was tested at the STU Center in a session of 41 minutes involving Student 1, Student 2 and two employees. During the test, three cameras were placed in the room. Two cameras recorded the session from different angles, and one camera livestreamed the session to another room from which two of the three researchers observed. As we have agreed to keep all participants involved in the testing of the prototypes anonymous, none of the videos recorded at the STU Center will be made available. As mentioned, the findings from our pilot study regarding the Hawthorne effect indicate that plainly visible video equipment and researchers have a distracting effect on both employees and students. Despite this, a lack of flexibility in the Touch & Play interface resulted in other applications launching upon the cursor reaching the bottom of the interface, which necessitated a researcher being present to remedy the problem. To be as discreet as possible, the researcher present during the sessions remained quietly in a corner behind the participants, and only interfered when necessary. During this testing session, the applications used were mainly games such as: popping balloons, puzzle games and the "catch the mouse"-game. Music was also a part of this session, but the usage weighed more towards games.

After the session, a semi-structured interview [34, p. 51-66] was conducted with the two attending employees to uncover potential improvements that could be made to the prototype. For this purpose an interview guide was created, which can be found in the appendix.

Through the first test and the interview with the employees, we found some areas in which there was potential for improvement of the prototype. Firstly, there were some issues with the buttons. As the blue button was placed directly beneath the other buttons, resting your arm on the prototype could result in a click on the blue button. Furthermore, the employees would prefer if the buttons linked to the four directions had individual colors, as that would make it easier to instruct the students on which button to press. Secondly, there were some issues with the box itself. During the test, the employees found that the students felt some discomfort when resting their arm on the prototype, as the edges of the box were too sharp. Furthermore, they argued that the effort required by the students to push the buttons could be diminished by slanting the box more. Finally, they felt that the cursor moved too quickly, which made it hard for the students to hit their target.

4.3.3 Second Iteration of the Traditional Assistive Technology Prototype

To amend the issues uncovered during the test of the first iteration, a second iteration of the traditional AT Prototype was built. The second iteration of the prototype can be seen in figure 16.

Figur 16. Second iteration of the developed traditional AT Prototype. As can be seen the edges are now softer, and the buttons are colored.

In relation to the first issue mentioned above, the placement of the buttons was changed, such that the click button was moved to the side of the buttons linked to directions, in order to avoid misclicks. Furthermore, the buttons were all individually colored in four different colors (green, orange, blue and yellow). In relation to the second issue mentioned above, a new box was built with a larger slant and rounded corners and edges. In relation to the problem with the speed of the cursor, the mouse speed preprogrammed into the firmware of the MaKey MaKey is incremental, such that the longer you press one of the direction keys, the faster the mouse will move. Therefore, we replaced the MaKey MaKey with an Arduino Pro Micro [52] programmed to function as a computer mouse with a static movement speed.

4.3.4 Testing the Second Iteration of the Traditional Assistive Technology Prototype

A second test was conducted at the STU Center, using the same procedure as in the first test. This test was conducted in a session of 47 minutes with

Student 1, Student 2, Student 5, and two employees. During this test, the applications used was more of an equal balance between games and music. The games played this time were matching animals with sound, puzzles, and target shooting. In this test, it was observed that the changes made to the prototype, from iteration 1 to iteration 2, alleviated the issues they addressed.

4.4 Designing the Product Experience Inspired Assistive Technology Prototype

In this section, the basis for the design process leading to the PE inspired AT prototype is described. This basis consists of a video analysis and an overview made using an Affinity Diagram [31]. The conducted observations, used for video analysis, are described and the methods chosen for analysis are presented. Afterwards the concept of Affinity Diagrams are presented, followed by our usage and findings. Lastly, the general patterns and key points of the findings are presented.

As the three types of PE are (1) Aesthetic Experience, (2) Emotional Experience, and (3) Experience of Meaning, a deep understanding and analysis of the students' preferences and culture is required, in order to tailor the PE inspired AT prototype to include these. To achieve this understanding, a video analysis of multiple sessions of regular use of Touch & Play was conducted, and an overview of the themes, phenomena and criteria was made using an Affinity Diagram, which is a tool used to group the abovementioned elements [31].

This analysis is then followed up by the actual design of the prototype, a description of the prototype and a brief presentation of two testing sessions.

4.4.1 Conducted Video Observations

Observations of the students interacting directly with Touch & Play were used in this context to learn about the nature of the students' interactions and the context in which they are performed [48, p. 321]. For these observations we utilized video cameras to capture recordings of the sessions, which, as previously mentioned, is highly utilized in ethnomethodology. These recordings, as mentioned in section 4.1, allow multiple reviews for different video analytical stages. The video observations analyzed in this thesis were conducted during our pilot study, in preparation for this thesis. During the pilot study, approximately 135 minutes of video footage from observations at the STU Center was recorded. All of the observed sessions featured three students and two employees who used Touch & Play throughout the session on communication and motor skills. All students were present during at least one of the sessions.

4.4.2 Reviewing the Raw Video

To structure and analyze the content of our video observations, we followed the ethnomethodological approach to video analysis of Heath et al. [27, p. 61-85]. This methodology uses a preliminary review to catalogue the data corpus, followed by a substantive review based on the catalogue. The substantive review focuses on finding instances of events or phenomena, which could enable comparison. After the substantive review, an analytic review of the events and phenomena is conducted, where the data fragments are analyzed in detail with specific themes in mind.

The preliminary review of the data corpus, conducted for this thesis, was focused on cataloguing sequences of actions and interaction types. This allowed us to locate instances of users playing games, listening to music etc. Furthermore, the sequences were labelled with who the main users were, to allow us to find instances of interactions with specific students and do comparisons. A thorough cataloguing was done for each of the recorded videos. An excerpt of the preliminary review can be seen in Figure 17. The full preliminary review can be found in the appendix.

04:00 - 04:27	Employee 1, Student 1	Menus, point and touch	Employee 1 navigates menus. She asks if Student 1 wants the fish gar
04:27 - 04:35	Employee 1, Student 1	Fish game, menus, point and touch	Employee 1 moves the dolphin, and tells Student 1 to do the same whi
04:35 - 04:55	Employee 1, Student 3	Menus, fish game, point and touch	Employee 1 reenters, moves the fish and asks they should move it tow
04:55 - 05:31	Student 2, Employee 1, Employee 2	Fish game, point and touch	Student 2 makes a sound, Employee 1 asks if he wants to move. She
05:31 - 05:39	Employee 1, Student 3, Employee 2	Fish game, point and touch	Employee 1 asks Student 3, if it their turn. She moves the fish towards
05:39 - 06:43	Employee 1, Student 1, Employee 2	Fish game, point and touch	Employee 1 asks Student 1 if he wanna try and he tries. Employee 1 s
06:43 - 07:08	Employee 1, Employee 2, Student 1	Menus, Catch the mouse, point and touch	Employee 2 and Employee 1 navigates menus, Student 1 presses "Ca
07:08 - 07:17	Student 1	Catch the mouse, point and touch	Student 1 correctly catches the mouse three times, looks at camera.
07:17 - 07:59.	Employee 1, Employee 2, Student 2, Student 1	Catch the mouse, point and touch	Employee 1 asks if Student 2 can see the mouse, she notices him look
07:59 - 09:17	Employee 1, Employee 2, Student 2, Student 1	Catch the mouse, menu, point and touch	Same thing again, Student 1 looses interest. Game ends. Employee 1
09:17 - 09:50	Student 1, Student 2, Employee 2	Target shooting, throw ball	Student 1 throws ball, staff retrieves. Employee 2 throws the ball via St
09:50 - 15:33	Student 1, Employee 1	Target shooting, throw ball	Student 2 throws the ball away. Employee 1 accidently minimizes the i
15:33 - 17:36	Employee 1, Employee 2,	Menus, "Find a pair", point and touch	Employee 1 and Employee 2 navigates to the game. Nothing much ha
17:36 - End 1	Employee 1, Employee 2, Student 2, Student 1	Menus, Fish game, point and touch	They navigate to Student 2 profile, he chooses the fish game and the
00:00 - ~03:10	Employee 1, Employee 2	Fish game, point and touch	Employee 2 and Employee 1 move the fish around. Employee 2 and E
03:10 - End 2	Employee 1, Student 1	Menus, music, point and touch, watch and listen	Employee 1 mentions the different kinds of music, Student 1 chooses
00:00 - 01:45	Employee 1, Employee 2, Student 1, Student 2, Student 3	Music video, watch and listen	Everyone watch and listen in silence. Song ends. Employee 1 decides
01:45 - 02:40	Employee 1, Employee 2,	Menu, point and touch	Employee 1 and Employee 2 navigates to Student 3s file, only one gan
02:40 - 03:00	Student 1, Employee 2	Catch the fly, point and touch	Student 1 cought the fly once, looses focus.
03:00 - 04:30	Employee 1, Student 1	Menus, "smash the fly game", point and touch	Employee 1 navigates to another fly game. Student 1 seems a bit more
04:30 - 06:00	Employee 1, Employee 2	Menus, "feelings game", point and touch	They open the "feelings game", way too hard.
06:00 - 09:40	Employee 1, Employee 2, Student 3	Menus, another hard game	They go back from the second hard game, and finds some music. Stud
09:40 - 11:37	Student 2		Next music video starts automatically. Papirsklip. Student 2 is amused,

Figure 17. Excerpt of the preliminary review.

The substantive review was done with the interaction types and the students' moods in mind. To narrow down specific interactions where a focus on PE could have an effect, we focused on sequences with high, medium or low levels of user experience goals [48, p. 26], which Rogers et al. argue are goals to strive for when designing products. The three user experience goals we chose to focus on and look for are (1) engagement, (2) social interaction, and (3) joy, since these either closely relate to the aspects found to be important to the students and employees, or could indicate what they prefer or enjoy doing.

Not only did this allow us to look at the variables that changed when the mood levels changed, but this also allowed future comparison to our results from evaluations. An excerpt of the substantive review can be seen in Figure 18. The full substantive review can be found in the appendix.

Time and video	User(s)	Interaction type	Mood	Mood level	Notes
01:14-03:52 @ Video 1 Vis. cam., vis. res.	Student 2, Student 1	Game - Match 2	Engaged	Medium	Student 2 in the beginning. They di
07:15-09:04 @ Video 1 Vis. cam., vis. res.	Student 1, Student 2, Student 3	Game - Catch The Mouse	Engaged	Low	Student 1 being distracted, caretake
09.17-15.33 @ Video 1 Vis cam., vis. res.	Student 1, Student 2, Student 3	Game - Target shooting	Joy	High	Student 1 pranking the staff, Studer
04:18-End @ Video 2, 00:00-01:39 @ Video 3, Vis cam., vis. res.	Student 1, Student 2, Student 3	Music	Focused	High	Everyone in deep focus, listens to a
03:14-04:30 @ Video 3 Vis cam., vis. res.	Student 1, Student 2, Student 3	Game - Smash the flies	Joy, Engaged --> Semi bored	High --> Medium	Everyone plays the "smash the flies
06:15-09:40 @ Video 3 Vis cam., vis. res.	Student 1, Student 2, Student 3	Music	Joy	High	Everyone really likes Kim Larsen, a
09:40-End @ Video 3 Vis cam., vis. res.	Student 1, Student 2, Student 3	Music	Joy, focus	High, Medium	Student 1 and Student 3 seems to
10:35-13:45 @ Video 1 Vis cam., hid. res.	Student 2	Music	Boredom?	Low?	During the relaxation / meditation m
4:58- 05:50 @ Video 2 Vis cam., hid. res.	Student 2	Navigation	Joy	High	Student 2 is very engaged in choos
06:34-07:23 @ Video 2 Vis cam., hid. res.	Student 2, Student 1, Steen	Game - Catch The Mouse	Social interaction	High	Student 2 chooses to play catch the
03:55-07:45 @ Video 3 Vis cam., hid. res.	Student 4, Student 2	Music	Joy, Boredom	High, Low	Student 4 enjoys Bøllebob alot, actu
09:47-10:59 @Video 3 Vis cam., hid. res.	Student 2, Student 1, Student 4	Game - Catch The Mouse	Engagement	Low	Student 2 chooses to play catch the
06:38-07:59 @Video 1 hid. cam., hid. res.	Student X, Student 1	Game - Pop the balloons	Social Int, Joy	High	Employee 1 works well as a facilitat
08:25-09.30 @Video 1 hid. cam., hid. res.	Student X, Student 1	Game - Pop the balloons	Social Int, Engagement	Low	Just a few minutes after the game a
10:40-15.34 @Video 1 hid. cam., hid. res.	Student X, Student 1	Game - Match 2	Social Int	High	Staff facilitates social interaction rea
11.10-15.01 @Video 2 hid. cam., hid. res.	Student X, Student 1, Student 4	Music	Joy, Engagement	High	No social interaction what so ever,
01.42-04.13 @Video 3 hid. cam., hid. res.	Student X, Student 1, Student 4	Music	Joy, Engagement, Social Int.	Medium	Social interaction, through dancing.

Figure 18. Excerpt of the substantive review.

The analytic search of the data corpus was done individually by each of the researchers and had visible conduct as the main focus. Since verbal communication is more or less non-existent during the videos, the main focus was to look at body language of the students during different scenarios and interaction types, to find indications of the three previously mentioned user experience goals.

4.4.3 Patterns and Tendencies

An Affinity Diagram is an organized overview of *an individual interpretation session, in a wall-sized, hierarchical grouping of data, under labels of key issues that reveal the customer's needs* [31, p. 160].

Figure 19. The Affinity Diagram [31] showing the Post-It's and groupings of findings.

The Affinity Diagram is built bottom-up, by taking all notes from the individual interpretation session, and grouping them all under distinct labels. These labels are named after apparent key issues that emerge, during the building of the diagram. The diagram is typically built using Post-It notes, that can be easily moved around, to accommodate rearranging of groups and individual notes, in case a more suitable grouping appears. One color of Post-It's is used for the main groupings, and afterwards another color is then used for the labels. Lastly, a third color can be used as headliners that groups the labels with key issues.

The analytic search of the data corpus functioned as our individual interpretation session. Each of the individual researchers' findings were noted on Post-It's, and each finding was marked with either - or +, to indicate a negative or positive effect. In a few cases a finding was marked with both, since it contained both aspects. In some other cases, a note would be marked with ?, if there were any uncertainty in regards to whether it had negative or positive effect. If the observation was deemed neutral, no marking was used. Each of the researchers then presented their Post-It notes one at a time, in plenum. The content of each Post-It was discussed and then placed in a suitable group. The placement of the groupings was done on a 'negative to positive' scale, from left to right. On the far left the negative findings were placed, while the positive findings were placed on the far right. In the middle, a continuum of findings were placed, depending on their weight towards negative or positive. After all Post-It's were placed in the diagram, a range of key issues, in the shape of patterns and themes, had appeared. These patterns and themes were labelled as follows (from left to right): 1) General Challenges, 2) Content Challenges, 3) System, 4) Other Positives, 5) Social, and 6) Rich Input and Output. The complete Affinity Diagram can be seen in Figure 19. A high resolution, digital version can be found in the appendix.

1) General Challenges

The theme of this label is challenges that do not necessarily have anything to do with the Touch & Play system, or the interaction with this. Under this label there are notes like *"Distractions"*, meaning students being easily distracted, and *"No consequence"*, meaning that for example pranking the employees does not have any consequences. This label can be seen more as a pool of challenges that should be kept in mind, when designing for the system.

2) Content Challenges

The overall theme of this label is challenges that are related to the content of the Touch & Play platform. The label contains two sub-labels: Flow Theory [40] and Content Challenges.

The Flow Theory label contains notes with challenges, which we believe can be approached and potentially solved with Flow Theory [40].

Notes like *"Engagement in animal game quickly drops -"*, *"Repetitiveness -"* and *"Too complex layout -"* give an overall view of what the theme of this label is.

The Content Challenges sublabel mainly concerns the music and video content. Examples are *"Upbeat music > slow music? Lack of people, or action in the video? -"* and *"Relaxing music with just pictures -."*

In short, this label indicates that there seems to be a challenge in regards to the content of the platform being either too dull or too difficult.

3) System

The system label consists of two sub-labels as well. These are called Bad Tech and Good Tech. The Bad Tech sub-label contains challenges in regards to the technical part of the platform, while the Good Tech contains positive parts. Examples of Bad Tech notes are: *"Touch input - Screen too big when sitting in front -"* and *"Touch screen - Staff has to be mediator -."* Under the Good Tech sub-label, notes such as *"Work-around - Foam rod, ball etc +"* and *"Touch input - Infrared touch +"* can be found.

The main take-away from this label is that there are physical challenges in regards to using the interface, even though a suitable touch sensitive technology has been used. An attempt to solve this challenge is a work-around in the shape of a foam rod, but this has not managed to solve the challenge sufficiently. This foam rod can be seen in figure 9. This also confirms the findings from the pilot study.

4) Other Positives

Under this label, the sub-labels Pranking Staff and Miscellaneous are found. The Pranking staff sub-label contains notes like *"Game: Target Shooting - Prank with ball '?'"* and *"Student 2 really likes fooling the staff +."* On a different Post-It, this behaviour was marked as negative, as it indicated that it was more fun to do the pranking, than focusing on the content of the application.

The Miscellaneous label contains notes like *"It's quite obvious they have each their favourites in music.* [...] *Big difference in preferences"* and *"Familiarity might be good in general. +* [...] *When they recognize something +."* This indicates that they each have very distinct preferences in what they like to do, and that the familiarity of content gives their experience a positive boost.

5) Social

The Social label differentiates itself, in that it is built on a continuum between the sub-labels Staff Engagement and Student Social Interaction. A general and very definitive finding is that social interaction is very positively reinforcing, be it between staff and student, student and student, or between everyone present.

Notes found under the social label can be "*Positive reinforcement from staff +*", "*Everyone plays together +*" and "*Cheering from the staff has a positive effect on the students +.*" A side note to the Social label is that it is the label with the absolutely highest number of notes, indicating its significance to the interaction.

6) Rich Input and Output

The last label is the Rich Input and Output label. This label is divided in two sub-labels, Visuals and Sound. A lot of the notes under these sub-labels fit well under both, and in general, richness in visuals and sound plays a large role in the engagement of the students, when interacting with Touch & Play. Examples of notes under the Rich Input and Output label can be: "*Animal game sound = engaging +*", "*Music seems to be the most captivating activity +*", and "*Even the visuals of the music they like, excites them. Especially Student 3 +.*" Overall rich visuals and sound seem to be very stimulating for the students, especially when it also tallies with something that is familiar to them, or is one of their personal preferences.

4.4.4 Guiding the Design Towards a Focus on Product Experience

As described earlier in this thesis, Desmet & Hekkert mention Aesthetic Experience, Emotional Experience, and Experience of Meaning as key points to consider when focusing on PE in a design process [18]. To get a firm grounding on these key points, a literature review was conducted on these three types of PE, in addition to what Desmet & Hekkert describe, as a way of establishing a pool of knowledge and to figure out what to keep in mind when ideating. No rigid guidelines on how to conduct a design process focusing on PE were established, but some topics to consider during a design process focusing on PE were found. These topics were:

Aesthetic Experience:

- Design Articulations [46]

Emotional Experience:

- Appraisal [17]

Experience of Meaning:

- Cognitive Response [16]
- Metaphors [29, 14]

All of these topics, with related subtopics, will be unfolded throughout the description of the design process, as reasoning for our design decisions.

4.4.5 Sketching the Idea

The creation of the Affinity Diagram presented some initial design constraints for the PE inspired AT prototype. In order to support the highest amount of engagement and positive experience in general, the prototype would have to entail a level of social interaction, as well as rich input and output, preferably both visual and auditory. Furthermore, the auditory feedback should be musical as this seems to be captivating to the students. Besides the Affinity Diagram, the literature review of the three types of PE also presented some topics of discussion that could help shape the initial design constraints. Particularly helpful in this regard were the concepts of metaphors, and appraisal. The concept of metaphors means, in this context, to use elements from something familiar to the students, in the design of the prototype, in order to suggest similarities between the prototype and the thing from which elements were used. Hekkert argues that the use of metaphors can aid associative processes when appropriating a product, by accessing and utilizing the users' preconceptions [29]. Furthermore, Nazli Cila argues that metaphors can be used to promote rich sensorial and emotional experiences, and that this can be attained by telling a story through a product or creating a fun or witty product[14, p. 14]. Using the concept of metaphors also goes well with the finding from the Affinity Diagram, that familiarity seems to have a positive effect on the students.

The concept of appraisal is described by Desmet as a promising way of describing how products elicit emotions through use [18, p. 62]. In appraisal theory, emotion is defined as *"the felt tendency toward anything intuitively appraised as good (beneficial) or away from anything intuitively appraised as bad (harmful)"* [17, p. 108]. A basic model of emotions in appraisal theory is illustrated in figure 20.

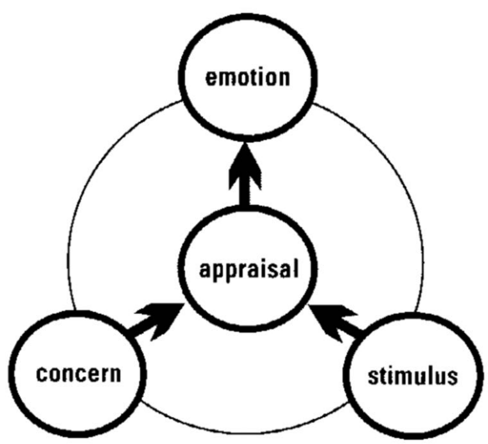

Figure 20. Basic model of emotions as described by Desmet [17, p. 108]

Emotions are, according to appraisal theory, products of an appraisal, which is a non-intellectual, automatic evaluation of the significance of any perceived change, for one's personal well-being. Such a change is, in appraisal theory, known as a stimulus, and can be anything from an event occurring, to encountering an object. This stimulus is then appraised in relation to a person's concerns. A concern, in this respect, is a person's preferences for certain states of the world. The number and variety of human concerns are vast. Some examples of concerns are drives, needs, instincts, motives, goals and values. Keeping the concept of appraisal in mind, as part of our initial design constraints, would aid in the elicitation of positive emotional responses by attempting to design the prototype in such a way that it supports the concerns of the students and employees at the STU Center. Concerns of the students and employees that could be interesting to support could be (1) the three experiential qualities found in our pilot study to be the most important aspects of Touch & Play, (2) the students' love of music or (3) their desire for social interaction.

With this initial set of design constraints we conducted an ideation phase in the form of an individual sketching session that would lead to a discussion and brainstorm in plenum.

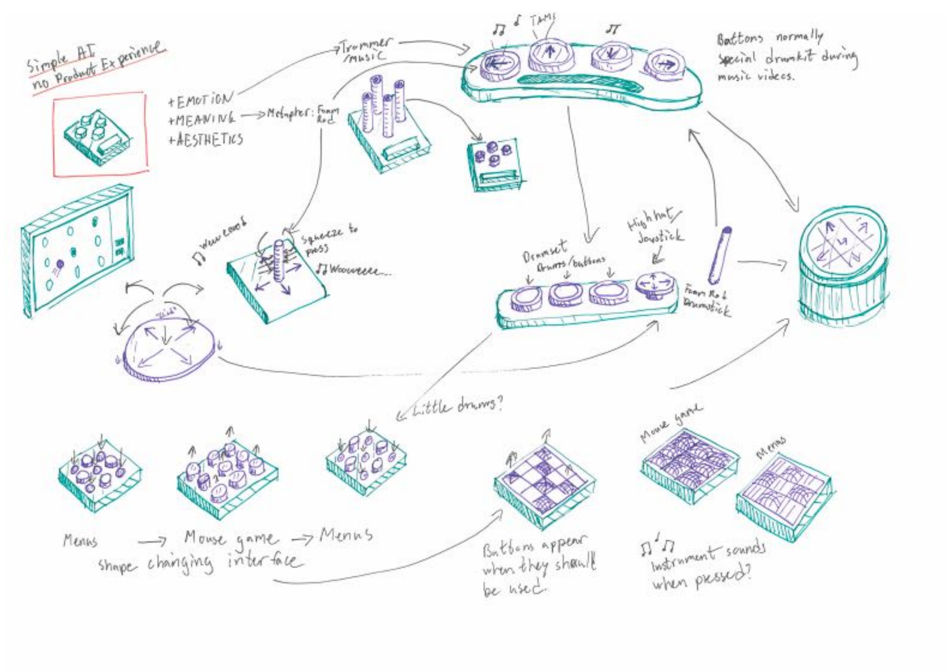

Figure 21. A sheet of sketches made during the ideation phase.

As can be seen in figure 21, nearly all of the ideas discussed revolved around creating input devices to be controlled by hand. Most of the ideas sketched above add a different tactile aspect to the interaction with Touch & Play, and nearly all of the sketches involve music or sound in some way.

During the discussion it became apparent that most of the ideas revolved around music and musical instruments, but one particular idea, namely a drum kit that would function as an input device, was present among the ideas sketched by all researchers. This idea complied with all design constraints, and was therefore chosen as the idea with which to continue the design process.

4.4.6 The First Iteration of the Product Experience Inspired Assistive Technology Prototype

At first in this section, the PE inspired AT concept and prototype is described piece by piece, followed by design argumentation, using the experience concepts and subconcepts mentioned briefly earlier in this chapter, and the findings made clear in the Affinity Diagram.

The First Iteration of the Product Experience Inspired Assistive Technology Prototype Briefly Explained

The first iteration of the PE inspired AT prototype consisted of a drum kit with five drums and a control panel. Four of these drums were situated around a center drum, that also acted as the base for the whole kit. Each drum had an illuminated drumhead with one of four primary colors (green, blue, yellow, and red), which was inspired by the feedback from the AT prototype. The drum kit and control panel can be seen in figure 22. The control panel is described later in this section.

Figure 22. The PE Inspired prototype; the full drum kit.

The drum kit was used as an interface to control the mouse cursor, in accordance with the minimal requirements explained earlier in this chapter. It had four small drums that could be used to control directional movement of the cursor in small steps; the yellow drum on the left, moved the cursor left, the red drum on the right moved the cursor right, etc. The center drum acted like a left-click.

Each drumhead is dimly lit up in their individual color and, when hit, the drum would very briefly turn up the brightness as feedback for the user's action.

The drum kit was placed between the user and the Touch & Play screen. The user could use the drum kit to navigate to whichever application he or she wanted, and then play the game, listen to music or just play the drums. This functionality will be elaborated later in this section. In case an application was chosen where multiple users was a possibility, each of the small drums could be detached from the center drum and placed in front of different users, who could then control each of the directions.

The Product Experience Inspired Assistive Technology Prototype in Detail with Design Decisions and Argumentation

Each of the four small drums were built using a ⌀ 20 cm PVC pipe, cut in pieces of 15 cm in height. As can be seen in figure 22, the PVC was covered in wallpaper with a wooden texture to make the drums as authentic as possible, following the metaphor concept mentioned earlier. The wooden bongo look was chosen to distance it from a regular drum kit, while still being sufficiently recognizable to the students, to avoid any preconceptions that might interfere with the findings. Continuing this metaphor, white 30% opaque acrylic was chosen as the drumhead, to both keep the look and feel of a real drum, while also giving the drums the necessary sturdiness to withstand enthusiastic use. Just below the acrylic drumhead, each drum was equipped with a piezo element [54] and 12 NeoPixels [53], to first sense vibration from the drum being hit and then give feedback via light. Furthermore, a speaker embedded in a control panel, which will be described later in this section, provides audio feedback. The NeoPixels were used to light up and give the drums their respective colors. The large center drum was built in the exact same manner, except being 53 cm tall and fitted with four wooden feet to keep the complete setup stable. An exploded view of a drum can be seen in figure 23.

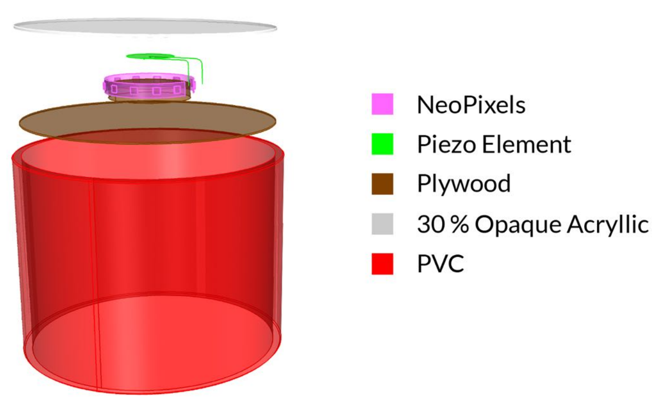

Figure 23. An exploded view of a drum, with each of the components used in the setup.

Why a Drum Kit?

Hekkert argues that, to not overstimulate the user, a metaphor in the design can be used to let her or him recognize the meaning of the design in an easy way [29, p. 165]. When a user has to recognize the meaning of a design, Crilly argues that he or she goes through a five step process [16]. One of these steps is the Cognitive Response, which is determined by, among other things, the Semantic Interpretation and Symbolic Association. The Semantic Interpretation pertains to how the user interprets the affordances of the design, while the Symbolic Association pertains to how the user feels the design will affect his or her personal image. The Cognitive Response is built on messages received via the senses of the user, which the Semantic Interpretation and the Symbolic Association then helps translate into meaning, which in turn helps the user make sense of a design and in the end gives the user an idea of how to interact with the designed product. An example of the use of a metaphor, to give the user an idea of how to interact with the system, is the desktop metaphor, developed for the Xerox Star computer. In the desktop metaphor, concepts such as files, folders, and a mailbox, was used to utilize the user's preconceptions about these objects, to indicate how to interact with the interface [48, p. 55-57]. In addition to the use of a metaphor as a way of making sense of a product, Cila [14, p. 14] adds that a metaphor can also be used to create a rich sensorial and emotional product, which can make the user smile via fun and wittiness, as previously mentioned.

Seeing in the Affinity Diagram how the students were very positive towards music, sound and rich input and output in general, a music metaphor seemed suitable. Furthermore, the students were already familiar with musical instruments, as the school contains a music room equipped with a variety of musical instruments, and some simple musical instruments such as a guitar and a piano are already present in the room, in which Touch & Play is located. The drum metaphor, more specifically, was chosen as the drums require only limited manual dexterity, but also as it is a common and easily recognizable musical instrument that can take many shapes, such as a drum kit, bongo drums etc., and can easily be arranged in front of the students, in regards to mapping the placement of the drums to the directional movement of the mouse cursor. Besides this, the drums could be placed at a suitable distance to the students, eliminating the problems of the hard to reach areas of the Touch & Play screen. An additional reason for choosing the drum metaphor was that it could potentially be a rich sensorial product as suggested by Cila [14], which might cater to the cognitive and motor abilities of the students, by both being a tactile instrument and by having rich output in the form of sound.

To top off the rich output, we chose to install the NeoPixels as a light feedback system, signaling the difference between the drums and giving immediate feedback when hit. The NeoPixels were placed in a circular shape around the piezo element encasing the most input sensitive part of the acrylic plate in a circle of light, as an indication of where to strike the drum. In relation to this, Krogh & Petersen describe three Design Articulations, that function as guiding categories of articulation for what designed artifacts aim at expressing and by what means this is pursued, in order to enhance the Aesthetic Interaction of a product. One of these Design Articulations is called Clues of Use, which states that having a physical feature that invites for interaction, without explicating what effect it might have, encourages exploration, which can support Aesthetic Interaction. A picture of the NeoPixels and the circles can be seen in figure 24.

Figure 24. The circular shape seen in the middle of the drumheads, meant as a hint of where to hit the drums.

The use of the drum metaphor also corresponds well with Krogh & Petersen's Design Articulation Style. Style, in this context, means exposing meaning, ideology, values etc. through the visual appearance of an object. Playing music is inherently a social, explorative and playful activity. By using the drum metaphor, these values are embedded into the visual appearance of the prototype. By using both sound and light, in combination with the tactility of the physical drum, we aimed to spur the Sensory Qualities as described by Krogh & Petersen [46], to create an explorative dialogue between the bodily sensory input and the reflective mind of the students. As Krogh & Petersen explain, this is done through designing the immediate perceptual experience in a way that helps the user identify and confirm what they are experiencing through intellectual appropriation. To cater to the intellectual appropriation of the students, we decided to keep the sound and lighting output on a relatively simple level that would not interfere with the easily recognizable drum metaphor. Furthermore, Hekkert argues, regarding sensory effort, that 'less is more' [29, p. 163] and that simple sensory feedback can create a more holistic sensory experience. Hekkert also advocates that designers make all the sensory messages congruent with the intended, overall experience, since incongruity between sensory messages is displeasing to the user. Therefore, to create a congruous message between the drum metaphor and the sound feedback, we chose to use auditory icons [23, p. 75-76] in the form of bongo-sounds. These require less sensory effort since the sounds are familiar, and do not need to be interpreted by the user. Bongo drum sounds are also a sound the users are not exposed to so often. This means that a slight alteration in sound-fidelity will not disturb the experience. As Cila also argues [14, p. 18-19], sound and material/texture are both salient properties when mapping from a metaphor source to a target. To cater to the material/texture property we chose to wrap the PVC pipes in textured wallpaper, as described above, to give the drums an authentic wooden feel, staying true to the look and feel of a real drum.

As it was clear from the Affinity Diagram, social interaction was vital to the engagement for both students and employees when using the Touch & Play system. For this reason we decided to make the drum kit modular, making it possible to distribute the drums to each of the students. The goal of this was to let them cooperate in games or tasks, giving each other a helping hand, as this was deemed one of the important social boosters in the Affinity Diagram.

Technical Details

To attach the small drums to the large center drum, a 3D-printed [57] mount was bolted to each drum, which would then fit on two screws each on the center drum. The mount was designed to enable quick detachment of each of the smaller drums from the center one, without the use of tools. The feature of allowing the drums to be detached, is used to cater to the social aspect of the design constraints. The mount can be seen in figure 25.

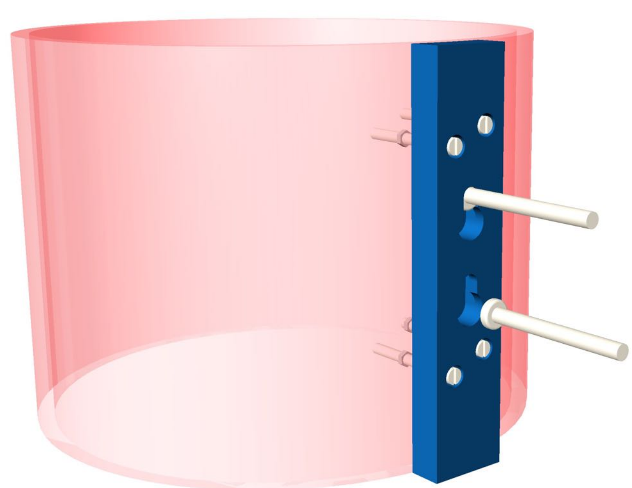

Figure 25. The mount (blue) displayed on a drum, with bolts and screws.

The control panel contained an Arduino Leonardo [51], a DFPlayer Mini [19] with a built-in amp and the necessary components such as resistors and capacitors, on a PCB [61]. These are concealed within a laser-cut wooden box. The box is 30x25x18 cm and made using 6 mm plywood. Additionally the box was fitted with a rotary potentiometer to control the volume of the bongo-sounds, a speaker to play said sounds, and three two-way switches to control mode, mouse-function and speed of the mouse cursor. These functionalities will be elaborated later in the section. Indications of each of the functionalities of the switches were laser-engraved beside the switches. Each of the drums are individually connected to the PCB with a cable. A photo of the box and PCB with electronics can be seen in figure 26 and figure 27. A complete technical schematic can be seen in figure 28.

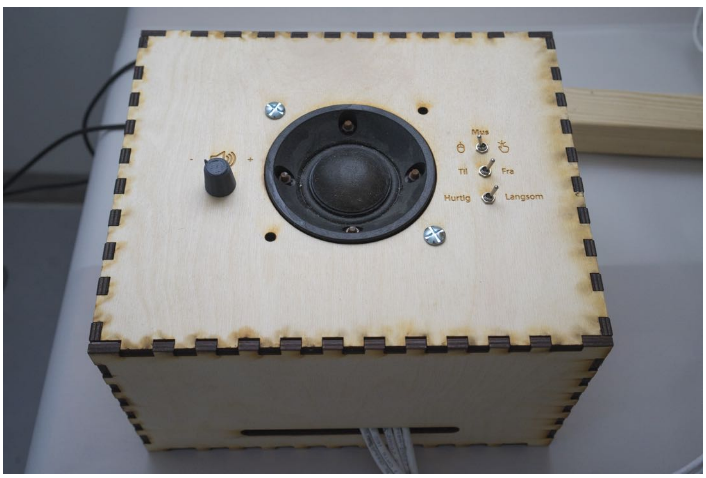

Figure 26. The control panel which is used to adjust the settings, while also containing the electronics.

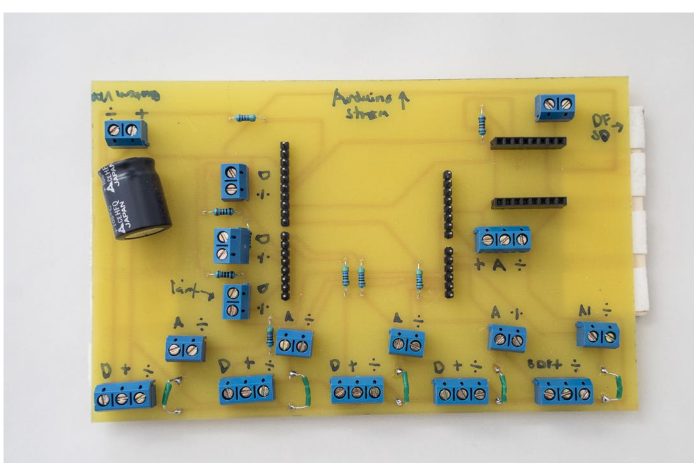

Figure 27. The PCB in the first iteration of the PE inspired AT prototype.

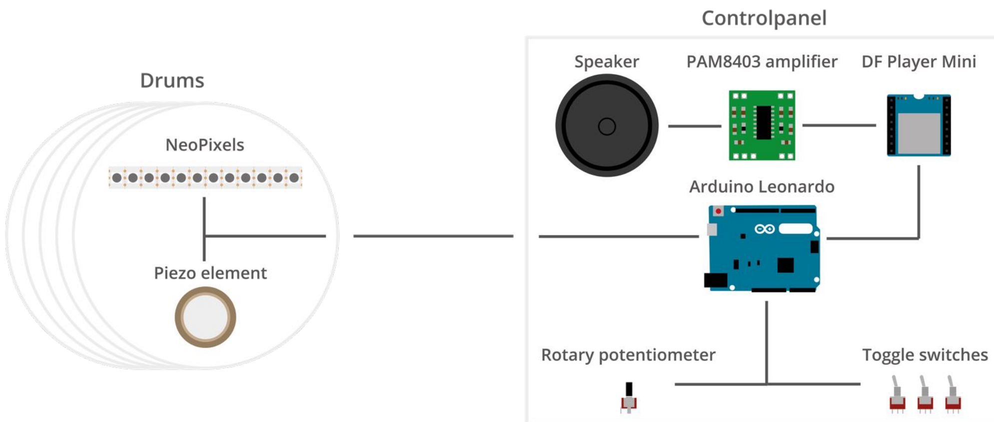

Figure 28 - Technical schematic of the second iteration of the PE inspired AT Prototype. The only difference in technical components between first and second iteration, is that the first iteration did not have an amplifier. For simplicity, the connection between external power and Neopixels, as well as the USB cable connecting the prototype to Touch & Play, have been omitted.

Functionality

The drum kit had a few different functions, determined by the settings of the switches on the control panel. The reasoning behind adding the different functionalities to an external box was based on a wish expressed by the employees, during the focus group interview of the pilot study, to keep some control away from the students, e.g. volume control. For the first iteration of the prototype, the first switch was left without any specific functionality, to enable open ended development of the setup, by letting the employees at the STU Center think of a potential function at the first testing session. This will be elaborated later in this chapter. The second switch enabled or disabled the mouse function, allowing the student to play the drums without influencing the mouse cursor. Lastly, the third switch changed the cursor movement speed between slow and quick.

The user can then activate the drums either with a red foam drumstick (as seen in figure 29) or by hand. When the drum registers a hit or a touch, it will light up very briefly to signal that it registered the action, and control the cursor accordingly.

We chose to make the drumstick look like the foam rod, which the students were already familiar with when using the Touch & Play interface. As Crilly [16] argues, similar products can be used to guide the meaning making of a design. Since it was observed that the students knew how to point at, and hit, the Touch & Play interface, we chose to keep this foam rod as the pointing device. A positive side effect was that it would not physically stress the prototype too much, as it is soft and flexible.

Figure 29. The red foam drumsticks that can be used to interact with the prototype.

The decision to have a setting where the drum kit does not influence the cursor, was chosen based both on the student's love for music and music videos, and the idea of appraisal as described by Desmet [17]. As previously mentioned, the most used application in Touch & Play is a video application allowing the students to watch music videos on YouTube, and from the Affinity Diagram we can see that each of the students had very specific tastes in music. Giving the students the possibility to drum without influencing the cursor would allow them to play along to their favorite music videos, thereby influencing their appraisal towards positive emotions.

A video demonstrating the PE inspired AT prototype can be found in the appendix.

4.4.7 Testing the First Iteration of the Product Experience Inspired Assistive Technology Prototype

The first iteration of the PE inspired AT prototype was tested in the same setting as the traditional AT prototype. The session lasted about 33 minutes and involved Student 1, Student 3, Student 4 and two employees. For this session only music videos were chosen, which means no games were played. Again, two cameras recorded the session, while a third camera streamed the session to two of the three researchers. For this session the third researcher was again quietly present in the corner of the room, to be able to help in case of problems with flexibility of the Touch & Play interface. The testing session was finalized with a semi-structured interview with the attending employees.

During the testing session and the following interview, we found two main issues with the prototype. The first was, that the employees did not find the maximum volume of the speaker playing the drum sounds loud enough. The second was a suggestion of having the drums indicate which cursor direction they were linked to.

On a positive note, the size of the drums, the sounds and the combination of drumstick and hands were very well received.

4.4.8 The Second Iteration of the Product Experience Inspired Assistive Technology Prototype

The changes from the first to the second iteration were minor. To accommodate the problem in regards to sound volume, a bigger speaker and an external amplifier were added to the setup. This meant that the second iteration could play at a volume up to 12 decibels louder than the first iteration.

For this iteration, a functionality was added to the first switch, that was left without functionality before, allowing all drums to have the mouse left-click functionality. This decision was made by the researchers, since no ideas of use for the first switch came up during the testing session. This functionality was chosen to accommodate different modes of cooperation between the users, for example to include an interaction possibility, where the individual drums could be distributed to multiple students, who could all collaborate in, for example, a "left-click-only"-puzzle, where a puzzle is solved just by left clicking on a button.

In regards to the request of having the drums specifying the direction of the mouse-cursor, the light in the drums were changed to point in a direction based on the drum's placement, e.g left/right/up/down, when in the mouse movement setting. When the setup was in the abovementioned left-click functionality, the whole drum would still light up.

In addition to the issues noted in the testing session, some soft foam padding was added to the edges of the drums, to make them more comfortable to use with bare hands. Lastly, a new wooden box was laser-cut and assembled, to fit the bigger speaker, and a new PCB was made to accommodate the added amplifier.

4.4.9 Testing the Second Iteration of the Product Experience Inspired Assistive Technology Prototype

The second testing session was conducted in the same way as the previous testing sessions, and lasted approximately 41 minutes. Present at the session were Student 4, Student 5 and two employees. The applications used weighed heavily towards music, but some games were played. The games played were puzzles and matching sounds with animals. During this session, it was observed that the higher volume of the new speaker and amplifier made the bongo-sounds more noticeable, even when listening to music. Additional findings will be presented in chapter 5.

Chapter 5

Findings

This chapter will present the findings from the comparative evaluation of the two developed prototypes, based on the conducted testing sessions, the video analysis of the footage from the testing sessions, and the interviews with the employees. The section will commence with an evaluation of the degree to which the prototypes overcame the usability challenge chosen for the prototypes. Following this evaluation, the three main findings from the comparative evaluation will be presented; namely that the PE inspired AT prototype (1) enhanced engagement, (2) invited for a higher degree of social interaction and (3) created a more enjoyable experience for the students. Finally a summary of the findings will be presented to provide an overview.

The changes made to the prototypes from iteration 1, used at the first session, to iteration 2, used at the second session, are minimal and had minor observable impact on the actual interaction. Therefore, all four testing sessions were deemed relevant for quantitative and qualitative analysis, and observations from, and comparisons of, all four sessions will be described in this section.

When quoting the employees or students in the testing sessions, the quotes will be marked with an indication of which testing session, the quote has been taken from like so: "(From AT1 Interview)". In this indication "AT" represents the traditional AT prototype, whereas the PE inspired AT prototype would be denoted "PE". The number following this, denotes which iteration of the prototype is being tested. The number "1", indicates that it is from the first iteration, whereas the number "2", would indicate that it was from the second iteration. Furthermore, all interviews were conducted in Danish, and have since been transcribed and translated to English. Transcriptions of the original interviews in Danish can be found in the appendix.

5.1 The Degree to Which the Developed Prototypes Overcame the Usability Challenge

As mentioned in the Design Process section, the usability challenge chosen for the developed prototypes was:

Due to most of the students either being bound to a wheelchair or having limited gross motor skills, the dimensions and vertical position of the touchscreen, made it difficult or impossible for the students to use it by themselves.

On account of this usability challenge, the students with the most severe physical impairments, such as Student 2 and Student 3, were completely unable to interact with Touch & Play themselves, and the other students found it difficult or impossible to reach the top part of the screen. This also led the employees to feel the need to assume control of Touch & Play, and interact on behalf of the students.

To investigate to what degree the prototypes overcame this usability challenge, we chose a video from the pilot study, in which the students interacted directly with Touch & Play, to compare with the videos of the students interacting with Touch & Play using the prototypes. The video was chosen based on the requirement that Student X, the student who had graduated from the STU Center, was not in the video, to ensure the best comparability possible. Besides this requirement, the video was chosen at random. The video from the pilot study chosen for comparison lasted approximately 41 minutes. Present at the session were Student 1, Student 2, Student 3 and two employees. This video was compared to all videos recorded for this thesis. Figure 30 gives a brief overview of which students attended each of the recorded sessions, used for this analysis.

Pilot study	AT1	AT2	PE1	PE2
Student 1 Student 2 Student 3	Student 1 Student 2	Student 1 Student 2 Student 5	Student 1 Student 3 Student 4	Student 4 Student 5

Figure 30. Table describing which students were present at each testing session.

Three aspects were chosen for comparison; (1) the degree to which the students with the most severe impairments were able to interact with Touch & Play, with and without the prototypes, (2) the amount of times the students were unable to reach the desired part of the screen and (3) the amount of time the employees assumed control of Touch & Play completely.

5.1.1 The Degree to Which the Students with the Most Severe Impairments Were Able to Interact with Touch & Play

In relation to the first aspect of comparison, it was observed that Student 2 and Student 3 never interacted directly with Touch & Play, during the video selected from the pilot study. However, during the testing sessions recorded during this thesis, it was observed that the prototypes allowed Student 3 to interact with the prototype indirectly, in the sense that the employees guided his hands to the prototype and used his hands to activate the prototype. Furthermore, the traditional AT prototype allowed Student 2 to occasionally interact completely independently with the system.

Employee 1 (From AT1 Interview): *"In regards to Student 2, I think he seemed more present, and more, I mean, he followed it a lot with the eyes* [...] *and the happiness of him activating it. [...] I mean, we help him a lot with controlling it, but like, the feeling of 'Okay, it is actually me who activates something'."*

Employee 2 (From AT1 Interview): *"There were two times where it was very obvious that it was him, who activated it.* [...] *And I think that is pretty good, considering it is the first time, right."*

During the video analysis it was also discovered that the employees were both a bit surprised and delighted that Student 2 was able to activate the prototype by himself.

5.1.2 The Amount of Times the Students Were Unable to Reach the Desired Part of the Interface

In relation to the second aspect of comparison, it was observed that Student 1, in the video from the pilot study, encountered five instances of inability to reach the desired part of the GUI. This issue was completely resolved during the testing sessions recorded for this thesis, as not a single instance of inability to reach the desired part of the GUI was encountered for any of the students.

5.1.3 The Amount of Time the Employees Assumed Control of Touch & Play Completely

Finally in relation to the third aspect of comparison, the specific amount of time in which the employees assumed control of Touch & Play completely, was measured for both the video from the pilot study, and each testing session recorded for this thesis.

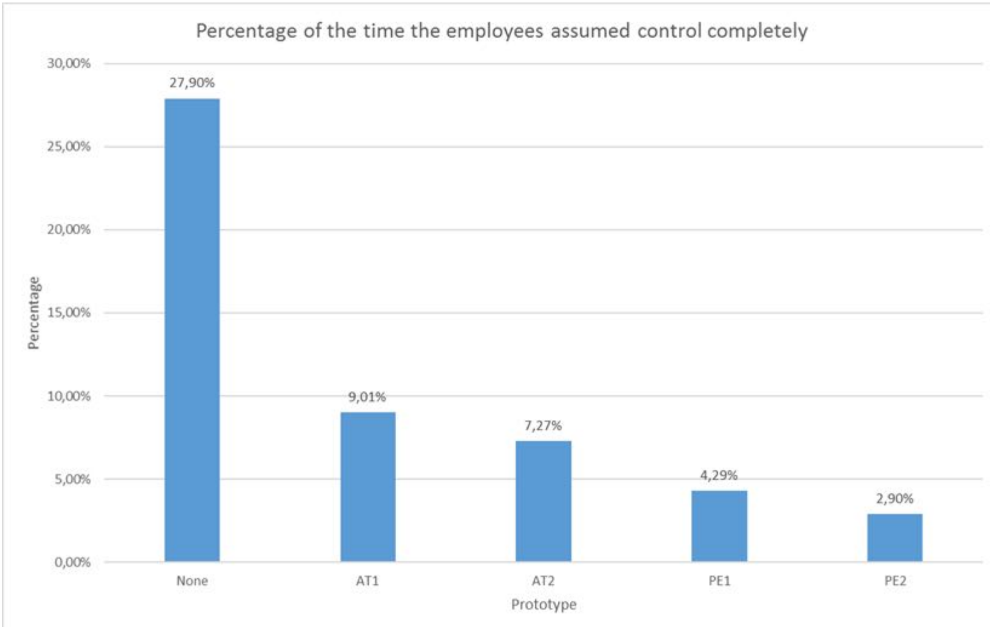

Figure 31. Graph showing the percentage of the time the employees overtook control of Touch & Play.

As can be seen from figure 31 the amount of time the employees had to assume control of Touch & Play completely was reduced to approximately a third for the two iterations of the traditional AT prototype and less than a sixth for the two iterations of the PE inspired AT prototype. This indicates an increase in the time the students interact with Touch & Play, when using the prototypes developed for this thesis.

Based on the three aspects chosen for comparison, we conclude that the issues raised by the usability challenge chosen for the prototypes were nearly entirely eliminated, and therefore, that the usability challenge chosen for the prototypes was overcome to a high degree.

5.1.4 Other Areas in Which the Prototypes Improved the Functional Capability of the Students

In addition to overcoming the usability challenge chosen for the prototypes, some additional areas in which the prototypes improved the functional capability of the students were observed.

From the observations of the testing sessions, there was a clear development in the usage of the traditional AT prototype from iteration one to iteration two. The researchers observed that the students found it easier to press the correct button, and it was easier for the employees to guide the students through the navigation, when using and describing colors. This was also the attitude of the employees, as found during the interview following the testing session:

Employee 1 (From AT2 Interview): *"I mean, I think it has helped a lot with the colors, because, it is easier for them to navigate."*

Employee 2 (From AT2 Interview): *"Yes, also from the outside, I can see that it is easier for you (Employee 1), to help Student 1 navigate."*

Employee 2 (From AT2 Interview): *"At one point he* (Student 1) *turned to me, and I said* (signed) *'The orange' and then BAM!.."*

With regards to the PE inspired AT prototype, the employees mentioned that, in addition to helping the students interact with Touch & Play, it could also work separately as a tool to teach the students to distinguish the different colors:

Employee 1 (From PE1 Interview): "[...] *it can be used for some fun, they can play drums, and we can also practice the colors this way, so there are more things in this* (pointing at the PE inspired AT prototype)*, than in the other one* (referring to the traditional AT prototype)*."*

The choice of using a programmable Arduino and NeoPixels made this particular use case a definite possibility, since the colors on the different drums can easily be altered or rearranged to help them make 'drills' or games using the colors on the drums. This will be discussed further in chapter 6.

Furthermore, in addition to alleviating the targeted usability challenge, the observations and statements from the employees indicate that this way of interacting with Touch & Play improved occurrences of the issue specified in the second challenge:

Due to limited fine motor skills, the students had a tendency to navigate to unwanted parts of the interface, due to multiple unintentional taps.

Student 1 was observed to encounter this issue multiple times during the pilot study. With the traditional AT prototype, this behavior was not observed to the same degree during the testing sessions or the reviewing of the video material. Additionally the employees seemed to have the same impression, as they said the following, during the first testing session of the traditional AT prototype:

Employee 1 (From AT1 Test): *"In any case he* (Student 1) *was better at not pressing too fast."*

Employee 2 (From AT1 Test): *"I think, already, that you can see* [...] *more understanding."*

In regards to the PE inspired AT prototype, the issue was observed as being solved to the same degree as the traditional AT prototype, meaning that the navigation errors happened less, but they were still not completely gone.

Even though alleviation of this challenge was not within the scope of this thesis, this indicates that aspects of the interaction with the prototypes were appropriated more easily than when working with Touch & Play regularly.

5.2 The Product Experience Inspired Assistive Technology Prototype Enhanced Engagement for the Students

During the testing sessions of the PE inspired AT prototype it was observed that the students seemed to be more engaged in the interaction, than when interacting with the traditional AT prototype. To investigate this further we evaluated four different aspects of the interaction that indicated enthusiasm and interest in all four testing sessions. These aspects were (1) the time it took for the students to appropriate the prototypes, (2) the amount of interaction that occurred with the prototypes, (3) the students' levels of concentration, and (4) the amount of time the employees assumed control of Touch & Play completely.

5.2.1 The Time It Took for the Students to Appropriate the Prototypes

For the scope of this project, looking at the amount of time it took for the students to understand the link between Touch & Play and the prototype, e.g that the prototype controls what happens on the interface, was used as an indicator of how quickly they appropriated the prototypes. This was quantified by looking at the difference in time between the student's first interaction with the prototype in each session and the first time the students consecutively interacted with the prototype and looked up at the screen.

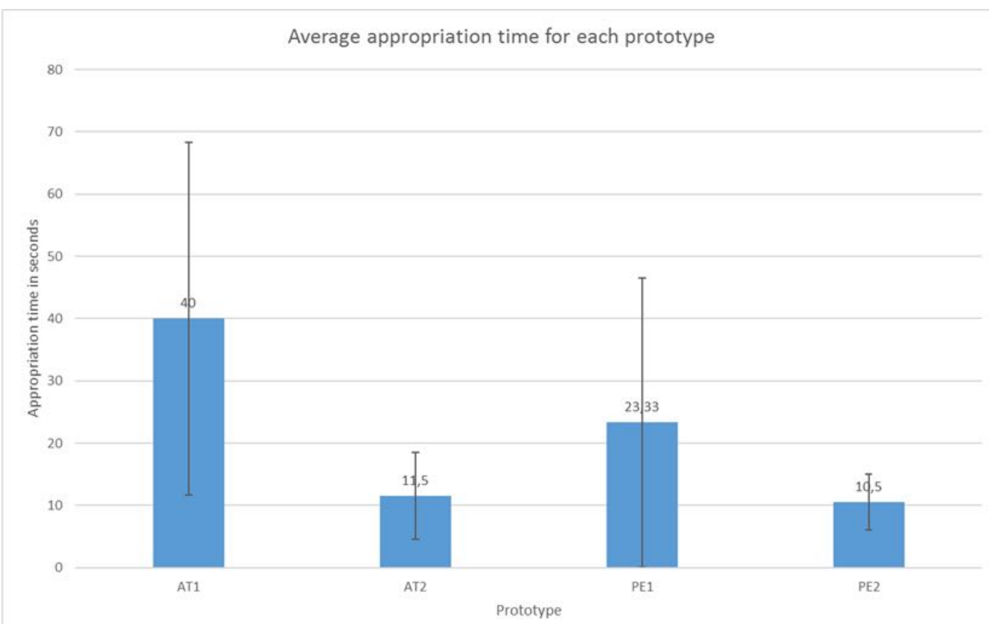

Figure 32. Graph showing the average appropriation time of each of the prototypes. As the PE inspired AT prototype was analyzed comparatively to the traditional AT prototype, the pilot study is not included in this graph.

As can be seen from figure 32, all of the prototypes were appropriated in less than a minute. Furthermore, there was a significant drop in appropriation time from the first to the second iteration for both prototypes, which indicates that the student's familiarity and experience with the prototypes allow them to start interacting with Touch & Play more rapidly after the first encounter. Furthermore, as can be seen from figure 32, the students appropriated the PE inspired AT prototype faster than the traditional AT prototype. This is hypothesized to be caused by the students having tried the traditional AT prototype beforehand, and therefore already having some familiarity with using input devices to interact with Touch & Play. Furthermore, the standard deviation, depicted in figure 32 as a black line, is quite large for the first iteration of both prototypes. As previously mentioned the students' cognitive abilities differ, which results in their appropriation times differing as well. It should be noted that the two PE testing sessions only had one student in common, while the two AT testing sessions had two students in common.

5.2.2 The Amount of Interaction That Occurred with the Prototypes

The amount of interaction that occurred with the prototypes was measured in two different ways. Firstly, the percentage of the time the students spent physically interacting with the prototypes was measured. This percentage was calculated as the amount of time the students physically interacted with the prototypes, in relation to the amount of time they had the possibility of interacting with the prototypes, as opposed to the entire session. This means that periods of time where they transitioned between students, or where the employees assumed control of the prototypes, were not included in the calculations, as these do not give an indication of the students' levels of engagement. Secondly, the amount of actuation of the prototypes in each session was counted. This amount was counted as the amount of times the students, either by themselves or guided by employees, activated the prototypes either by using their hands or a foam rod functioning as a drumstick.

At the end of the first testing session for the PE inspired AT prototype, both employees and students realized that when deactivating the mouse functionality on the prototype, it could be used to drum along to the music videos displayed on the screen. This interaction with the prototype invited the students to interact more rigorously with the prototype, and heightened engagement. This rigor and engagement can be seen in two ways from figures 33 and 34.

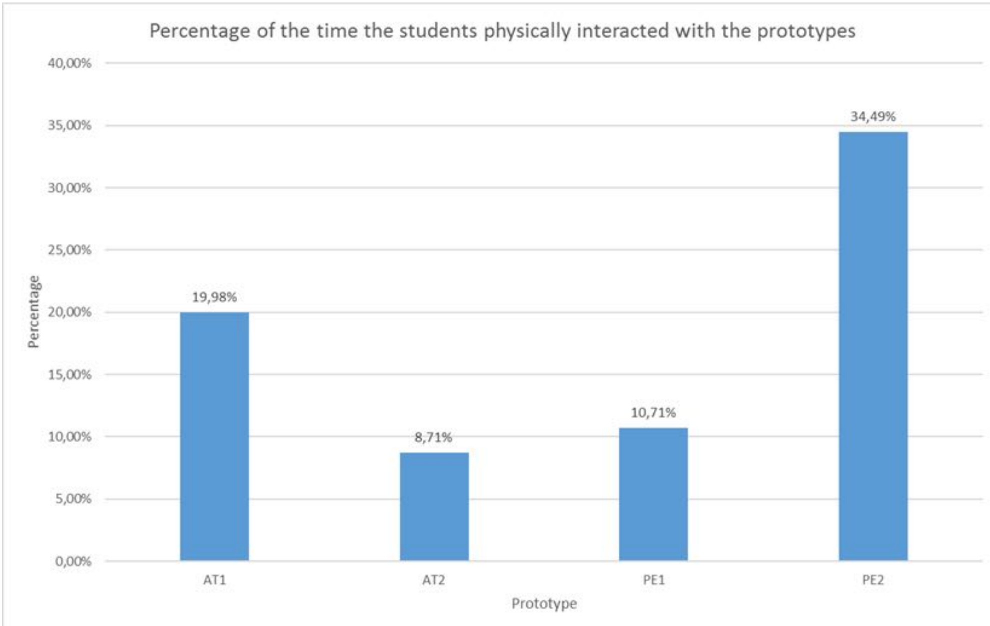

Figure 33. Graph showing the percentage of the time the students physically interacted with the prototypes. As the PE inspired AT prototype was analyzed comparatively to the traditional AT prototype, the pilot study is not included in this graph.

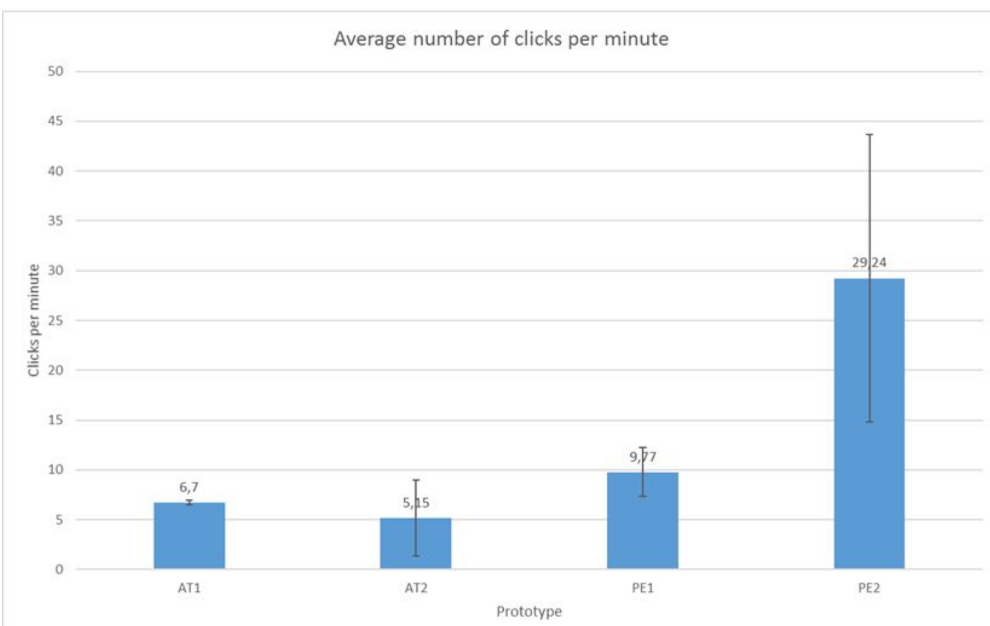

Figure 34. Graph showing the average amount of clicks per minute for each prototype. As the PE inspired AT prototype was analyzed comparatively to the traditional AT prototype, the pilot study is not included in this graph.

Firstly, as can be seen from figure 33, the percentage of the time the students physically interacted with the prototypes was more or less steady, albeit a little lower for the PE inspired AT prototype, up until the second iteration of the PE inspired AT prototype. Though this is the case, the average clicks per minute is higher for both iterations of the PE inspired AT prototype, than for the traditional AT prototype, as can be seen in figure 34. Secondly, as can be seen from both figure 33 and figure 34, the interaction peaked during the second iteration of the PE inspired AT prototype. The standard deviation for average amount of clicks, depicted in figure 34 as a black line, was quite large for the second session of the PE inspired AT prototype. This difference in amount of clicks per minute, is caused by Student 5 spending nearly all of her time during the session, drumming along to music videos. When drumming along to music videos, the amount of interaction with the prototype is often larger, as the students no longer need to be deliberate in their interactions, and can instead just interact with whichever drum they want.

5.2.3 The Students' Levels of Concentration

During the testing sessions of the traditional AT prototype, it became apparent that the students were still struggling with their concentration during their use of the Touch & Play system and the traditional AT prototype. At the first testing session of the traditional AT prototype, it was observed that especially Student 1 had a few periods of time in which he would just randomly press buttons on the prototype, seemingly without paying any attention to what he was doing. During one of these periods, it was also observed that Employee 1 said to Employee 2 that:

Employee 1 (From AT1 Test): *"It is because he does not look up at the screen, that is why."*

Employee 2 (From AT1 Test): *"Yes, that is his issue with the concentration."*

As described in chapter 3, all of the students have very limited attention spans.

For Student 2, who was previously completely unable to interact with Touch & Play, the traditional AT prototype did seem to help a bit on his concentration, as he was actually able to interact with the prototype, and decide for himself which button he wanted to press, even though it at times required the help of an employee:

Employee 1 (From AT1 Test): "[...] *if it gives him the feeling of him being more engaged, then it can maybe outweigh it* (his challenge in regards to fine motor skills)*, there is a certain happiness to it..."*

Employee 2 (From AT1 Test): *"Yes, definitely. And that it keeps the concentration... "*

This means that, with the traditional AT prototype, slight improvements to the concentration of some the students were found, but the issue still persisted.

As the PE inspired AT prototype was tested, there was a clear tendency in the observations that the students were more focused on their use of the prototype and Touch & Play. An example is Student 1, who would use the prototype while looking at the screen, while seemingly having an actual goal with his usage of the prototype, and not using it randomly, like he would with the traditional AT prototype. The tendency was not just visible with Student 1. Student 5 was also observed to be concentrating to a much greater degree than the researchers had ever seen before.

The tendency was furthermore highlighted by the employees, both during testing sessions and the interviews. During the second testing session of the PE inspired AT prototype, Employee 1 said to Employee 2:

Employee 1 (From PE2 Test): *"Also just the fact that she is focused for this long, think of all the tasks we've given her, where she just...* (She is talking about student 5.)*"*

And from the following interview:

Employee 1 (From PE2 Interview): *"We were talking about, that someone like Student 5, usually she is concentrated for..."*

Employee 2 (From PE2 Interview): "(finishing Employee 1's sentence) *... A very short amount of time."*

Employee 1 (From PE2 Interview): *"Very - something like five minutes, and then she is like 'done, over, new activity'. In fact we have never had an activity with her for so long, where she... yeah."*

This points towards a tendency that the students are more concentrated when interacting with the PE inspired AT prototype, than when they interact with the traditional AT prototype.

5.2.4 The Amount of Time the Employees Assumed Control of Touch & Play Completely

As mentioned in section 5.1.3., the amount of the time the employees assumed control of Touch & Play completely was less than half for the PE inspired AT prototype, in relation to the traditional AT prototype. This could also indicate that the students are more engaged when interacting with the PE inspired AT prototype, than when interacting with the traditional AT prototype. The increased engagement could lead the students to put more effort into the interaction, thereby minimizing the amount of time the employees felt the need to take over control of Touch & Play.

5.3 The Product Experience Inspired Assistive Technology Prototype Facilitated a Higher Degree of Social Interaction for the Students

The PE inspired AT prototype was designed to give a larger amount of social interaction, than the traditional AT prototype via the detachable drums. Unfortunately during the testing sessions, the opportunity to detach and spread out the drums never occurred, deeming it impossible to conclude anything in this regard.

It was observed that the drum functionality, without any influence on the mouse, did seem to yield a larger amount of social interaction. When any student was playing along with music, it was observed that they wanted the employees to drum along with them. Especially when Student 5 was drumming, it yielded large amounts of social interaction. At one point, while Student 5 was navigating to a certain piece of music, using the PE inspired AT prototype, Employee 2 asked whether Student 5 found it fun or not. To this she answered with a laugh, closely followed by:

Student 5 (From PE2 Test): "*You should take that!* (Pointing at a drumstick.)"

This indicates a wish from Student 5 for a shared use of the PE inspired AT prototype. This is further substantiated at a later point in the same testing session, as Employee 2 joined the drumming session, followed by Student 4 dancing by the screen, and lastly Student 5 bursting out:

Student 5 (From PE2 Test): "*Employee 1, come!*"

Based on observations and accounts from the employees, Student 5 usually seems to be very secluded and has even been observed to not want to share the prototypes at first (neither the traditional AT prototype nor the PE inspired AT prototype). This suggests a definite improvement in regards to the social aspects.

A very similar scenario happened when Student 4 was drumming along to the music, where Employee 3 played along with her, but the situation was never observed with the traditional AT prototype. A few situations where some students started rocking along to the music were observed, but there were never any gatherings around the traditional AT prototype, like those observed with the PE inspired AT prototype.

Even though the modular feature of the drums was never tested, a large amount of social interaction occurred when the students interacted with the PE inspired AT prototype, which did not happen with the traditional AT prototype. Therefore, it is concluded that the PE inspired AT prototype facilitated a higher degree of social interaction for the students.

5.4 The Product Experience Inspired Assistive Technology Prototype Created a More Enjoyable Experience in General for the Students

While observing the testing sessions, and while going through the video material, the researchers got the impression that both students and employees had more fun, and a better time in general, while using the PE inspired AT prototype than when they were testing the traditional AT prototype. Though the traditional AT prototype was not found to be boring as such, the PE inspired AT prototype elicited more smiles and positive reactions in general. During the first testing session of the PE inspired AT prototype, Student 4 started laughing when she discovered the possibility of drumming along with the music, and kept laughing for several minutes. It should be noted that the researchers had never seen this student laugh before, and she had rarely even broken a smile at any of the sessions. During the second testing session of the PE inspired AT prototype, Student 5 had a similar reaction where she went from her typical secluded and non-social presence in the room, to being very engaged, smiling, having fun and wanting everyone to participate in a drumming session.

The employees also seemed to have the same impression, as seen from the video- and interview quotes below:

Employee 3 (From PE1 Test): *"This, I mean, this is fun."*

Employee 1 (From PE1 Test): "(She's talking to Student 4, who's laughing) *So you have tried playing the drums today! That was fun to try."*

Employee 1 (From PE2 Test): "(She's talking to Student 5, who's playing the drums) *Is it fun to play the drums to the music?"*

Student 5 (From PE2 Test): *"Yeaah..."*

Employee 1 (From PE2 Test): "(Directed towards Student 5) *Was it fun?"*

Student 5 then answers with something that sounds like *"Fun, fun, fun"*, while she is waving her arms around triumphantly.

After the session was finalized, Student 5 seemed to want to keep playing for a bit longer:

Student 5 (From PE2 Test): (Something inaudible)

Employee 2 (From PE2 Test): *"Are you just ready to play some more?"*

Student 5 (From PE2 Test): *"Yes."*

Student 5 then proceeds to hit the drums a few more times, before the employees make it clear to her that they have to stop for the day.

Between the second testing session of the PE inspired AT prototype and the following interview, Student 5 reached out directly towards the researchers for the first time, and said:

Student 5 (From PE2 Test): *"Hi! It was fun!"*

This came as a surprise, and gave the impression that she really had fun. Employee 1 even commented on the fact that she told the researchers it was fun:

Employee 1 (From PE2 Interview): *"And that she can say herself, when you enter, that she thought it was fun."*

From the interview after the first testing session of the PE inspired AT prototype, when asked what they thought about the prototype, the employees answered the following:

Employee 1 (From PE1 Interview): *"I mean, this was a good bit more fun for them, that's my impression."*

And from the interview after the second testing session of the PE inspired AT prototype, when they were asked if it was still their impression that it was easier to use than the traditional AT prototype:

Employee 1 (From PE2 Interview): *"Yes, and more fun."*

Summing up this finding, it seems that both students and employees agree that the PE inspired AT prototype is more fun than the traditional AT prototype in general.

5.5 Summary of the Findings

In summary, there are four main findings from the testing sessions of the two developed prototypes. Firstly, both prototypes were found to overcome the usability challenge chosen for the prototypes to a high degree, through a comparative review of a video from the pilot study, in which the students interacted directly with Touch & Play, and the videos recorded for this thesis. Secondly, through analyzing four different aspects of the interaction with the prototypes that indicated enthusiasm and interest, it was found that the PE inspired AT prototype was more engaging for the students, than the traditional AT prototype. Thirdly, through analysis of the video footage, and interviews following the testing sessions, it was found that the PE inspired AT prototype yielded more social interaction than the traditional AT prototype, even though the modular functionality of the PE inspired AT prototype was not tested. Finally, through observations during, as well as analysis of the video footage from, the testing sessions, it was found that the students found interacting with the PE inspired AT prototype more enjoyable than interacting with the traditional AT prototype.

Chapter 6

Discussion

In this chapter, a discussion of the findings, the research question, and the validity of the research, is presented. Firstly, based on the findings, the extent to which we answer the research question is discussed. This is followed by a discussion of the Problem-Solving Capacity of the research conducted for this thesis, based on the meta-theory by Oulasvirta & Hornbæk [44]. Following this, potential directions for future work are presented and, finally, a brief summary of the discussion is presented.

6.1 Answering the Research Question

In the beginning of this thesis, the research question was presented:

How can the introduction of a focus on Product Experience impact the usage of Assistive Technology?

As seen in the findings section, some clear differences between the traditional AT prototype and the PE inspired AT prototype were found. In general, the findings highlight several positive effects of the PE inspired AT prototype, in comparison to the traditional AT prototype. Tendencies such as more social interaction, more inclusion of the students, and a more enjoyable experience in general, were found. The traditional AT prototype did succeed in extending the functional capability of the students, like an AT should, but lacked the experiential qualities that had been in focus in the PE inspired AT prototype.

When looking at the findings from the two prototypes, which are equal in regards to features, and where the only difference is the addition of the PE mindset during the design process, we argue that the addition of a focus on PE seems to have a positive impact on the usage of AT. With this specific user group, and for this specific purpose and context, the designed PE inspired AT prototype gives the impression that a focus on PE is a valuable addition to the design process when designing Assistive Technologies. We argue that the field of AT can benefit from moving towards the later waves of HCI, when designing AT for contexts like this. It should be noted that PE is a part of all interaction, but what is suggested here is an additional focus on PE, as there have previously been little to no focus on this during the design of AT products.

6.2 Reviewing the Problem-Solving Capacity of This Research

In this section the concept of Problem-Solving Capacity, as explained by Oulasvirta & Hornbæk is briefly presented as a basis for the discussion [44]. Following this, the significance and effectiveness described by Oulasvirta & Hornbæk, is discussed in relation to the findings of this thesis. Afterwards, the efficiency of introducing a focus on PE in an AT design process is discussed, by looking at the time and resources needed to design a traditional AT versus an AT that includes a focus on PE aspects. The possibility of transfer is then discussed, in regards to how the findings from this particular context, can be transferred to the general field of AT. Finally, the confidence of the research is discussed.

6.2.1 Research Validation Methodology

The concept of Problem-Solving Capacity is a part of the meta scientific theory of HCI Research as Problem-Solving, by Oulasvirta & Hornbæk [44]. It should be noted that Problem-Solving Capacity is only part of their general framework, but this specific part was deemed valuable for this thesis, since it can be used to discuss the validity of the findings.

To ascertain whether research is valuable, Oulasvirta & Hornbæk describe the Problem-Solving Capacity as a unit of measurement for evaluating whether the conducted research has helped raise the overall Problem-Solving Capacity of the field of HCI. The concept of Problem-Solving Capacity was originally described by Larry Laudan, who defined four criteria, which Oulasvirta & Hornbæk have made an addition to for the sake of design and engineering. The first four criteria are the ones by Laudan and the fifth is then added by Oulasvirta & Hornbæk: Significance, Effectiveness, Efficiency, Transfer and Confidence. All five of these criteria are then meant to be used as a measuring tool, as to whether the conducted research has any ability to lift the general Problem-Solving Capacity of the field of HCI. In the table below, figure 35, Oulasvirta & Hornbæk briefly present each of these criteria:

Criterion	Evaluation Criteria	Heuristics for Refining Ideas
Significance	Number of stakeholders involved; importance of the improvement for stakeholders; costs incurred when the improvement is *not* achieved	Target a different stakeholder group or a larger number of stakeholders; aim at a greater improvement over the present baseline; report on direct comparisons against baseline solutions
Effectiveness	Capture the essential aspects of the problem; match between evaluation metrics and priorities	Use multiple evaluation criteria and richer evaluation contexts; validate evaluation criteria; address unnoticed real-world difficulties
Efficiency	How much effort or resources it takes to create or deploy the solution; scalability; size	Develop tools for practitioners; share datasets and code; reduce price/cost
Transfer	Number of users, tasks, and contexts for which the solution can be applied; qualitatively new contexts wherein the solution can be applied	Identify and target new user groups, contexts, or tasks; demonstrate broad-based generalisability
Confidence	Empirical validity; reliability; replicability; reproducibility; robustness	Replicate the result in different contexts; report on different metrics for judging validity and reliability; allow reanalysis

Figure 35. The five criteria for determining Problem-Solving Capacity, as described by Oulasvirta & Hornbæk [44].

In short, the proposed solution to a research question may either be weak or strong, depending on how well the criteria are met.

6.2.2 The Significance and Effectiveness of the Research

In regards to the Significance of the research [44], the findings in this thesis point towards a potential need for a change in, or addition to, how Assistive Technologies are designed in the future. Based on the thoughts of Hedvall [28] and Frauenberger [22], there seems to be a wish for moving Assistive Technologies into the more modern waves of HCI. Combining this wish with the findings from this thesis, the Significance of this research can be argued to be high, as the research has the potential to move AT towards the later waves of HCI. As this could potentially influence how Assistive Technologies are designed for a large amount of users with impairments (i.e. stakeholders in the terms of Oulasvirta & Hornbæk), it can be argued that the research is significant.

As discussed later in this section, there are limitations to the findings, which means that more work needs to be done before any final conclusions can be made. However, the current findings yield sufficient Significance to suggest that further research and investigations on the matter should be conducted.

In relation to Effectiveness[44], the research of this thesis yielded rather satisfactory results, in that it highlighted the differences between a traditional AT and a PE inspired AT. In the following section a limitation in regards to our relatively small user group is discussed, meaning that the Effectiveness for the complete range of potential users of Assistive Technologies is yet to be determined, but the essence of the research problem investigated by this research, has been captured for the specific user group targeted by this thesis. It should be noted that, when evaluating user experience, it is fruitful to question the user about the experience [48, p. 585-595]. In this case, interviews, or even just simple questionnaires, were not possible with the main users of the prototypes. Instead the evaluations had to rely on observations from the researchers, and statements from the employees, which most of the time came down to an assessment. Since the moods of the students can differ a lot from day to day, it has to be expected that their reactions towards the prototypes can differ a lot as well. Quantitative data is used in this thesis to indicate tendencies and usability. However, it is not an option for the measurement of User Experience, since it cannot easily be quantified, especially in situations where communication with the primary user is not an option [35].

Despite these limitations in regards to evaluating the User Experience, there seemed to be a range of positive tendencies, in regards to introducing a focus on PE into AT, that highlight the potential benefits of moving AT towards the newer waves of HCI.

6.2.3 The Efficiency of Introducing a Focus on Product Experience into the Design Process

When it comes to the Efficiency [44] of introducing a focus on PE into the AT design process, there seems to be some challenges. Looking at the differences in preparing the prototypes developed for this thesis, it required more time and energy to finalize the PE inspired AT prototype. Even though the traditional AT prototype was appropriated from an already existing design, it is argued that the requirements and opportunities for a purely functional AT requires less user research than the requirements and opportunities for a PE inspired AT prototype. This is due to the fact that a more thorough analysis of the users via video analysis and the Affinity Diagram was needed to design the PE inspired AT prototype.

6.2.4 Transferability of the Findings

Even though the students in this user group are relatively different, this specific group is relatively small and does not necessarily represent the average user of an AT. Potential AT users can range from Student 2 who, as mentioned, has a severe degree of impairment, to a veteran who lost a leg or an arm, but who is not impaired in any other way. Therefore, it is difficult to make any general assumptions in regards to how the introduction of a focus on PE more generally impacts the usage of Assistive Technologies. For this reason, it is difficult to transfer the findings of this research to the general field of AT, and even more difficult to other fields. However, as Hedvall [28] and Frauenberger [22] argue, there does seem to be a wish to move the AT field forward in the waves of HCI, and this study suggests that they are correct, at least for this specific group of users, in this specific context.

6.2.5 Limitations and Overall Confidence of the Findings

The findings from the comparative analysis of the two developed prototypes do indicate a difference in the usage of the two prototypes, in favor of the PE inspired AT prototype. Despite this, the findings do have some limitations. A few of these limitations are related to the evaluation of the prototype in situ. First of all, it was concluded during the pilot study that the Hawthorne effect [48, p. 641] had a big impact when evaluating or doing empirical studies with these users. For the best possible evaluations, none of the researchers should have been present in the room during the sessions, but because of technical challenges in regards to the Touch & Play system and the cursor, one researcher had to be present during the evaluations. This leads to a limitation in regards to the findings, since the researcher's presence might have influenced how the sessions panned out. To minimize the effect of the researcher being present, he was situated quietly in a corner of the room, out of sight of the students. Only in very few instances did the students seem to be distracted by the presence of the researcher, which leaves the findings in good credibility, but his presence should be regarded as a limitation, and should be kept in mind nonetheless.

Secondly, the employees play a large role in how the students act during the sessions. Since the students are highly influenced by the guidance of the employees, how the prototypes are understood by the employees will in turn have a large impact on how the students understand the prototypes. An example of this, is when Student 4 initially pressed the drums of the PE inspired AT prototype, instead of using the foam rods as drumsticks, because the employee explicitly told her to "press the drums" instead of telling her to use the drumsticks.

Thirdly, the students who participated in the design process are very different from each other, both in regards to cognitive abilities and motor skills, but also in regards to their personal preferences. This means that it is difficult to say anything concrete in regards to general findings. However, since more positive tendencies were found for all students when interacting with the PE inspired AT prototype, than with the traditional AT prototype, we get the impression that they liked the experience mediated by the PE inspired AT prototype better. As mentioned, in addition to the students differing a lot from each other, the students' moods vary from day to day, which might mean different results on different days. Student 5 appeared to have a somewhat negative attitude and wanted to go home at first during the second testing session of the PE inspired AT prototype, but ended up being engaged and actually exclaimed that she wanted to stay and keep playing the drums. This gives us the impression that the PE inspired AT prototype has the ability to positively affect the mood of at least one of the students. A feat that the traditional AT prototype could not claim for Student 5, when tested.

Fourthly, the PE inspired AT prototype was designed to be modular to enable sharing of the interface between the students. Unfortunately no circumstance where this feature was utilized came up, due to the spontaneousness of the activities chosen during the sessions. For this reason we cannot conclude anything in relation to this specific design feature, but as was observed on multiple occasions, social situations still occurred around the PE inspired AT prototype, during the drum along sessions with music videos. These were also the periods where the most positive emotions and amount of fun was observed, which gives the impression that social interaction is indeed important, when designing for this specific context. Furthermore the drum kit, in its nature as a musical instrument, achieved the social aspect, though not in the way originally intended.

Fifthly, the chronological order of the testing sessions, and the fact that the use of color mapping of the drums was inspired by the color mapping of the buttons from the traditional AT prototype, could potentially have influenced how fast the students appropriated the PE inspired AT prototype.

Sixthly, it was observed, and confirmed via interviews with the employees, that Student 2 was able to physically interact with Touch & Play via the traditional AT prototype, which was not previously observed without it. As a way of letting him physically participate in the interaction with the PE inspired AT prototype, the detachable drums could be placed in front of him, on the tray of his power wheelchair. Unfortunately, and as mentioned before, an opportunity to test this feature never occurred, which means that we cannot conclude anything in regards to how the PE inspired AT prototype could be independently used by this particular student. In turn, this means that the traditional AT prototype might be more usable by this student, but further testing of the PE inspired AT prototype would be needed to conclude anything in this regard.

Lastly, the applications used during the Touch & Play sessions are determined by what the students want, or by what is decided by the employees, which means the decision was out of the control of the researchers during the testing sessions. As described earlier in the thesis, the students' favourite application is an application that allows them to watch music videos, and in part because of this, the PE inspired AT prototype was designed as a musical instrument. The prototype was designed in such a way that it would be possible to control all the applications observed to be used the most, but the emphasis was on music. Since the actual choice of application was out of the hands of the researchers, situations where the prototype might not make sense to use could potentially appear. From the video analysis, a tendency was observed that the general usage of Touch & Play moved towards more music, instead of games and other applications. The PE inspired AT prototype might have had an influence of the usage in this regard, but the tendency was also observed in the pilot study, which yields the possibility that the employees wanted to demonstrate and test functionality as broadly as possible in the beginning for the sake of the research, and that they have a natural tendency to move gradually towards more music.

Based on these limitations, it is difficult to conclude anything general in regards to confidence. To reach a definitive level of confidence, a more comprehensive study would be needed. This will be elaborated further in section 6.3. What can, however, be concluded with confidence from these findings, is that there appears to be a clear tendency towards more positive emotions and experiences with the PE inspired AT prototype.

6.3 Potential for Future Work

For future work with the introduction of a focus on PE into AT, it would, as previously mentioned, be interesting to conduct a more comprehensive study. Such a study could involve more control over the variables, e.g. applications used and users present, and be conducted in different contexts. This could also uncover whether some of the positive aspects, found when testing the PE inspired AT prototype would persist or diminish over time. When asked, the employees said that they would definitely use the prototypes if they had them at their disposal, but since the employees might also be influenced by the novelty of the prototypes, this attitude could potentially also change over time.

The use of Cultural Probes could potentially be beneficial since, during the pilot study, such probes provided insight into scenarios of use that were not anticipated. Conducting a Cultural Probe study could not only contribute findings and knowledge about how the prototypes were appropriated and in what context they were used, but could also give a better indication of whether the students and employees maintain their interest in using the prototypes.

A finding regarding the PE inspired AT prototype, in the context of a class on communication and motor skills, was that it matched the learning goals and intentions of the class well. In the class they used Touch & Play to exercise their cognitive abilities through puzzles and the social setting, and physical abilities through games requiring movement and some degree of precision. As mentioned by the employees, the PE inspired AT prototype offered aspects that could be incorporated in the class:

Employee 2 (From PE2 Test): *"It's a festive touch, but not just fun and games, there is actually quite a lot to it. Eh, I mean, there's both the social, there's the motoric, and there's the cognitive in that you can look at it. So it pays out very well, in all aspects."*

Furthermore, as explained earlier, the employees could imagine scenarios where the PE inspired AT prototype by itself could be used in a learning context, for example to practice distinguishing colors. This could potentially be one way of letting the prototype evolve over time, by e.g. letting the employees change the color of the drums, once the students had mastered the basic colors.

On a different note, it would be interesting to develop more PE inspired prototypes for other subgroups of users that need Assistive Technologies. As mentioned earlier, the transferability of the findings from the thesis is rather low, without having tested the hypothesis on a broader range of users. This would also help raise the confidence of the findings. Furthermore, for this thesis, an appropriated design- and evaluation-methodology consisting of certain elements from ethnography, ethnomethodology and User-Centered Design was argued for, based primarily on findings from the pilot study. Working with this particular user group means dealing with certain limitations in communication and therefore which methods can be utilized, which in turn means using a strict Participatory Design approach, as suggested by Frauenberger, would not be possible. Since direct communication with the main users of the prototypes is not possible, doing Participatory Design, and including them in the development of the prototypes, would not be an option. Doing an investigation of the impact of a focus on PE factors in Assistive Technologies with a group of users with less severe impairments could allow the use of Participatory Design, and could yield additional results and elaborate further on the investigated impact.

6.4 Summary of the Discussion

To conclude the discussion, the research presents some clear tendencies in the findings; namely more engagement, more social interaction, and a more enjoyable experience in general. This makes the research of this thesis a stepping stone for further research on how to advance the field of designing AT; an advance that seems to be sought after by researchers such as Hedvall [28] and Frauenberger [22].

The research also meets the problem-solving criteria to some degree, especially Significance and Effectiveness, which means that the research is not without value to the field. The overall Problem-Solving Capacity of the research conducted for this thesis can not be deemed conclusively, since the findings are not yet generalizable enough to raise the overall Problem-Solving Capacity of the field of HCI.

Chapter 7

Conclusion

This section will conclude on the research conducted for this thesis, as well as the findings, limitations and potential for future work.

A pilot study conducted with the students at the STU Center indicated that the primary aspects leading to enjoyable interaction with Touch & Play were three qualities connected to the concept of Product Experience: Touch & Play at the STU Center mediated interaction, that (1) helps the students feel included, (2) strengthens the social relationships between the students, and (3) allows them to feel heard. Since Touch & Play was developed as a tool, aiming to facilitate learning in communication and motor skills, this finding was surprising and indicated that other aspects are more important and pleasing to these students, in this particular context. Based on this finding, this thesis aimed at investigating the following research question:

How can the introduction of a focus on Product Experience impact the usage of Assistive Technology?

The research question has been investigated through the development and evaluation of two Assistive Technology prototypes, that targeted the same usability challenge:

Due to most of the students either being bound to a wheelchair or having limited gross motor skills, the dimensions and vertical position of the touchscreen, made it difficult or impossible for the students to use it by themselves.

The traditional Assistive Technology prototype was purely built to extend functional capability, and the Product Experience inspired Assistive Technology prototype was built to extend functional capability, while having a focus on enhancing Product Experience qualities. The design of the traditional Assistive Technology prototype was based on an existing product, and is therefore seen more as evolution than development. The design of the Product Experience inspired Assistive Technology prototype required a survey of the field of Human-Computing Interaction, more specifically third wave Human-Computer Interaction and the related experience aspects.

This prototype was built to enhance the students' experiences while interacting with the prototype, using a series of design guidelines found while surveying the field of Human-Computer Interaction.

In summary, the answer to the research question is threefold.

(1) The introduction of a focus on Product Experience into Assistive Technology offers interaction possibilities that enhance the amount of social interaction during the sessions with Touch & Play. The Product Experience inspired Assistive Technology prototype facilitated more social interaction between the students, but also between students and employees. During the evaluation sessions, the large amount of social interaction was observed to include both the active student and the spectating students who were often smitten by the mood of the engaged students and employees.

(2) Both prototypes were observed to have a positive effect on the engagement level of the students. The prototypes were quickly appropriated by the students, which indicates a mild learning curve, and thereby more time to actively engage themselves with the applications in Touch & Play, and the prototypes. During the testing sessions, the Product Experience inspired Assistive Technology prototype was observed to have a positive effect on the students' ability to concentrate for extended periods of time. In addition to this, the students were more engaged with the Product Experience inspired Assistive Technology prototype than the purely functional traditional Assistive Technology prototype. This effect is hypothesized to be due to the additional focus on Product Experience, facilitated through visual and auditory feedback, as well as the ability to creatively express themselves, by playing drums while listening to their favorite music. Furthermore this effect is emphasized by quantitative data revealing that the employees had to overtake and finish tasks for the students less with the Product Experience inspired Assistive Technology prototype than with the traditional Assistive Technology prototype.

(3) Introducing a focus on Product Experience into Assistive Technology seems to create a more enjoyable experience. During testing sessions with the Product Experience inspired Assistive Technology prototype, the students seemed to smile and laugh more, and were interested in prolonging the sessions because of the prototype.

Besides the three main findings in regards to the impact a focus on Product Experience can have on the usage of Assistive Technology, there are some additional notes in regards to the design process. When designing Assistive Technology, the user has to be the center of focus, in order to extend functional capability most effectively. During this thesis, to enhance Product Experience, the specific users' concerns have been studied and taken into account, to effectively use custom feedback, metaphors and aesthetics. The knowledge about the students' preferences and feelings has been obtained through observations, video analysis, and expert accounts from the employees. This allowed tailoring the Product Experience inspired Assistive Technology prototype to fit the concerns of the users in this exact context.

However, in order to fully conclude on the long term effect and appropriation of the Product Experience inspired Assistive Technology prototype, the work in this thesis could benefit from a more comprehensive study. This study could incorporate Cultural Probes to, for example, gain additional insights into further use scenarios, and accounts from another source of expert knowledge about these particular users e.g. their families. Though the additional focus on Product Experience makes the design process of an Assistive Technology more challenging, the process is still compatible with a traditional Assistive Technology design process. In conclusion, this thesis has shown that the additional focus on Product Experience in the Assistive Technology design process, can improve User Experience with Assistive Technology, and it is hoped that the work reported here will inspire future research in this area.

Bibliography

[1] Chadia Abras, Diane Maloney-Krichmar, and Jenny Preece. User-centered design. *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, 37(4):445–456, 2004.

[2] Applikator. Touch & play. `http://applikator.dk/touchandplay/`, 2017. Accessed: 2017-06-12.

[3] BJLive! AT. Bjoy button. `http://www.bjliveat.com/access/bjoy-button.html`, 2014. Accessed: 2017-06-12.

[4] ATIA. What is at? `https://www.atia.org/at-resources/what-is-at/`, 2017. Accessed: 2017-06-12.

[5] Liam Bannon. From human factors to human actors: The role of psychology and human-computer interaction studies in system design. *Design at work: Cooperative design of computer systems*, 25:44, 1991.

[6] Rosaline Barbour. *Doing focus groups.* Sage, 2008.

[7] David Benyon, Phil Turner, and Susan Turner. *Designing interactive systems: People, activities, contexts, technologies,.* Pearson Education, 2005.

[8] Susanne Bødker. When second wave hci meets third wave challenges. In *Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles*, pages 1–8. ACM, 2006.

[9] Susanne Bødker. Third-wave hci, 10 years later—participation and sharing. *interactions*, 22(5):24–31, 2015.

[10] Jaimie F Borisoff, Steven G Mason, Ali Bashashati, and Gary E Birch. Brain-computer interface design for asynchronous control applications: improvements to the lf-asd asynchronous brain switch. *IEEE Transactions on Biomedical Engineering*, 51(6):985–992, 2004.

[11] Patrick Carrington, Amy Hurst, and Shaun K Kane. Wearables and chairables: inclusive design of mobile input and output techniques for power wheelchair users. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 3103–3112. ACM, 2014.

[12] John M. Carroll. Human computer interaction - brief intro in the encyclepedia of human-computer interaction.

https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/human-computer-interaction-brief-intro, 2013. Accessed: 2017-06-12.

[13] CAVI. Aarhus by light. http://cavi.au.dk/research/aarhus-by-light/, 2013. Accessed: 2017-06-12.

[14] Nazli Cila. *Metaphors we design by: The use of metaphors in product design*. PhD thesis, TU Delft, Delft University of Technology, 2013.

[15] Roger Coleman and Cherie Lebbon. Inclusive design. *Helen Hamlyn Research Centre, Royal College of Art*, 1999.

[16] Nathan Crilly, James Moultrie, and P John Clarkson. Seeing things: consumer response to the visual domain in product design. *Design studies*, 25(6):547–577, 2004.

[17] Pieter Desmet. *Designing emotions*. Delft University of Technology. Department of Industrial Design, 2002.

[18] Pieter Desmet and Paul Hekkert. Framework of product experience. *International journal of design*, 1(1), 2007.

[19] DFRobot. Dfplayer mini. https://www.dfrobot.com/wiki/index.php/DFPlayer_Mini_SKU:DFR0299, 2016. Accessed: 2017-06-12.

[20] Bella Dicks. Action, experience, communication: three methodological paradigms for researching multimodal and multisensory settings. *Qualitative Research*, 14(6):656–674, 2014.

[21] Karen E Forgrave. Assistive technology: Empowering students with learning disabilities. *The Clearing House*, 75(3):122–126, 2002.

[22] Christopher Frauenberger. Disability and technology: A critical realist perspective. In *Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility*, pages 89–96. ACM, 2015.

[23] William W Gaver. The sonicfinder: An interface that uses auditory icons. *Human-Computer Interaction*, 4(1):67–94, 1989.

[24] James Gips, Margrit Betke, and Philip A DiMattia. Early experiences using visual tracking for computer access by people with profound physical disabilities. In *HCI*, pages 914–918, 2001.

[25] Martyn Hammersley and Paul Atkinson. *Ethnography: Principles in practice*. Routledge, 2007.

[26] Steve Harrison, Deborah Tatar, and Phoebe Sengers. The three paradigms of hci. In *Alt. Chi. Session at the SIGCHI Conference on Human Factors in Computing Systems San Jose, California, USA*, pages 1–18, 2007.

[27] Christian Heath, Jon Hindmarsh, and Paul Luff. *Video in qualitative research*. Sage Publications, 2010.

[28] Per Olof Hedvall. Towards the era of mixed reality: Accessibility meets three waves of hci. In *Symposium of the Austrian HCI and Usability Engineering Group*, pages 264–278. Springer, 2009.

[29] Paul Hekkert. Design aesthetics: principles of pleasure in design. *Psychology science*, 48(2):157, 2006.

[30] Marion A Hersh. The design and evaluation of assistive technology products and devices part 1: Design. *International Encyclopedia of rehabilitation*, 2010.

[31] Karen Holtzblatt, Jessamyn Burns Wendell, and Shelley Wood. *Rapid contextual design: a how-to guide to key techniques for user-centered design*. Elsevier, 2004.

[32] Simeon Keates, P John Clarkson, Lee-Anne Harrison, and Peter Robinson. Towards a practical inclusive design approach. In *Proceedings on the 2000 conference on Universal Usability*, pages 45–52. ACM, 2000.

[33] Simeon Keates, Patrick Langdon, John Clarkson, Peter Robinson, et al. Investigating the use of force feedback for motion-impaired users. In *Proceedings of the 6th ERCIM Workshop*, pages 207–212, 2000.

[34] Steinar Kvale. *Doing interviews*. Sage, 2007.

[35] Effie Lai-Chong Law. The measurability and predictability of user experience. In *Proceedings of the 3rd ACM SIGCHI symposium on Engineering interactive computing systems*, pages 1–10. ACM, 2011.

[36] Simon Madsen and Simon Christensen. Investigating ethnomethodological approaches for users with severe impairments and improvements for an assistive large touchscreen interface. 2017. FOUND IN APPENDIX.

[37] MaKey MaKey. Front page. `http://www.makeymakey.com/`, 2016. Accessed: 2017-06-12.

[38] Steven G Mason, Ziba Bozorgzadeh, and Gary E Birch. The lf-asd brain computer interface: on-line identification of imagined finger flexions in subjects with spinal cord injuries. In *Proceedings of the fourth international ACM conference on Assistive technologies*, pages 109–113. ACM, 2000.

[39] John McCarthy and Peter Wright. Technology as experience. *interactions*, 11(5):42–43, 2004.

[40] Jeanne Nakamura and Mihaly Csikszentmihalyi. Flow theory and research. *Handbook of positive psychology*, pages 195–206, 2009.

[41] Don Norman. *The design of everyday things: Revised and expanded edition*. Basic Books (AZ), 2013.

[42] The Municipality of Aarhus. STU: Aarhus. `https://www.aarhus.dk/da/borger/Beskaeftigelse-og-uddannelse/Uddannelse-for-unge/Saerligt-Tilrettelagt-Ungdomsuddannelse.aspx`, 2017. Accessed: 2017-06-12.

[43] The Congress of the United States of America. Technical Assistance to the States Act, Section 3. https://www.gpo.gov/fdsys/pkg/STATUTE-102/pdf/STATUTE-102-Pg1044.pdf, 1988. Accessed: 2017-06-12.

[44] Antti Oulasvirta and Kasper Hornbæk. Hci research as problem-solving. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 4956–4967. ACM, 2016.

[45] Matthew Pattison and Alex W Stedmon. Inclusive design and human factors: Designing mobile phones for older users. *PsychNology Journal*, 4(3):267–284, 2006.

[46] Marianne Graves Petersen and Peter Krogh. Design articulations for aesthetics of interaction. *4th Designing Pleasurable Products and Interfaces (dppi)*, 2009.

[47] Yvonne Rogers. Hci theory: classical, modern, and contemporary. *Synthesis Lectures on Human-Centered Informatics*, 5(2):1–129, 2012.

[48] Yvonne Rogers, Helen Sharp, and Jenny Preece. *Interaction design: beyond human-computer interaction*. Wiley, 2009. 2nd Edition.

[49] Marcia J Scherer. Outcomes of assistive technology use on quality of life. *Disability and rehabilitation*, 18(9):439–448, 1996.

[50] Kristen Shinohara and Jacob O. Wobbrock. In the shadow of misperception: Assistive technology use and social interactions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, pages 705–714, New York, NY, USA, 2011. ACM.

[51] Sparkfun. Arduino leonardo. https://www.sparkfun.com/products/11286, 2017. Accessed: 2017-06-12.

[52] Sparkfun. Arduino pro micro. https://www.sparkfun.com/products/12640, 2017. Accessed: 2017-06-12.

[53] Sparkfun. Neopixel stick. https://www.sparkfun.com/products/12661, 2017. Accessed: 2017-06-12.

[54] Sparkfun. Piezo element. https://www.sparkfun.com/products/10293, 2017. Accessed: 2017-06-12.

[55] Kazuyoshi Wada, Takanori Shibata, Takashi Asada, and Toshimitsu Musha. Robot therapy for prevention of dementia at home. *Journal of Robotics and Mechatronics*, 19(6):691, 2007.

[56] Mark Weiser. The computer for the 21st century. *Scientific american*, 265(3):94–104, 1991.

[57] Wikipedia. 3d printing. https://en.wikipedia.org/wiki/3D_printing, 2017. Accessed: 2017-06-12.

[58] Wikipedia. Graphical User Interface. https://en.wikipedia.org/wiki/Graphical_user_interface, 2017. Accessed: 2017-06-12.

[59] Wikipedia. Laser cutting. https://en.wikipedia.org/wiki/Laser_cutting, 2017. Accessed: 2017-06-12.

[60] Wikipedia. Next unit of computing. https://en.wikipedia.org/wiki/Next_Unit_of_Computing, 2017. Accessed: 2017-06-12.

[61] Wikipedia. Printed circuit board. https://en.wikipedia.org/wiki/Printed_circuit_board, 2017. Accessed: 2017-06-12.

[62] Jacob O Wobbrock, Htet Htet Aung, Brad A Myers, and Edmund F Lopresti. Integrated text entry from power wheelchairs. *Behaviour & Information Technology*, 24(3):187–203, 2005.

[63] Peter Wright and John McCarthy. Empathy and experience in hci. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 637–646. ACM, 2008.

Appendix

The contents of the appendix of this thesis can be found on the attached flash drive. A table describing the individual folders of the flash drive, as well as the contents of these, can be found below.

Folder	**Contents**
Demo Videos	This folder contains video segments demonstrating the two developed prototypes.
Interview Guide	This folder contains the interview guide used during the interviews following the testing sessions for the developed prototypes.
PACT Analysis	This folder contains the full version of the PACT analysis of Touch & Play in use at the STU Center.
Photos	This folder contains high resolution versions of images that are relevant to this thesis.
References	This folder contains screenshots of all references that might be unavailable online at a later date.
Sketches from Design Process	This folder contains sketches from the PE inspired AT prototype design process.
The Pilot Study	This folder contains the paper describing the pilot study that functioned as a precursor to this thesis.
Transcriptions	This folder contains the transcriptions of passages of interviews that were deemed relevant to this thesis.
Video Analysis	This folder contains documentation for all video analysis conducted for this thesis.