JÖNKÖPING UNIVERSITY
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Haptic enhanced microinteractions

A study of how haptic feedback affects perceived usefulness of microinteractions in handheld touchscreen devices

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Abstract

This research explores how haptic feedback can increase the usefulness of microinteractions on touchscreen devices. With the importance of microinteraction in user daily lives and with the increase of availability of haptic generating devices, this thesis studies how a realistic user group perceive haptic feedback in microinteractions. It studied the perceived usefulness of haptic feedback in correlation to specific microinteractions. Microinteractions are defined as small actions responding to user interaction, examples tested in this study included, simple buttons, radio buttons, checkboxes and dropdown menus. The participants also test and evaluated generic haptic patterns currently available on iOS devices. A software prototype was produced in a prototype tool called Protopie and then tested on an iOS device (iPhone 11 pro).

This study is of qualitative character meaning it relies on qualitative data. The collection method relied on a combination of two types of research methods, usability studies and in-depth interviews. Nine participants were interviewed and studied using these methods. This data was analysed using a qualitative analysis method called Applied Thematic Analysis (ATA). This method allows for the creation of themes to be used in the final discussion of the report. In this thesis, a number of four themes were found. These themes combined with previous haptic principles serve as the academic foundation on which answers to the research questions was made. The results show a general increase in the perceived usefulness of tested microinteractions. With microinteractions such as checkboxes and radio buttons benefitting greatly by the haptic enhancement. The conclusion of the research found several future areas of research within HaXD.

Keywords: Haptic feedback, microinteractions, increased usefulness of microinteractions, enhanced microinteractions, tactile feedback, haptic usability test, HaXD, Haptic experience design, Accessibility.

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1. Introduction

Technological development has undergone a transformation in recent years from developing innovative features and solving systematic issues to focus on quality experiences (Saffer, 2013). The focus and improvement of user satisfaction in technologies have become a major area of research (Shin, 2017). Users now necessitate seamless experiences and have placed sophisticated demands on the quality of their interactions (Richmond, 2017). Companies that are able to meet these demands have a strategic advantage as they increase customer loyalty, repeat purchase behaviour, and increase engagement (Garrett, 2010). Online interactions that place emphasis on collaborative facilitation and social interaction have shown to add to the overall customer experience (Anh Nguyet Diep, 2018). To meet consumers' needs, importance is now placed on designing for quality interactions in areas of functionality and responsiveness.

Microinteractions are the functional interactive details of a product that create interaction responses to a trigger (Saffer, 2013). Despite their small size and near-invisibility, microinteractions are there every time you set an alarm, pick a password, or like something by providing feedback through small, highly contextual (usually visual) changes in the user interface, see fig. 1 (Saffer, 2013). By adding a visual microinteraction as an animation, a button can change appearance to simulate the user pressing down the button (Saffer, 2013).

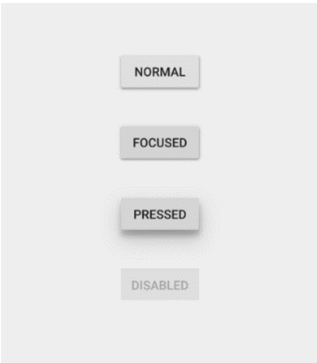

Figure 1. Example of visual microinteractions to help differentiate a button state (Alphabet, 2021)

Although these interactions may seem trivial, microinteractions are experienced by users daily, even on an hourly basis. As microinteractions continue to become an integral part of technical implementation. Research has shown microinteractions can lead to increased engagement, deepening relationships, and increased value to the overall experience users have with a product or service (Lucas, 2017). A lack of or bad implementation of these interactions could lead to the service or product being experienced as frustrating, non-responsive, or overpowering by the users (Richmond, 2017). Therefore, the attention to microinteractions can be the difference between a dull experience to one that is engaging with users (Lucas, 2017). To avoid losing engagement and to continue stimulating interactions with users, designers must consider innovative ways to add interaction with users.

The sensation of touch represents a new technique of interacting with users through small vibrations; part of a design technology called Haptics (Almedia, 2020). Haptics is a key technology found in a variety of electronic devices and are used as a part of the user interface

(Hayward, 2021). This technology aims to enrich interactions, increase trust while increasing interactions with digital experiences (Lucas, 2017; Van Erp & Toet, 2015; Saffer, 2013). While interacting with an application and/or feature, haptics allows users the ability to receive vibrations generated by small vibrating elements called haptic actuators (Rao, 2012). These high-fidelity haptic actuators can generate a wide array of patterns differentiating in the strength, sharpness and frequency of the vibration (Culbertson, Schoor, & Okamura, 2018; Strohmeier & Hornbæk, 2017). Haptic vibration patterns can thus be modified to help users differentiate between different types of notifications or aid in the overall user experience (Case, 2015). Examples of haptics include alerts in a vibrating smartphone or smartwatch, to replacing buttons with force sensors as in cars in attempts to create realistic touch sensations (Hayward, 2021).

Haptics creates a system of affective communication that adds a sense of social context to the interactions between people and digital devices (McLean, 2009). Moving communication from descriptions on a one-dimensional level to engaging with the user more profoundly by creating interactions and reactions (Attari, 2018). The capability of touch can be increasingly applied in interactions with digital devices to allow users to feel more immersed in virtual environments, and add a sense of realistic interactions (Van Erp & Toet, 2015; Self, Van Erp, Eriksson, & Elliott, 2008) The adoption of Haptics can be an effective means of creating engagement, increasing value and deepening relationships with users in impoverished situations as in digital environments (Van Erp & Toet, 2015; Gallace & Spence, 2010).

1.1. Problem statement

Engaging touch in human-computer interactions is involved in various markets from enhancing robotic control and product innovation, to creating realistic virtual environments, assisting in education, and adding to navigation features (Van Erp & Toet, 2015) (Hayward, 2021). With a variety of fields that haptic technology is involved, there continue to be growth opportunities for haptic technology in the foreseeable future (Hayward, 2021).

Most digital interactions rely on distinctive sound patterns or a visual popup assisting users to differentiate an email from a text, so-called visual and auditory feedback cues (McLean, 2009). As digital devices get increasingly entrenched into our daily lives, visual and auditory cues have increased in both fidelity and frequency. These notifications add to the noise that users must endure through their input sensory systems and can lead to negative and/or overpowering interactions (Hansson, Ljungstrand, & Redström, 2001). This has led many users to mute sound on their devices and limit the amount of active visual notifications, essentially decreasing user engagement (Pierce, 2017).

Often underestimated, affective communication as touch provides the ability to process large amounts of abstract information and reduce the risk of visual and auditory overload (Van Erp & Toet, 2015). Interactions aimed towards the touch sensory system have shown to promote a stronger emotional engagement that impacts the decision-making process (Attari, 2018). Research has shown that adding a touch or tactile sensation enhances users perceived social presence (Haans & IJsselsteijn, 2010). Details like these are important since they generate insights into particular patterns of user preferences, behaviour, and interaction activity with digital devices (McDaniel, 2015).

Incorporating haptics into digital devices is not a new concept, with the gaming industry incorporating tactile sensations and force feedback over 40 years ago (Haans & IJsselsteijn, 2010). The haptics industry as a whole involves haptic actuator technology being included in over a billion devices each year (Hayward, 2021). As growth in key industries begins to plateau, companies throughout the value chain are exploring new opportunities where haptics can generate additional value (Hayward, 2021). Current research involves constructing more natural haptics, mimicking different materials and surfaces users naturally encounter (Van Erp & Toet, 2015).

Research has since, under the last six years, identified a significant shift and requirement in developing haptic technologies that are more accessible to users (Hayward, 2021). Companies are seeking to understand where the implementation of haptic features can be instrumental in adding to the overall user experience and user interface in different types of products (Hayward, 2021).

To efficiently evaluate the research gap in haptic technology research, it is essential to focus the investigation on where haptic interactions have the potential to evolve. One of the relatively new areas of haptic research is the combination of haptic technology and interaction design, which creates the field of Haptic Experience Design (HaXD) (Self, Van Erp, Eriksson, & Elliott, 2008). HaXD allows for the possibility to create meaningful haptic driven interactions between the user and the products and/or services offerings (Barsky, 2020; Hutson, 2018). By implementing HaXD on a large scale, as in microinteractions, allows designers to add haptics in areas best suited to stimulate and enhance user interactions (Hutson, 2018; McDaniel, 2015). As microinteractions are experienced by users daily and are a primary feature of users' interaction with the digital, this area represents the largest growth potential of haptic research. By focusing on the value and perceived usefulness of haptic technology can provide in microinteractions, a new area of research is presented.

It is of importance to investigate if the implementation of haptics can lead to increased perceived usefulness for users while strengthening the quality of interactions/engagement in microinteractions. In turn, this provides growth areas for companies engaging in haptic technology (Hayward, 2021; Hutson, 2018). By creating these growth areas and exploring if haptic have the potential to increase user engagement companies have more reason to increase their research, development and implementation of haptics (Hayward, 2021). Which have the potential to create better understanding and better haptics.

1.2. Purpose and research questions

By exploring haptics and haptic feedback this research’s purpose is to add to the practical understanding of the value of haptics. It will do so by investigating how haptic feedback can enhance user engagement. The thesis will focus on a specific aspect of the user interaction process, which is tactile feedback in microinteractions. The research will explore the following research questions:

RQ. 1 How is haptic feedback increasing or decreasing the usefulness of microinteractions?

RQ. 2 What type of microinteractions can benefit from haptic feedback?

RQ. 3 What type of haptic feedback is perceived as increasing and/or decreasing user interaction and engagement?

1.3. Scope and limitations

With haptic research moving at a rapid pace combined with a wide variety of fields where haptic research can be applicable, this thesis will not be able to cover it all. Therefore, this section will describe the scope of research to help bring focus. Additionally, it will describe the delimitations and limitations of this research.

This thesis will focus specifically on Haptic Experience Design (HaXD) which refers to the study of haptic directly involving user experiences and interactions. Therefore, the definition of haptic shall be read as the same as HaXD. This limits this thesis to not cover fields of haptic research that involves other parts not directly involved in UX. It will study HaXD from a user-centric view using qualitative research methods on a small sample. By relying on qualitative data and a small sample this research goal is not to apply this data to generalise larger demographic groups, opinions or thoughts. The research will use this small sample size to test specific microinteractions.

Haptic technology can be applied to a variety of physical and technological devices. This research will only test on handheld touchscreen devices as smartphones. This research will limit its test to only devices using the Operating System called iOS. These limitations are made based on the limitations of the prototype tool. The prototype software is called Protopie, an already existing application that allows the creation of interactable prototypes on several devices. This limits the type of customization of haptic patterns as the software is only able to generate premade patterns. These limitations include the type of haptic pattern that can be generated on each specific OS. Resulting in iOS patterns only being generated on iOS devices and the same for android. Limiting the research to iOS is still deemed sufficient due to the OS number of users and widespread usage. Future research on android based devices is discussed in chapter 6. Conclusions.

All interviews and tests were done on location with the researcher and participants being in the same room. The same device will be used as a prototype device for all the participants. This limited the sample size to a smaller geographical area and participants who were willing to meet the researcher face-to-face, discussed more in detail in chapter 2.1.2. Participant selection

1.4. Disposition

The Disposition allows for readers to gain a general understanding of the structure of this thesis and provides an outline for each chapter.

Chapter 1 - Introduction covers the background of haptics and microinteractions, the research gap in haptic research is identified in the problem statement, the purpose of the study identifies the research questions, and lastly the delimitations are analysed.

Chapter 2 - Method and Implementation illustrates the chosen method and objectives, sampling selection, the data collection techniques of interview and prototype, how the data will be analysed, how this research is considered credible and reliable, concluding with considerations for this research.

Chapter 3 - Theoretical Framework presented important theories concerning established and current haptic research along with identifying key frameworks that aid in understanding the need for this study.

Chapter 4 - Results of the study are introduced as well as the analysis of interview data. Here the coding of key themes from interviews provides the needed results in answering research questions.

Chapter 5 - Discussion is where the results are investigated and important considerations are identified when implementing haptic feedback in microinteractions. Furthermore, the implications of the study are discussed.

Chapter 6 - Conclusion encompass practical and scientific implementations of the findings, and what the research adds to the field of haptic research.

Chapter 7 - References includes the works cited

Chapter 8 - Appendices include additional theoretical information, prototype screenshots, interview transcription data, Thematic Analysis of variables and themes, etc...

2. Method and implementation

To investigate the functionality and desirability of adding haptic feedback in microinteractions, it is crucial to determine what type of research method provides the most insightful information (see fig. 2 for visualisation). In order to understand if users perceive haptic technology as useful, the researcher needs to understand the users underlying reasons, opinions and motivations (Rohrer, 2014). These behaviour traits are best researched by using a qualitative research method. This since qualitative research methods uncover trends in thoughts and opinions of users while diving deeper into where haptic feedback will serve functionality in potential engagement. With the type of research defined the next step is to find a research method that best compliments a qualitative study.

Figure 2. Figure 2 Research Landscape and methods explained, based on work made by Rohe (2013)

The Nielsen Norman Group developed a framework that aims to guide User Experience design (UX) to identify the most suitable approach in user research methods (Rohrer, 2014). By looking at user research through three dimensions, researchers can determine which of the many user research tools are best suited to collect data, see fig. 3 (Rohrer, 2014).

The first dimension is used to segment users' actions and insights by categorising methods as behavioural, what people do, or attitudinal, what people say. To best answer the research questions this study will use a combination of both behavioural and attitudinal.

The second dimension focuses on how data is collected, Qualitative vs Quantitative. Based on this framework, purpose and research questions it was deemed that a qualitative research method would most suitable for this research.

Lastly, the third dimension covers the context of product use. This dimension decides how the research method will be conducted. In this dimension, there is natural, scripted, hybrid and not using a product or service methods. This thesis will rely on a scripted method since the aim is to test a specific technology, haptic feedback, in a specific part of the user interaction, microinteractions.

2.1. Research method

By utilizing Rohre's (2014) framework for user research methods (see appendix 1 for a detailed description of the framework), the method of usability testing was deemed to be the most appropriate. Usability testing consists of three core elements; the researcher, the participant (user) and the task(s) (Moran, 2019).

Tasks represent realistic and probable scenarios in the use of haptic technology (Moran, 2019). Further explained in the prototype section (chapter 2.2.2). Tasks will be instructed to the participant verbally, through spoken instructions from the researcher, and by written instructions (Moran, 2019). This to eliminate misunderstanding due to the complexity of certain haptic tasks. The instructions explain the process to participants when engaging in different haptic scenarios and reduce any confusion.

The researcher's role is to administrate the tasks, observe and interview the participant before, during, and following each task (Moran, 2019). The researcher will ask the participant to describe their line of thought or explain how a certain task is experienced (Moran, 2019). This to gain detailed information concerning users' perception and behaviour. The interview additionally allows the researcher to collect valuable information and qualitative insights from the participant (Moran, 2019). During the experiment, the researcher will inquire about the participant's motives, for example "How was the haptic pattern Disturbing/Useful".

The participant is the user that is going to perform the established task and is the main focus of this type of research (Moran, 2019). The participant should be a realistic user, defined as someone that may already be using haptics or a user from a target group that the product aims to reach (Baxter, Courage, & Caine, 2015). In this study, a realistic user is defined as a user that interacts with a smartphone, is insightful about haptic technology, and uses microinteractions daily. The participant aims to add to the research by assessing the potential implementation and usage of haptic technology in microinteractions.

2.1.1. Usability study objectives

A usability lab study focuses on three main objectives with the intent to address both predictable and unpredictable data points (Moran, 2019). These three objectives include uncovering problems, discovering opportunities and learning more about a user's behaviour and preferences towards haptics (Moran, 2019).

Usability studies allow for the examination of specific haptic interactions by creating scenarios that represent potential implementation areas (Moran, 2019). The usability study used in this thesis allows the testing of specific microinteractions and how specific haptic feedback patterns can enhance these interactions. By asking the participant to reflect verbally throughout the test, the research intends to discover new areas, unforeseen issues and/or opportunities for HaXD. Additionally, it lends itself to further exploration of users' preferences - what type of haptic feedback do participants prefer, and general behavioural characteristics - where haptic feedback in microinteractions can increase or decrease user engagement.

Through understanding users' perspectives concerning haptics, research can help drive research within HaXD. Further, it allows a better understanding of haptic implementation where haptics can lead to increased/decreased user engagement by understanding to whom it matters most - the user.

2.1.2. Participant selection

The sample was selected based on a combination of self-selection sampling and a convenience sampling method (Saunders, Lewis, & Thornhill, 2012). The self-selection sampling approach is applied when there exists an interest in the research topic or consideration for the research to be valuable by participants (Thornhill, Saunders, & Stead, 1997). Self-selection helps improve the response rate and willingness to provide insightful attributes and behavioural variables into haptic research (Sharma, 2017). Convenience sampling means participants were targeted based on availability and convenience to partake in the research study, either through digital channels or geographical location (Saunders, Lewis, & Thornhill, 2012). Both self-sampling and convenience sampling methods are considered the most suited when investigating a new phenomenon as haptics where participants may be uncertain or have low knowledge levels of the research topic (Saunders, Lewis, & Thornhill, 2012).

"For a qualitative usability study of a single user group, we recommend using five participants to uncover the majority of the most common problems in the product" (Moran, 2019, Types of Usability Testing, Qualitative vs. Quantitative, Para. 4). With this qualitative study, the purpose is to uncover and explore initial opportunities and opinions about haptic feedback. A sample of 10 participants was established to generate diversified data to answer research questions and still be feasible within the scope of a bachelor thesis.

2.2. Data collection

As this thesis is an exploratory research, detailed information is gathered to identify solutions or issues in research not clearly established in the field, as discussed by Saunders et.al. (2012). Exploratory studies intend to provide insights into haptic feedback implementation and growth areas in microinteractions. With a lack of previous haptic user research studies to rely on, this thesis will offer insights into the attitudes of users while not intending to offer conclusive solutions to existing problems (Saunders et al., 2012). This thesis relies on primary data collected through interviews and usability tests. This intertwining of usability tests and interviews is an integrated approach that aims to provide a deeper understanding of haptic implementation than single method data collection and analysis (Glogowska, 2011); (Zhang & Creswell, 2013)

In this thesis, the data collection was conducted through three steps using semi-structured interviews and an interactive prototype. First, an initial interview is conducted to establish demographics, prior knowledge of haptics and current usage patterns. Research suggests previous knowledge understanding is a crucial initial step to evaluate the extent of previous knowledge the participant has. This, since a participant with previous knowledge may have developed more biased opinions towards implementation and usage (McDaniel, 2015).

Following this, the participant is asked to perform unique haptic tasks one by one within a prototype. During which the researcher observes participants' responses. Before moving on to the next task the researcher inquires open-ended questions to gain a deeper understanding concerning participants' behaviour and attitudes towards haptics tasks. After the prototype tasks are completed, a final interview is conducted to allow the participant to further elaborate or add any thoughts and opinions. Additionally, the researcher follows up on any opinions and/or statements made by the participant during this final phase. See fig. 4 below for a visualization of the data collection process.

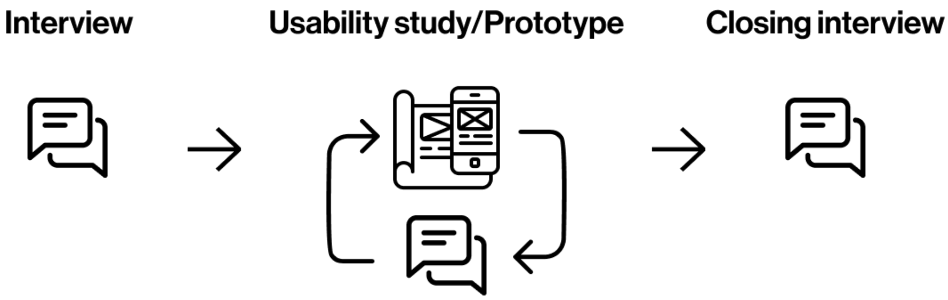

Figure 3. Data collection method visualization

The complete time of collection per participant was between 40-60 minutes, all tests were done in person with the researcher acting as both interviewer and notetaker. The notetaking was assisted by the use of an audio recorder that recorded both the participant and the researcher during the complete interaction with the consent of the participant. The tests were conducted a variety of times during the days and in total 9 participants were interviewed.

2.2.1. Prototype

Protopie is a prototyping tool that can create customised interactive prototypes. Protopie has the ability to work on different operating systems and is easily shared through the Protopie companion app. Other alternatives, as developing a completely custom prototype application through coding or using a framework in combination with coding. These approaches were ultimately rejected mainly as Protopie outperformed both in all aspects. Protopie offered solutions to problems such as interactivity by allowing the research to quickly create, edit and test different prototypes. Protopie additionally limited the amount of time required to learn and create an interactive prototype compared to using code to develop a custom application. By decreasing the time needed to learn and create the prototype more complex and interactive tests could be created and tested. By using Protopie, this research got the ability to create a number of microinteractions that can be used to simulate haptic enhanced microinteractions.

It was advantageous for this research to utilise microinteractions that are commonly understood by participants when experimenting with adding new functionality to interactions or feedback (Saffer, 2013). Buttons, radio buttons, checkboxes and dropdown menus, were therefore chosen as these interactions are established and their function is well-known (Saffer, 2013). As haptic technology needs to be established in areas accessible to a large variety of participants, these microinteractions are deemed most appropriate to test (Hayward, 2021).

The prototype created contained five tasks, each testing a specific microinteraction, where the participant will be asked to perform and evaluate (Description of each task found below).

The first test contained eight numbered squares each with a unique haptic pattern. All squares were identical in terms of shape and colour, with no visual feedback. Different haptic patterns were connected to each numbered square, see fig. 5. The participants were instructed to press one at a time and then describe the pattern, if it symbolized anything to them and what it could be used for in terms of functionality. In this test, all of the six premade Apple haptic patterns that were available in the software were used. Two custom made patterns were also tested, these patterns were designed by the researcher using the premade patterns “iOS Impact soft/medium/hard”.

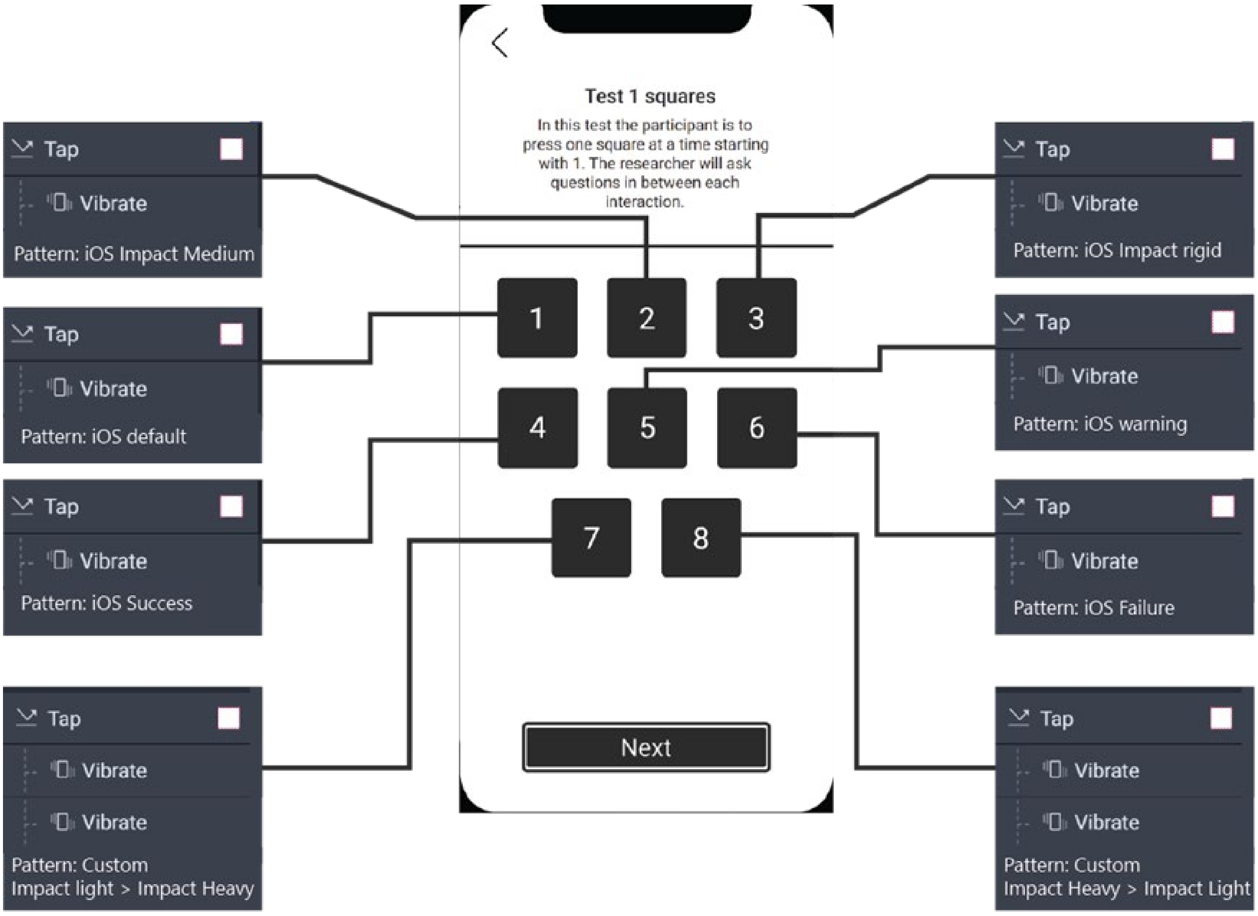

Figure 4. Test 1: Squares haptic pattern chart

In test two, the participant was presented with a set of two buttons, one button is shown with only a frame and the other one being filled, see fig. 6 for the haptic pattern chart. The participants were asked to press one button at a time and then rank the button's usefulness and satisfaction, the researcher then asked questions for the participant to further explain and elaborate on their choices and opinions. The ranking and questions were aimed for the participant to rank the specific pattern connected to this specific button and test.

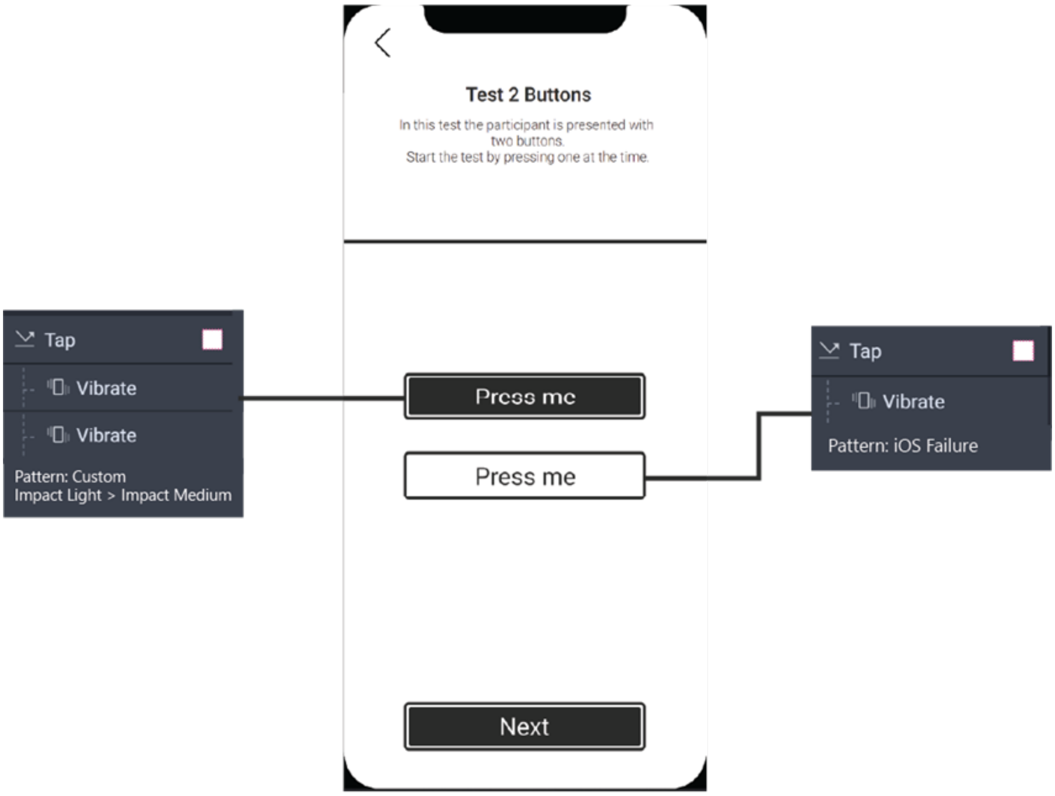

Figure 5. Test 2: Buttons haptic pattern chart

In test three, the participants were presented with a set of five radio buttons, each displaying a season and one displaying none, see fig. 7. All the radio buttons had the same haptic pattern connected to them, both for select and deselect. The participants were instructed to choose their favourite season and when a choice had been made, they were asked to change their selection. A small dot served as a visual feedback to show which season the participant had chosen.

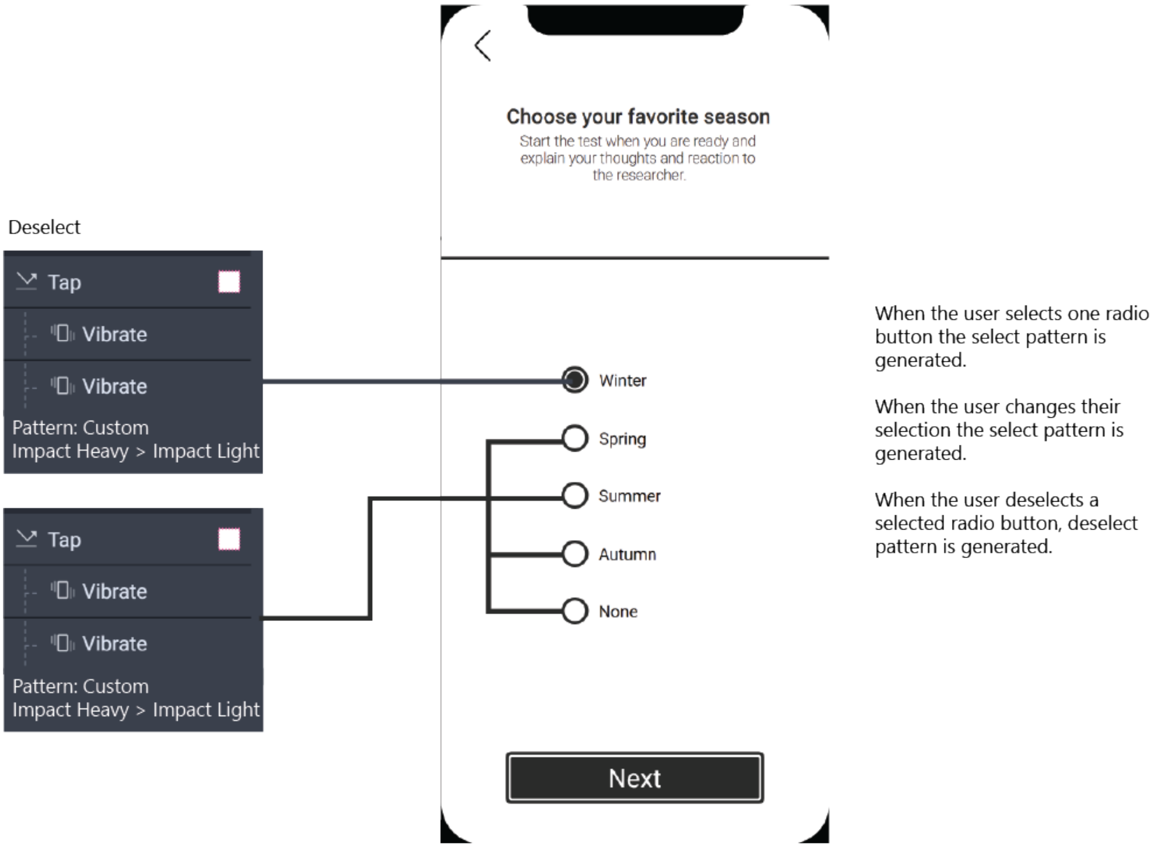

Figure 6. Test 3: Radio buttons

In test four, the participants were presented with six checkboxes with animal names next to them. The participant was instructed to choose four animals. All the checkboxes were connected to the same haptic logic pattern. In this instance, it therefore did not matter which animals were selected or in what order, the logic stayed the same.

The logic was as follows: The first, second and third selections made using the same type of pattern, called the iOS Impact. With a small indifference in the impact, an increase in intensity, for every selection made. The third selection accordingly feels more intense than the second and first. The fourth selection generates the iOS Failure haptic pattern, a different vibration pattern. This was to indicate to the participant the increase in the number of selections. The fourth haptic pattern thus symbolizes that the maximum amount of selections had been reached.

The reasoning behind this test was to investigate if the participant could feel how many selections were made. Furthermore, if by using haptic feedback, instead of a visual feedback, inform a participant that the maximum had been reached. An example of a visual feedback commonly used is to disable the other checkboxes or make them "grey" when max selections are reached for example.

The questions were divided between the two major haptic patterns, with 1-3 using the impact and the fourth selection using iOS failure.

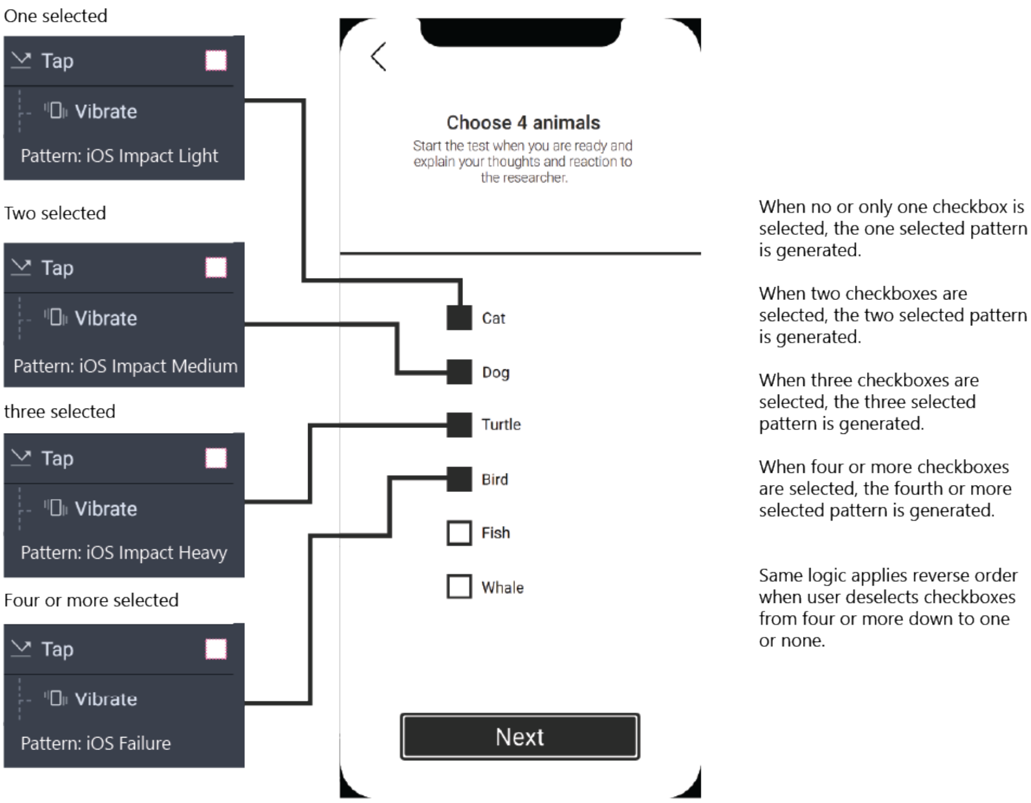

Figure 7. Test 4 Checkboxes screenshot

In test five the participant was presented with a minimalistic dropdown menu with as limited visual aid as possible. The only visual feedback that was created was a short animation opening and closing the list when the user pressed the input field. Two types of haptic were generated, the first being generated when the user opens the dropdown menu Custom 1 iOS Impact light > iOS Impact heavy. The second pattern, Custom 2 iOS Impact Heavy > iOS Light, was generated when the participant selected an item in the list or closed it down by pressing the same input field that opened it.

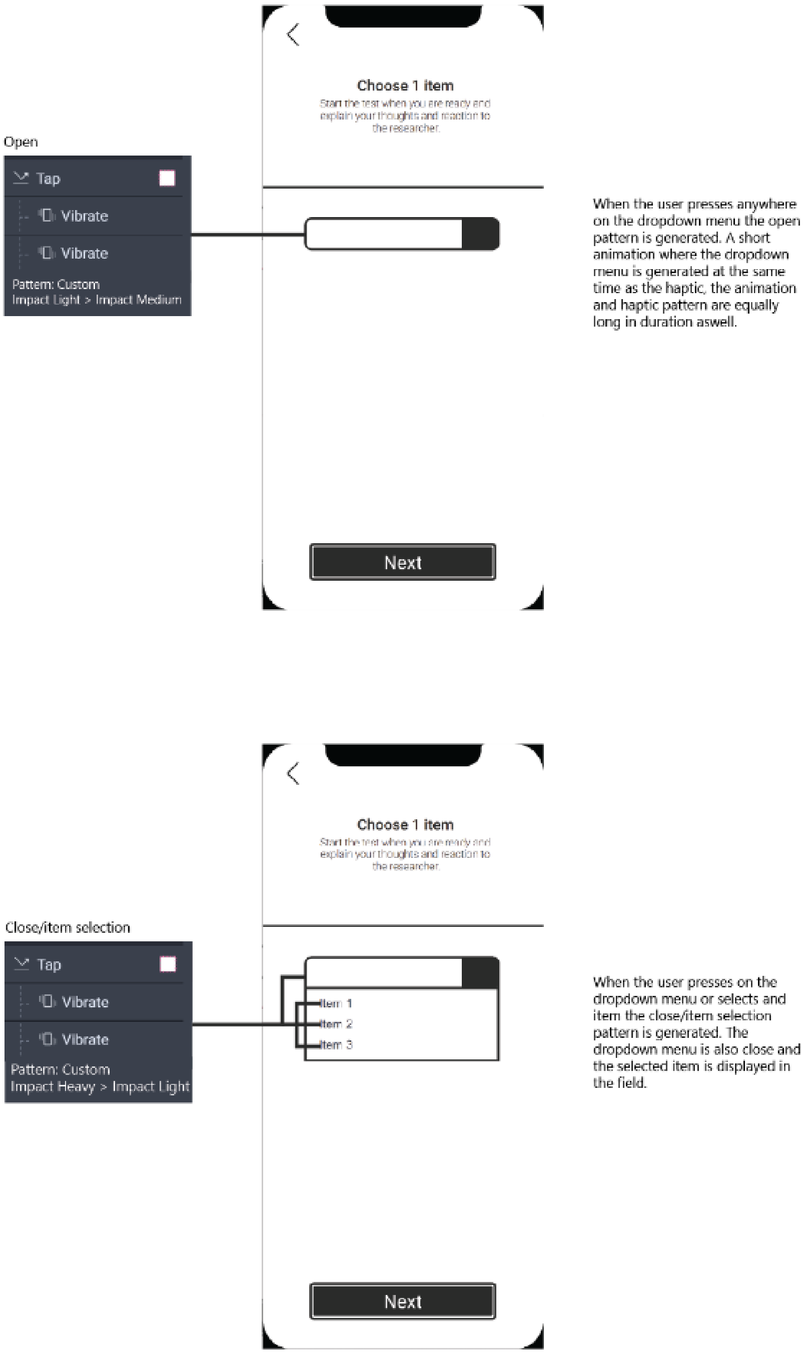

Figure 8. Test 4 Dropdown screenshot

Each task has the purpose of gathering data on haptic feedback patterns when using a specific microinteraction. The tasks are designed to collaborate with basic instincts as it is a human tendency to expect an action to have a reaction (Batchu, 2020). For example, a microinteraction is designed to represent the click of a button and an added tactile response is present. The researcher then interviews users to gather data concerning the perceived usefulness and satisfaction of the haptic feedback.

The design process of the prototype started by exploring the boundaries and limitations of Protopie in terms of haptic feedback and microinteractions. Through this process, it was found that Protopie currently only supports the built-in standard haptic patterns created by Apple, for iOS devices, and Google, for Android devices. With each pattern only being able to be tested on a device using that specific OS. For example, iOS patterns could only be generated on an iOS device. Due to the lack of amount patterns and limited abilities to create custom patterns, Android device testing was rejected. The iOS haptic feedback library did not only contain premade patterns, but also singular vibrations, so-called impacts with different intensity and sharpness. By chaining different types of impacts together a basic form of a custom haptic pattern can be generated. Though this was limited as the only control the researcher has over the patterns is amount, time and with some limitations in intensity and sharpness. After these initial experiments, it was decided to utilize and test on an iOS device.

To limit the feedback the participant received through other sensory systems than haptic, both visual and sound were limited as much as possible. No sound was generated when the user interacted with the device. Visual feedback was kept minimal. No colours were used, except black and white, throughout the prototype and animations are removed. However, some tasks required visual feedback to create basic functionality within the microinteraction and test the connection between haptic and visual feedback.

2.2.2. The interview

To complement the Prototype, a semi-structured interview method was conducted that combines structured questions with unstructured exploration (Wilson, 2014). By conducting a semi-structured interview, it is possible to get a detailed understanding of participants' attitudes and feelings towards the chosen topic (Collis & Hussey, 2014). This type of interview requires less insightful knowledge by participants as the interviewer has a set of specific questions available as a starting point (Wilson, 2014). By utilizing semi-structured questions the interview supports spontaneous investigations that admit the exploration and elaboration of answers which is useful when proceeding with a complex and innovative topic as Haptics (Wilson, 2014), making semi-structured a favourable method for this thesis.

To eliminate the impact of question order as it may impair participant responses, three steps were taken (Schuman & Presser, 1996; Schensul, Schensul, & LeCompte, 1999; Wilson, 2014) Wilson, 2014). Research suggests that first conducting a preliminary structured questionnaire to gather demographic data allows for an initial understanding of the sample (Dillman, 2007). Then a short structured interview is performed before the participant interacts with the prototype. This interview allows the extraction of data on participants' previous knowledge and attitudes regarding haptic feedback and microinteractions. Both these steps allow responses to be gathered that are more reasonably comparable as the same set of questions are asked each participant (Wilson, 2014). This crucial information allows comparisons to be made in data analysis if attitudes and opinions change during the course of the experiment with the prototype. This adds to the credibility and reliability of research comparisons as opinions have been known to alter in the course of experimentation (Dumas and Redish, 1999; Wilson, 2014). As findings of unstructured interviews can be hard to generalise, carefully selected questions in semi-structured interviews allow patterns and attitudes to be detected (Wilson, 2014).

All interviews were recorded using a voice recorder (Olympus dm-650) to document participants' responses, to assist the researcher during the interview. An audio recording of the interviews facilitates the reliability and validity of the research (Rutakumwa, o.a., 2020). By having an audio recording of the complete interview, the researcher could primarily focus on the participants' answers and reactions. Furthermore, the researcher noted any behavioural and attitudinal actions in a Word document, so comparisons in these aspects can be taken into account (Wilson, 2014). This adds to the research since aggregation, frustration and/or confusion might be expressed through actions rather than verbal reflections (Fowler & Mangione, 1990). To eliminate guiding answers, the researcher used neutral prompts promoting individual reflections by participants (Wilson, 2014). As

- “describe verbally what you thought of this haptic sensation”
- “could you explain a bit more what you meant by”
- “how do you feel about..”

During the usability test, the researcher continually interviewed the participant using this semi-structured approach combining closed-end questions and open-end reflections. The main goal of usability tests and interviews is to gather data on how the participant perceived the task, the usefulness of the haptic feedback and how the haptic feedback enhanced a microinteraction. This allows the participant to express thoughts and concerns, which reveal problems or opportunities previously unknown to research in haptics. The closed-ended questions were based on factors such as the usability of a specific haptic sensation, the ease of use and the overall satisfaction experienced on a scale of 1-8. According to Wilson (2014), structured questions on an 8 point system are applicable for new innovative investigation when uncertainties exist. Then the interview continues to ask the participant to reflect in their own words concerning the general experience and where the implementation of this haptic sensation could be useful. These questions allow in-depth qualitative information that adds to the scope of haptic research. As anonymity is an important concept in semi-structured interviews, each participant is given a number to eliminate any personal data and subjects remain confidential (Wilson, 2014).

When the participants have completed all tasks within the prototype, a finalizing interview is conducted using a set of open-ended questions. This is done to minimise the risk of missing thoughts or opinions by asking the participant to contemplate all the tasks and reflect on the total experience (Dillman, 2007). These questions serve as a way to dig deeper into specific parts of the test, thoughts that the participant might have, or tie up loose ends.

Interviewing the participant before, during and after the prototype experiment is a valid approach and is the foundation of usability testing as a method (Moran, 2019). Additionally, utilizing both close-ended and open-ended questions in combination increases reliability and validity (Baxter, Courage, & Caine, 2015; Rohrer, 2014).

2.3. Data analysis

The collected data were analysed using inductive reasoning. Inductive reasoning was utilized to generate meanings from the dataset by identifying patterns and themes in participants' responses (Streefkerk, 2019). The intention of using inductive reasoning is to develop explanations, based on the behaviour and attitudes of participants, and find common patterns in haptics research (Streefkerk, 2019). These explanations assist in formulating theories that in turn can help answer the research questions (Bernard, 2011; Streefkerk, 2019). This approach is applicable in this thesis due to the scarcity of previous research on how haptic feedback can add to the field of microinteractions.

With the qualitative type of data collected, a Qualitative Data Analysis (QDA) method is optimal for analysing the data. QDA methods assisted with filtering, analysing and understanding the opinions, thoughts and behaviour of the participant in order to draw conclusions (Guest, MacQueen, & Namey, 2012). QDA focused on analysing behavioural and attitudinal data from transcriptions, audio recordings, and interviews etc (Guest, MacQueen, & Namey, 2012).

This dissertation employed a method within QDA called Applied thematic analysis (ATA). ATA's primary concern is to present and analyse the participants' opinions, thoughts, and experiences as accurately and comprehensively as possible (Guest, MacQueen, & Namey, 2012). The analysis method does this by focusing and describing themes within the dataset, using both explicit and implicit data (Guest, MacQueen, & Namey, 2012). Through utilizing the ATA, the research was able to identify patterns and suggest possible explanations in order to formulate theories about haptics within microinteractions (Guest, MacQueen, & Namey, 2012).

2.3.1. Transcribing process

The collected data was first transcribed, converting all audio files into text form (Guest, MacQueen, & Namey, 2012). To assist the research process, an AI-driven transcript software Trint was used to create a written transcript of the audio file (Trint, 2021). Trint uses a transcript method called verbatim transcription that transcribes every word, pause, stutter, and filler word, such as “ahs” and “ums”(Guest, MacQueen, & Namey, 2012). This method generates a very detailed transcript, but the transcript is cluttered with misinterpreted words, stuttering or repeating sentences. Therefore, Trint provides the ability to manually correct any misunderstanding in the transcribing process. This is done manually by the researcher using an additional method called intelligent transcript method (Flick, 2013). The intelligent transcript method excludes pauses and keeps only the relevant filler words, significant pauses (confusion, negative sighs) that are applicable (Flick, 2013). This is utilised as the first step in screening and segmenting the data, without risk of losing important data that can aid the ATA theory. This transcript is then exported as a text file for analysis and coding.

2.3.2. Coding

To better organize and get an overview of all the collected data were imported into a qualitative analysis software (short CAQDAS) for further organization and labelling. When the data is organized the researcher starts coding the data, which is used to create summary markers that can later be analysed (Guest, MacQueen, & Namey, 2012). Coding is essential in forming and establishing themes to draw conclusions in the raw data (Guest, MacQueen, & Namey, 2012). The process allows interview questions and answers, specific phrases made by the participant, or other insightful data to be marked and categorized. By using these markers and codes, themes and patterns can be generated. More in-depth analysis of the coding of the collected data in this research is presented in section 4 Results.

2.3.3. Perceived usefulness and perceived ease-of-use

With the research purpose to evaluate haptics ability to affect the usefulness and user engagement, it will need a set of keywords. These keywords were used throughout the data collection phase to generate comparable data between the participants. These keywords were based on an academically proven theory called the Technological Acceptance Model (TAM), created by Davis in 1989. This model was chosen due to its focus on novel technological acceptance and can be employed as a metric for understanding the potential usefulness (useful) and ease of use (satisfying) of haptic feedback patterns in microinteractions. TAM has been used as a foundation for several academic papers and is a commonly known model in many fields of research (Hong, Hwang, H., W.-T., & Chen, 2011; Cheung & Vogel, 2012; Kowalczuk, 2018), and is used to define the usefulness of a product or service (Davis, 1989).

In TAM, Davis (1989) describes perceived usefulness as the tendency that users will or will not use an application, based on the belief that the application will aid them or not (Davis, 1989). Within the research of haptic feedback, perceived usefulness is placed on one end of the spectrum, using the keyword ”useful” to describe when a feedback is impacting the interaction positive, adding functional value to the interaction. Disturbing is placed on the other end of this spectrum, when a feedback is impacting the interaction negatively.

The second investigation metric from the TAM model is called the satisfying spectrum, which can be interpreted as the perceived ease of use in the TAM (Davis, 1989). Where satisfying was used to describe a pattern or interaction as gratifying and comfortable, adding a positive connection. On the other end of the spectrum is Annoying. Annoying is used to describe when an interaction was perceived as irritating, aggravating by the user, or creating discomfort.

These two spectrums are meant to work independently from each other, meaning a haptic pattern can be perceived as useful as it adds to the interaction, but the participant might perceive the pattern itself as annoying, as the pattern was not to their individual liking. A good comparison would be an alarm clock, it is useful but not pleasant. Similarly, a pattern can be perceived as disturbing, as negatively impacts the interaction in terms of usefulness. The pattern itself can however be perceived as satisfying, as in the pattern is perceived as feeling nice or generating a positive connection. The distinction was explained to the users before answering questions in order to effectively answer the research questions proposed in this study.

2.4. Validity and reliability

In qualitative data, researchers express validity and reliability by using terms as trustworthiness, transparency, plausibility and confirmability that gain traction as being more representative of interview data (Winter, 2000; Tashakkori & Teddlie, 2003; Onwuegbuzie & Johnson, 2006). This is achieved through transparency, detailed reasoning and description of the tools used to collect and analyse the data (Guest, MacQueen, & Namey, 2012). The importance of these findings is that credible conclusions can be identified that allow understanding of the implementation of haptics in microinteractions and whether this haptic phenomenon is preferred or rejected by participants.

Even though qualitative research methods naturally have lower reliability than quantitative research methods, the ATA creates plausibility through its credible and transparent way of analysing data (Guest, MacQueen, & Namey, 2012). ATA allows for themes to be identified that reflect the authentic opinions under consideration, increasing the accuracy and adherence to the data and findings (Babbie, 1990; Bernard H. R., 2000). The goal of ATA is to increase the degree to which themes can accurately be identified and measure the opinions of participants towards haptics. With the data collected being based on personal opinions by each participant, the researcher acknowledges that the exact replication of answers and opinions will not be possible. Analysing the data using ATA and coding specific themes to draw conclusions increases the plausibility and legitimacy of the study, as these themes can be used to explore haptics on a large scale (Guest, MacQueen, & Namey, 2012). As opinions of haptics continue to grow and develop with more devices being added the context may change. To increase consistency and conscientiousness, future research can be conducted by using similar collection methods and analysis utilizing the same codes and themes created for this study with new participants (Guest, MacQueen, & Namey, 2012). Interview questions and answers, alongside screenshots of the used prototype, collection and analysis methods (found in section 4 results) used in this usability study are included to increase reliability. It is important to emphasize that the goal of qualitative research is to provide descriptive data concerning haptic feedback and is imperative for credible methodological rigour (Bernard, 2000)

By relying on proven valid collection methods, detailed descriptions, arguments, and explanations in the thesis design process, the research is considered reliable. Furthermore, secondary sources were used to increase research reliability (Saunders, Lewis, & Thornhill, 2012). Secondary sources as online journals, industry research, and market perspectives ranging from the years 1990 to 2021 were included to build the basis for validity. This is considered compulsory for all types of studies in order to support findings and minimize possible errors in methodology choices, sampling and appropriate time scale (Saunders, Lewis, & Thornhill, 2012). Furthermore, the rationale behind combining usability testing, interviews and data sources (academia) is that by accumulating multiple reference points, researchers minimize intrinsic bias from single methods and theory studies (Guest, MacQueen, & Namey, 2012).

2.5. Considerations

Throughout this study, a number of considerations were taken in order to eliminate any potential misunderstandings and minimize the possible errors when adopting the methodology (Saunders, Lewis, & Thornhill, 2012). The considerations undertaken in this thesis were ethical, environmental and scientific analysis. This through identifying important issues as minimizing researcher bias, accumulating detailed qualitative data in participant opinions and ethical issues related to sampling.

During the data collection participants were informed about the outlines of the test, that the interview and test were completely voluntary, and that total anonymity was applied to the participants' answers and opinions. Furthermore, the participants were informed that they could withdraw their consent and quit the test at any point by simply informing the researcher. These ethical considerations are key to this thesis to verify that the participant does not feel pressured into partaking in the test, additionally, it minimises the risk of participant bias.

To increase reliability extra attention has been placed on identifying and acknowledging any biases pronounced by the researcher or participant. Careful attention was placed on limiting the researcher's biases during the methodology process and limiting any external influence on participants and comparable findings (Guest, MacQueen, & Namey, 2012). The researcher bias was addressed in the data collection phase through neutral questions and responses to the participants (Section 2.2 Interview and Prototype). The participants' biases were minimised by ensuring the participants that a negative response or no response is still useful. This to increase trustworthy answers and that no constraint was placed on answering questions. Research supports that informing participants that any answer, whether positive or negative, does not affect the research context (Guest, MacQueen, & Namey, 2012). This gives participants the freedom to provide more informative responses without any external pressure to answer a certain way. This decreases the likelihood of participants wanting to answer “correctly" in line with the study and increases the degree of transparency within the study (Guest, MacQueen, & Namey, 2012).

3.Theoretical framework

Due to the novelty of haptic feedback and HaXD previous knowledge is scarce. With this research aimed towards designers wanting to expand their knowledge, this chapter will start by explaining haptic technology and HaXD. Followed by an explanation of the principles that will serve as keystones in this research. A further explanation of microinteractions and their importance will finish the theoretical framework. All these parts together serve as the foundation of this research and are therefore vital to be thoroughly explained.

3.1. Haptic technology - the industry and purpose

Simply put, haptic feedback is vibration generated by a haptic actuator through the use of electronics and mechanics (Müller, 2020). With this research scope being of the user interaction it will not discuss details of the vital physical aspect of haptic feedback and HaXD. However, modern haptic actuators use an array of different methods to generate these vibrations, with all of them having pros and cons (Müller, 2020). Through research, they have shrunk in size, increased precision, and decreased in their power demands (Hayward, 2021). This enables modern haptic actuators to be used in a wide arrange of industries and products, with more to come (Hayward, 2021).

Moving past the novelty of a new technology, haptics has proven to offer more functionality than just being a noticeable feature (Van Erp & Toet, 2015; Haans & IJsselsteijn, 2010). Today haptic actuators can be found in a wide range of industries, spanning from the production industry, the car industry, to medicine, education and the digital electronic industry (Jones, 2018). Corporations such as Apple, Alphabet (Google), Microsoft, and Mercedes are already engaged in research and implementation of haptics (Apple, 2020; Alphabet, 2020; Microsoft, 2017; Daimler, 2018). An illustration is the Taptic engine developed by Apple in 2015 (Apple, 2020). By creating a haptic actuator that can simulate clicks, Apple started using haptic feedback to simulate mechanical switches in a variety of products such as laptops, smartphones, tablets and wearables (Apple, 2020; Case, 2015). Similarly, the adoption of haptics into the automotive industry is now accelerating, from various systems for driver assists/alerts and to the use in infotainment systems (Hayward, 2021).

Haptic technology is still considered to be in an inception phase with more industries considering the technology (Hayward, 2021). Companies today are now creating smaller haptic actuators that can flex and bend, which lends itself perfectly to create new types of services and products that can be enhanced with haptic sensations (Hayward, 2021). This can add value to everyday interactions or even be included in everyday products or services (Hayward, 2021).

Smartphones have been a key market for haptics, allowing the industry to rise to unprecedented sales volumes for actuators (Hayward, 2021). The primary application of haptics has been the haptic display, the vibration function in smartphones (Van Erp & Toet, 2015). Smartphone users worldwide recently surpassed four billion (Kepios, 2020; O'Dea, 2020) and have become an integral part of our daily interactions with technology. Smartphones remain “the critical market for haptics, accounting for over 50% of the total revenue in 2020” (Hayward, 2021).

The next phase in design for haptic technology within smart devices should consider where the implementation of haptics can add the most value (Hayward, 2021).

3.1.1. Tools for Designing Haptics

To design haptic feedback that follows these principles hapticians can alter three main components, granularity, amplitude and timbre (Müller, 2020). Granularity is the time in between the pulses of vibration, also known as the frequency of the pulses (Müller, 2020). Amplitude is describing how strong the haptic feedback should be, the higher amplitude the stronger vibration (Müller, 2020). This is also referred to as intensity. Timbre describes a pattern's sharpness (Müller, 2020). Sharpness is a bit subjective; it defines how rigid a feedback is perceived. The sharper feedback the more distinctly the user perceives it. A lower timbre, the "rounder" and softer the vibration feel (Müller, 2020).

Lastly, there are two types of events called continuous and transient events (Müller, 2020). Continuous events are longer lasting patterns, used when scrolling, or in a game to mention a few examples (Müller, 2020). Transient events are very short and are most common in buttons, switches or other smaller interactions (Müller, 2020).

3.2. Haptic Experience Design (HaXD)

Haptics has today moved from an engineering-focused industry to a user-focused industry thanks to the introduction of Haptic experience design (HaXD) and Haptic interaction design (HaID) (Schneider, MacLean, Swindells, & Booth, 2017). Similar to UX design, HaXD is a multidisciplinary field of design relying on a wide variety of knowledge and research (Schneider, MacLean, Swindells, & Booth, 2017). Simply, HaXD or Haptic UX is a design discipline that researches user experiences and interactions engaged with the touch sensory system as its main way of communication (Schneider, MacLean, Swindells, & Booth, 2017).

Schneider, MacLean, Swindells and Booth (2017) defines HaXD as the

"design (planning, development, and evaluation) of user experiences deliberately connecting interactive technology to one or more perceived senses of touch, possibly as part of a multimodal or multisensory experience."

(Schneider, MacLean, Swindells and Booth, Haptic experience design: What hapticians do and where they need help, International Journal of Human-Computer Studies Volume 107, page 5, 2017)

With HaXD being a relatively new field there is limited research and design knowledge (Jones, 2018), therefore this research will rely on both academic peer-viewed papers together with principles and guidelines made by industry-leading companies. Research such as Mclean (2017) and Müller (2020) will serve as the academic foundation supporting haptic principles. Companies such as Apple and Punchcut are used due to being the most current and up-to-date knowledge concerning haptic experience design principles.

By studying Schneider et.al (2017) research clear connections can be made between their results and principles created by Muller, Apple and Punchcut. Schnider et. Al. (2017) explains

HaXD through a wider scope using haptic experts to find general themes applicable to both hardware and software. Schneider et. Al (2017) research presented a set of definitions of HaXD, challenges to HaXD and future recommendations for HaXD and hapticians. It is best summarized through the overview figure presented in Schneiders et. al(2017) and shown below in fig. 4.

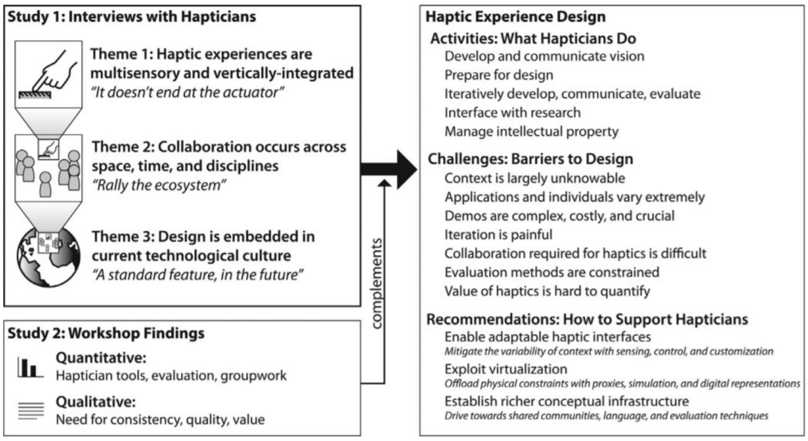

Figure 9. Overview of Schneider et. al process and contributions. (Schneider, MacLean, Swindells, & Booth, 2017)

Some of the challenges found and described in Schneider et.al (2017) research have already been resolved, through research and development of new software and tools for hapticians.

Building upon this, Müller (2020) creates more direct research to create principles that are simple to grasp to lower the learning curve for future HaXD designers. Punchcut (2020) serves as the middleman in this through using Schneider et.al. (2017) research as a foundation combined with gathered experience from within the industry, to create easy to understand haptic principles.

Throughout this process, these themes and principles will be mainly used as guidelines. During the prototype design the models are used as a foundation for the creation of specific tests and how to test haptic patterns. Later in the discussion chapter (see section 5.1) the models serve as an essential aspect of creating and analysing the themes generated by this research in order to effectively answer the purpose and research questions. Each model is explained and provides value to the research study, including the principles and themes identified.

3.2.1. Apple Human Interface guidelines

Apple's haptic principles are a part of its Human Interface Guidelines. These guidelines cover different parts of user experience design and user interface design. Apple's guidelines are created to keep consistency and cohesiveness in their products as a part of their Human interface guidelines. Within Apple's guidelines are a chapter discussing haptics. According to Apple, haptics engages people's sense of touch. The haptic chapter contains a short set of principles, presentations and explanations of the already implemented generic iOS haptic patterns.

Apple's Human interface guideline on haptic principles:

- *Build a clear, causal relationship between each haptic and its trigger.*
- *Use haptics in ways that complement other feedback in your app.*
- *Use haptics judiciously.*
- *Use haptics consistently.*
- *Avoid overusing a haptic.*
- *Be sure to test the haptics in your app.*
- *Make haptics optional.*
- *In a game, consider ways to use custom haptics to enhance the player's experience.*
- *Be conscious that playing haptics might impact other user experiences."*

(Apple, 2021, Human interface guidelines, chap. Designing with Haptics)

3.2.2. Designing with haptics principles

Müller (2020) created a set of principles as a result of their research. This thesis covers both the UX designer aspect and from a product designer standpoint (Müller, 2020). With principles similar to Apple's how a UX designer should think when implementing haptic features. Additionally, Müller covers principles regarding the product design of haptic. In this research the focus will be on the principles covering the software part.

Müller divides the principles into five main parts of the development timeline. These areas are called Planning, Defining, Prototyping, Modulating, and Evaluating (Müller, 2020).

Starting with Planning, which defines vital points that need to be considered before the project starts (Müller, 2020). These three principles cover the physical aspect of implementing haptic feedback into a device, the difficulty of isolating haptic to a specific part of a device, and that a multimodal experience should be considered when possible.

Defining contains principles to consider while framing and specifying the project (Müller, 2020). These principles focus on how the haptic should be perceived. Stating that haptics:

- be differentiated from other surrounding influences,
- replicate existing physical feedback users are already accustomed to
- functionality, characteristics and content should be defined first
- be tailored for the specific body part it intends to communicate through

In the prototype part, the principles focus on the electronic and physical parts of the haptic feedback. Covering the importance of the selection of the correct haptic actuator and driving electronics (Müller, 2020).

Modulating is a key area for this research as it covers the UX design part of haptics. The four principles that are contained in this chapter states that haptic be

- kept short, simple, and consistent
- have coherent characteristics and be perfectly timed
- used with adequate intensity and amount
- clearly differentiate between different haptic sensations.

As with all iterative design haptic also have an Evaluation phase. Here the implemented haptic is evaluated using three principles:

- Evaluate and iterate in multiple instances
- Put it into the final object or material
- Make it work in the final context

3.3. The punchout principles

Punchcut is a user interface company that has worked with multiple big brands, such as Samsung, LG, FitBit, Nissan and Toyota to name a few (Punchcut, 2020). Punchcut has created a set of 10 principles developed through working with haptic in a variety of products.

The punchout principles states that haptic feedback should be:

1. *Keep it simple*
2. *Respond to action.*
3. *Stay consistent*
4. *Give and take*
5. *Think holistically*
6. E*xpand on nature*
7. *Chart the body*
8. *Maintain illusion*
9. *Build bonds*
10. *Address needs*

3.4. Microinteractions

Microinteractions are small and simple, often only doing one thing. Well-designed microinteractions are effortless and near-invisible (Saffer, 2013). However, they serve powerful purposes and without them many features, programs, apps and even physical devices would be hard or even impossible to use (Saffer, 2013). One of the first microinteractions was the electronic button (Saffer, 2013). By pressing this button, a user could do anything from turning on the light in a room to starting the washing machine (Saffer, 2013).

3.4.1. The structure of microinteractions

To create a well-designed microinteraction four different demands are needed to be fulfilled (see fig. 5).

Figure 10 The structure of Microinteractions, (Saffer, 2013)

1. Starting with the trigger which initiates the microinteraction,
2. followed by the rules that define how the interaction should function,
3. feedback provides the user with a reaction about how the stated rules work, and
4. finally loop and modes (termed states).

An example of this could be when a user wants to lower the volume. The user presses the volume down button, which triggers the microinteraction connected to that specific button. When interactions have been triggered by the user and the rules clearly have stated what needs to be done and how, one of the most important steps comes next (Saffer, 2013). The rules state that the volume should be lowered every time the user presses the button. When designing these rules, the designer needs to be aware of many aspects such as the users need, the anticipated function of the specific microinteraction, and how often the interaction will be called, to mention a few.

The feedback part of the microinteraction explains the rules and what was done through metaphors humans more easily can comprehend or relate to (Saffer, 2013). It is a metaphor to help the user understand by comparing it to a physical folder system (Saffer, 2013). This feedback can use many types of ways to communicate with the user through, visual, sound or haptics (Saffer, 2013). With visuals including both static feedbacks, such as pictures or text messages, as well as animated feedbacks, such as small movement of elements (Saffer, 2013).

The loops and modes decide how an interaction should appear after the initial trigger and feedback have been performed (Saffer, 2013). The loop and modes define what purpose the microinteraction serves over time (Saffer, 2013). The microinteraction can be designed to stay in its chosen state, for example, a light switch which will stay on until a new input is made by the user turning it off (Saffer, 2013). Alternatively, the interaction can only be active for a set time or change if the conditions change as a loopable interaction (Saffer, 2013). Sometimes the interaction needs to stay active until the user actively changes its state, such as with a mute button (Saffer, 2013).

Microinteractions thus play a crucial role in a product's overall design philosophy and can add to a brand's recognition from the user (Saffer, 2013). The way a user unlocked the first generations of iPhones is a good example of this. Through the implementation of this new way to unlock your phone, Apple did not manage to only create a useful microinteraction. This microinteraction became so synonymous with the iPhone that users instantly knew they were interacting with an iOS device. Making a simple unlock microinteraction part of Apple's brand.

Microinteractions are a crucial part of a user's experience with a device (Saffer, 2013). Considerations on what type of feedback to use and how to implement it is therefore crucial (Saffer, 2013). Therefore, when combining microinteractions with feedback designers need to start basic and through iterative design create better microinteractions (Saffer, 2013).

4. Results

This chapter will start by present the collected data. The data will be presented through summaries of thoughts and opinions expressed by participants regarding each test and individual question. The data was collected from a total of nine participants through the use of interviews and prototype testing. Following the data collection results is the data analysis where the four themes found through the analysis phase will be presented. The data was analysed using a Thematical Analysis Method (ATA), as described in more detail in chapter 2.

4.1. Data collected

During the interview and prototype tests a set of four keywords were utilized: Useful versus Disturbing, Satisfying versus Annoying. These four types of keywords were based on the TA Model made by Davis (1989), explained in more detail in section 2.2.3.

4.1.1. Previous Knowledge

Data regarding the users' usage patterns, what type of device and what OS they have interacted with was collected as a control since all the participants performed the usability test on an iOS device that used patterns created for the iOS and Apple Taptic engine. It was important to collect data on what OS the participants were using since the interactions and characteristics differ greatly between iOS and Android.

4.1.1.1. Microinteractions

In this part, the participants' previous knowledge regarding microinteractions was collected. None of the participants was familiar with the term of microinteractions, however, after a short explanation, all participants confirmed that they had previously used microinteractions. With sounds and visual types of feedback being the most common amongst the participants.

All participants answered that they had interacted with microinteractions daily and through several devices and products, such as smartphones, smartwatches, vehicles and many more. Most common were microinteractions on smartphones through mobile applications and system features, as social media apps, music apps, changing settings, setting alarms, changing volume, rearrange applications on the start screen etc.

What features do you want to use with microinteraction?

Most participants agreed that microinteractions should be used to generate a feedback or reaction to the user’s interaction. Microinteractions should increase the interactivity with the device. Some participants wanted microinteractions when the user demands something from the device, like a confirmation or warning. Participants also agreed that microinteractions should only be used when they are needed and that the users should have the ability remove certain types of microinteractions, for example sound.

One participant described

"I like that we have come to an age where the quality of my interactions is important. Where you have technology communicating back some sort of response, whether it's a notification or an action. I need to feel the communication with our technology, which is where it will be very useful."

What industries do you think microinteraction could be useful in?

The consensus amongst the participants was that all industries that they could think of could benefit from microinteractions, examples varied from medical, cars, heavy machinery, production, tech, social media, eCommerce and shopping to mention a few. A participant described

"The more industries that add microinteractions, the more we start communicating with our technology. The more interaction technology becomes the more useful it is. So, not only does it have functionality in simple things as password changes but in bigger industries such as medicine - there is a huge potential in a lot of different industries."

4.1.1.2. Haptic feedback

Here participants' previous knowledge with haptic feedback is explored. Here two-thirds of the participants knew the terminology of haptic feedback before presented with a short description and basic examples. All participants claiming to have previous use of haptic feedback, even though they might not have been aware of what it was called or what it was. Most participants recognised haptic feedback as the vibration they feel when they receive a phone call or notification, very few mentioned any previous experiences such as haptic connected with microinteractions or any smaller interactions except notifications and big vibrations. As stated with microinteractions the research needs to understand what previous knowledge or experience of haptic feedback the participants have. It is also important to document how and where participants think haptic feedback could be useful for future research.

How often have you used haptic feedback?

When asked how often the participants have used haptic feedback seven used daily and two used weekly. The participants had previously used haptic feedback on devices such as smartphones, smartwatches, game consoles, household products and vehicles. With the smartphone being the most common device.

Most scenarios where the participants have used haptic feedback is mainly then receiving a call, text message or other notification on their smartphones or smartwatches. Other common scenarios included games on game consoles such as Sony PlayStation or Nintendo Wii.

What features do you want to use with haptic feedback?

Many participants mentioned haptic features as an aid for either sight or sound impaired users when interacting with a touchscreen device. Other major themes included confirmations features, alerts or other attention generating features in mobile applications and during interactions with devices that you can't look at, such as when driving cars or operating a machine. These attention generating features were also mentioned in combination with gaming, console gaming, smartphone gaming etc. Lastly, a few participants mentioned that they would benefit from haptic feedback in the future in smart clothing, home appliances, more feedback in cars. Participants also saw future opportunities for haptic feedback to simulate real-life material and interactions when interacting with Augmented Reality, Virtual Reality or touchscreens to simulate physical dials, switches and buttons.

What industries do you think haptic feedback could be useful in?

Participants mentioned the same or similar answers as to this question for microinteraction, which is that almost any industry could benefit from haptic feedback being implemented. Few examples that were given were cars, medical, entertainment, tech, eCommerce, heavy machinery and production.

4.1.2. Test one: Squares

In this test, the participant was presented with a set of eighth squares. All squares were identical in terms of shape and colour, with no visual feedback. Different haptic patterns were connected to each numbered square, see fig. 5. This test was designed as a warm-up test, to get the participants accustomed to the haptic feedback. After each square, the participant was asked to describe the pattern, if it symbolized anything, and what type of function or usefulness the pattern could have.

Square 1

Description: The participants described this pattern as a single, medium-long, constant vibration. It was perceived both as strong and rough or gentle and positive. One participant mentioned it reminded them of the standard vibration felt on an android device when receiving a call with the phone set to mute.

Symbolize: Participants perceived/symbolized the haptic pattern as an attentive reaction. This in the form of a Warning as do not push this button or a notification. Even used as an attention grabber as a small in-game explosion far away, activation of a device, device starting up or a notification.

Usefulness: Participants identified this as being used as a confirmation when pushing a button, alarm, ringtone vibration, notification, catastrophe area warning, wrong password, driver alert.

Square 2

Description: The participants described this pattern as a Short, very light, single pulse

Symbolize: Typing on a keyboard or typewriter. A participant illustrated that this square had a "mechanical functionality about it".

Usefulness: When typing or interacting with a smartphone. Used as a confirmation, automatic responses and has a push switch feeling. Participants identified that this haptic feedback can be useful when confirming that the user has pressed a button on a touchscreen device. All participants felt that this particular haptic feedback is most useful for multiple single interactions, keypress, when there is a need for short reactions in a short amount of time.

Square 3

Description: Participants expressed this reaction was stronger, felt harsher or more distinct than square two. Could be used to differentiate keys and reactions from one another as on a keyboard by using number two and three vibrations for different keys.

Symbolize: As three participants expressed *"it felt less intensive than number two".* With one participant describing it as
"feels like it can be used in guiding functions like turning/pointing/guiding to the right".

Usefulness: Same as number two. When typing or interacting with a smartphone. Used as a confirmation that the users have pressed a button on a touchscreen device. Useful for multiple interactions, keypress, in a short time.

Square 4

Description: Double pulse, with the second pulse, described as a little more intensive/stronger.

Symbolize: Heartbeat, something bouncing, an echo of interaction, One step forward one step back.

Usefulness: Alerting when missed imputing important information, Alert in a racing game, go back and look for something you missed, incomplete form. One participant expressed that they would appreciate this in medical devices "I would like to feel my heartbeat when checking it on an echo"

Square 5

Description: Two vibrations, similar to square test number four. Participants disagree if it is shorter or longer between vibrations compared to number 4.

Symbolize: Notification, Typing, Check off you did the right thing, move on, error wrong answer, question mark.

Usefulness: Notification when the screen is active, the wrong answer in a test or game.

Square 6

Description: Three or four vibrations, same strength equal spacing. Participants were unclear as to the number of vibrations if it was two, three or four.

Symbolize: This reaction symbolised more concrete actions. As a machine gun in a game, falling down a set of stairs, notification, text message, hurry up, boss fight, end of a level, Positive stress.

Usefulness: Connecting disconnecting a charging cable, unplug something, error message, error 404, power up in a game, symbolize the end of a level.

Square 7

Description: Short with two vibrations, the second reaction was perceived as heavier or more blunt, direct and explicit.

Symbolize: Stumbling, Slider lock on iOS devices, iOS toggle switches, slides and locks in place, warning, end of a page when scrolling, turning off a device.

Usefulness: Shut down, close down applications, check out of an online shop, rearrange applications. As a participant described "short vibrations I always see as something like turning off my phone - like are you sure that you want this when its a bigger action/interaction"

Square 8

Description: This was perceived as similar to number seven. This haptic feedback had two short vibrations. Eight was perceived as quicker and instantaneous than square seven. The second vibration is lighter but slightly stronger than number seven. Essentially the first vibration is heavier while the second vibration is smoother and lighter.

Symbolize: Participants represent this vibration pattern as the end of the story in a game (conclusion), you failed or start over equivalent as number seven. One part of the vibration is up and the second one is down, so it was perceived as dropping something. The first vibration feels firmer/certain, the second vibration felt vaguer.

Usefulness: in a game, connecting a cable. Most participants did not express any more specific usefulness for this interaction.

4.1.3. Test two: Buttons

In this test, the participants were presented with two buttons, one filled in and on with only a border. These two buttons were connected to two different haptic patterns. See fig. 6 for more details. After each interaction, the participants were asked to rank the haptic pattern for each button in terms of usefulness and satisfying. See fig.6 for more details.

4.1.3.1. Button 1

How was the haptic pattern Disturbing vs Useful?

Most participants ranked the usefulness of the haptic pattern connected to button one as more useful than disturbing. With only two participants ranking it lower than 4. Three participants also ranked it as seven which is interpreted as a high degree of usefulness. The participants described the pattern as a good representation of a confirmation that they had initiated an action as pressed the button. Some participants argued that the double vibration should have been "split, so that the first vibration was generated when the participant pressed down the button and the second pattern to be generated when the button is released". Participants additionally mentioned that this pattern would be less useful if it was used in multiple buttons interactions that needed to be pressed in quick succession.

How was the haptic pattern Annoying/Satisfying?

In terms of satisfaction, the participants were divided with only two participants placing the perceived satisfaction of the pattern in the low value of one of the spectrums. Overall, the majority, six participants, agreed that the pattern was profoundly satisfying. The participants described the pattern as a good intensity in terms of strength referring to the pattern as a "gentle vibration that is felt in the right ways" and was not perceived as triggering or troublesome.

Out of the two participants who ranked the pattern as disturbing, one described it as *"skipping the first half of the interaction"*, in which they explained that they would have preferred a vibration split so the first vibration was experienced pressing down the button and while the second vibration was experienced on release. The participant in the middle expressed that "*I like it and I see the satisfaction and usefulness of vibration patterns... but simply did not know if I prefer vibrations connected to these type of microinteractions"*.

What did the haptic pattern symbolize for you?

The participants symbolized this pattern with a confirmation functionality. For example, one participant identified that this pattern was optimal for when a device had "received the input but could not execute the task". More specifically participants identified this haptic feedback to interactions as when completing online forms and not being able to proceed due to missed inputs.

"if you are filling out a form, or trying to close down an application without saving this could be useful, as a reminder. you end something and it's not done correctly. Because normally if you if it's been done right, it should just be one click, like check you are done! But now it is double which feels like oops something's wrong."

Any additional haptic functionality you think would be useful for this interaction? An example is given by a participant when asked what functionality this pattern could have noted *"I feel like I have felt this pattern when trying to move an application on the start screen of my smartphone but not succeeding. Acknowledge that I was indeed doing an action but somehow I made a mistake"*.

Agreeing to this statement two other participants thought the pattern reminded them of a haptic feedback pattern previously felt in iOS devices, but could not connect the pattern to one specific function. Another participant suggested that it could be used when selecting something into a shopping cart. Most participants were unsure of a specific clear suggestion for additional functionality.

4.1.3.2. Button 2

How was the haptic pattern Disturbing/Useful?

The majority of the participants ranked this pattern as more disturbing than useful with four participants ranking it as very or extremely disturbing. Three Participants ranked usefulness as a four. They expressed that they saw some usefulness and functionality. However, they firmly expressed that compared to the first alternative they did not appreciate this haptic pattern. Most participants (seven) described that the pattern felt overwhelming, not making sense in terms of the type of interaction and that it had too many vibrations. As a participant explained, *"it is just too much"*. The strength of the vibrations was generally not the problem as much as the number of vibrations.

How was the haptic pattern Annoying/Satisfying?

Again, participants ranked this pattern low on the satisfaction or simply on the annoying scale with the majority ranking it a three and lower. The participants describe this pattern as annoying with the same or similar reasons given to the usefulness. Overwhelming, not making sense, too many vibrations were a few examples given when asked.

What did the haptic pattern symbolize for you?

Some participants symbolized this pattern as a red flag meaning an interaction that aims to highlight negative actions as wrong passwords, not allowed to press that button, no questions mark more direct.

A participant described

"There's definitely negativity if something went wrong. something didn't open or something. Yes, something didn't open, "you can't do that", it's a nicer slap on the wrist, no question mark."

Another participant mentioned "I feel stressed from it" connecting it to negative emotions and the pressure of feeling stressed.

4.1.4. Test Three: Radio buttons

In test three the participants were asked to make a selection out of five checkboxes, each generating the same haptic feedback on selection and deselection. See fig. 7 for more details

How was the haptic pattern Disturbing/Useful?

Almost all participants ranked this haptic pattern for this microinteraction as useful. With ⅔ of the participants ranking it as very or extremely useful. Participants described the haptic pattern as positive and as a confirmation that a selection had been made. Additionally, the participant who ranked the pattern lower, ranked the pattern as very useful when asked to explain their choice the participant stated

"*I'm not getting any feedback when I press down, I only get feedback when I let go. But that's the same reason as the previous test. But when I changed my option, between one of these or a few of these. Then that two-part vibration kind of makes sense to me*."

How did you perceive the haptic pattern? Annoying or Satisfying?

Five participants ranked the satisfaction of the haptic in the middle, with the pattern not feeling annoying or satisfying. The opinions differentiate extensively due to those that found it useful had varied personal opinions about whether it was satisfying for them.

Participants did express that

"Felt it was as a Reassurance and a gentle nudge. So I definitely find it satisfying but I guess it all depends on what type of interaction. In this instance yes. But using this in other microinteractions. I'm not sure so a maybe (4)"

"I love this one. Just the right frequency and strength."

What did the haptic pattern symbolize for you?

The majority of the participants symbolized this pattern with confirmation. A reaction from the device based on the input from the user. One symbolized it as wrong, mainly because the pattern contained two vibrations and the participants' general opinion is that if it is correct then it should only vibrate once, two vibrations were equal to wrong for this participant. Another participant symbolized the pattern with money transfer or transferring items of value, it made the participant feel secure and safe that the device had confirmed the participant's input.

Any additional haptic functionality you think would be useful for this interaction?

Confirmation that an action has been performed successfully or increasing quantity on an e-commerce web app or cart function.

4.1.5. Test Four: Checkboxes

In test four, the participants were asked to select four checkboxes out of six. Each selection generated a haptic pattern with increased intensity until the fourth selection was made when the iOS Failure pattern, which is four rapid vibrations is generated. This feedback was to symbolize the number of selections made and when the target was reached. The questions were therefore divided between the first 1-3 selections and the fourth selection. See fig. 8 for more details.

4.1.5.1. Checkbox selection 1 - 3

How was the haptic pattern Disturbing/Useful?

Similar to the radio button test (test 3) a majority of the participants felt that the haptic pattern was useful when making the first three selections. With ⅓ of the participants stating it was very useful. Seven participants described this haptic pattern as very useful by providing the participant with a feedback confirming that they had made a selection. Additionally, a few users said the haptic pattern meant that they could focus on other things. Only one participant made a comment about the increase of strength and after realizing this change, altered their ranking to an eight instead of the original rank of six. This participant felt that the increase of intensity helped them understand that they were closing in on the maximum of selections.

”I'm feeling the boundaries with the increased strength that I'm closing in on the maximum value.”

Only one participant ranked it as disturbing with a similar argument to the previous test that the double vibration symbolized that the selected something rather than selecting it.

How was the haptic pattern Annoying/Satisfying?

All participants felt that the pattern was more satisfying with only a few being able to explain why. The participants explained that the haptic was again confirming, made them feel that they had accomplished something or crossed something off a list, others simply found the intensity and number of vibrations being just right. One participant made an extra remark that the increase of intensity when making the first three choices was the key to their high satisfaction ranking. Only one negative remark was made by one participant who wished for a slight increase in intensity.

What did the haptic pattern symbolize for you?

Only a few participants felt that the pattern symbolizes something for them, with one explaining it made them feel happy like the device complimented them. Others only explained it symbolized verification and acceptance.

Any additional haptic functionality you think would be useful for this interaction?
No additional functionality was presented.

4.1.5.2. Checkbox selection 4

How was the haptic pattern Disturbing/Useful?

Most participants found the pattern useful as it was different from the other three previous patterns. Two participants ranked prefer not to answer usefulness at first, but came back to say that the usefulness was five and a six. However, the participants also agreed that the specific pattern chosen was good in that aspect that they did identify the pattern as doing something wrong or faulty.

One participant (ranked 3) explained that *"if there existed a visual feedback the pattern would have made more sense and been perceived as more useful"*

How was the haptic pattern Annoying/Satisfying?

Participants were very split in their opinions in terms of satisfying or annoying. Participants described the pattern as too intense, with too many vibrations, participants felt overwhelmed and some thought they had pressed the checkbox twice. Some participants claimed that the pattern was annoying in a positive way since it helped confirm that they had reached the allowed number of selections. Others felt overwhelmed and explained that the pattern did not fit with the rest and what they expected to feel.

"was annoying because. It doesn't feel like it has any use. You press something one time and the phone vibrates four times. It's like, why? I want to know that I did something wrong but does it need four vibrations.. "

What did the haptic pattern symbolize for you?

No specific symbolism or similar experience was mentioned.

Any additional haptic functionality you think would be useful for this interaction?

One participant wanted this type of functionality or feedback connected to their credit card when they neared or reached their budget limit. Another suggestion was to implement this type of pattern in a game console controller.

4.1.6. Test 5: Dropdown Menu

In test five the participants were presented with a minimalistic dropdown menu containing three items. On opening and closing the menu a haptic pattern was generated. On item selection, a haptic pattern was generated, and the menu closed. See fig. 9 for more details.

How was the haptic pattern Disturbing/Useful?

In terms of ranking, the participants were split, with a small majority ranking it useful. The participants saw it useful as a stamp of approval and confirmation, with some perceived it as overwhelming or unnecessary. One participant felt that the haptic pattern would suit the interaction better if the list was longer or more important, for example, a slideout main menu.

How was the haptic pattern Annoying/Satisfying?

Again, the participants were very divided in their ranking. When asked to explain furthermost participants simply explained the pattern to be nice or ok. With a few explaining that it felt annoying because they already had the visual to confirm their interaction.

4.1.6.1. Test 5: Item Selection

How was the haptic pattern Disturbing/Useful?

A majority of the participants ranked the pattern as useful with most of that majority ranking it as very useful. Participants found the pattern useful since it confirmed that they had made a selection and that the list was closing. A few participants thought the interaction could have been improved if the device generated different patterns depending on what item was selected or if the participant didn't choose an item and closed the menu.

How was the haptic pattern Annoying/Satisfying?

The participants found the pattern satisfying because the pattern fits with the interaction and the visual of the menu closing. Others explained it was unnecessary because there already was haptic feedback when opening the menu. Participants identified the haptic feedback as useful but the pattern itself was annoying. Additionally, one participant felt that if this type of feedback were to be used on multiple dropdown menus it would quickly become annoying in its current state.

Any additional haptic functionality you think would be useful for this interaction?

One participant felt that the haptic feedback would be more useful if it symbolized a sliding effect when the menu opened and closed. Another participant wanted the haptic feedback to be smoother.

4.1.7. Concluding interview

Unique pattern or interaction

The most unique interaction was according to the participants' test four the checkbox test. Many participants felt that it was unique since it used two (correctly 4) different haptic patterns. Which many felt stood out from the rest of the tests.

The most unique patterns were the iOS default and the iOS Failure. iOS default with many participants perceiving it as very different compared to the rest of the patterns, intensive and many symbolized it with warning or alert. The iOS failure was unique with the number of vibrations, four vibrations in total, which the participants felt was overwhelming, hard to feel how many vibrations and symbolized very differently between the participants.

Most useful haptic

The interaction (test) where the haptic feedback was perceived most useful was test number 3 (radio buttons) and test 4 (checkboxes). The participants felt that the use of haptics to confirm their selection and give them feedback that assisted them to know when they reached an allowed maximum were very useful.

Least useful haptic

The iOS failure was mentioned as the least useful and most annoying haptic pattern. With test 5 (the dropdown) haptic being the least useful, because the participants felt that the number of vibrations generated was overwhelming or unnecessary.

4.1.7.1. Haptic usefulness

Would you find haptic feedback useful in our everyday life?

All participants explained that they would find haptic useful in their everyday life. Many participants added that they think haptic would be most useful as a complement to visual feedback. One participant stated that *”haptic feedback lets me know that I have done something, I have selected something. It confirms that I have interacted correctly or incorrectly, I can then use visual feedback to understand what I have done, selected or what have gone wrong.”*

Do you think that haptic feedback increased the usefulness of the tested microinteractions?

All participants agree that they could benefit from haptic feedback in terms of usefulness in their daily lives. Almost all participants agree that the tested microinteractions usefulness increased using haptic feedback.

4.1.7.2. Haptic replacing sound feedback

All participants agreed that haptic feedback can replace sound as a feedback. With haptic being viewed as a suitable replacement to communicate more directly with the user in loud environments where the sound cannot be heard, or in very quiet environments where sound is disturbing. Many participants argued that haptic would help industries and products become useful for people suffering from impaired hearing.

4.1.7.3. Haptic replacing Visual feedback

8/9 participants agreed that haptic could replace visual, however not completely. All participants agreed that haptic could be useful to replace visuals where the user has to use their sight on other tasks, for example when driving. All participants agreed that haptic would aid in making touchscreen devices and other products more accessible for people with impaired sight.

4.2. Data analysis

By applying Applied Thematic Analysis (ATA) to the collected data, four themes were found (see section 2.3 for more details on ATA). Themes were found through analysing the coded participants' answers, rankings, thoughts, and comments made during the interview and usability study. These themes represent a collection of data that is analysed, using the research questions as a guide, to find patterns that when later connected with the theoretical framework drives the discussion in the next chapter.

Identified themes:

- Less is more
- Multimodal preferred
- Haptic is individual
- Accessibility

Each theme is not directly connected to a specific research question, rather each theme represents the organised data that can be utilized to find answers to multiple research questions. By taking research question one as an example. The purpose of these questions was to research if haptic feedback could increase or decrease the usefulness of microinteractions. Themes such as Less is more and the Multimodal preferred contains data that supports different ways that haptic feedback can impact microinteractions. More details of how these themes add to the discussion can be found in chap. 5. Below is a detailed presentation of what each theme represents and what data aided in the conclusion of the theme.

4.2.1. Less is more

The Less is more theme refers to the haptic feedback's power to easily overwhelm a user and how complex haptic patterns often are viewed as decreasing the usefulness. By analysing the data it is clear that the user failed to understand the haptic feedback’s purpose of the more complex patterns. This was seen in tests four and five, where most of the participants felt overwhelmed by longer patterns such as iOS Failure. In test five participants felt the number of interactions generating haptic feedback was too many.

When analysing usability and interview results, it is clear that the patterns or scenarios testing more intricate use of haptic feedback created divided opinions amongst the participants. As seen in tests one, two, four and five. The opinions differentiated concerning the usefulness and functional features of the specific haptic patterns. Haptic patterns that relied on three or more vibrations caused participants to often feel overwhelmed which led to them perceiving the pattern less useful. Within test four there were specific two main types of issue, the first being with the increase in intensity for every selection made. Only one participant noticed the increase of intensity when making several selections. With the rest of the participants thinking the patterns were connected to each specific checkbox.

The second issue was when the participant made their four selections a new type of pattern was generated. This pattern is iOS Failure, which confused the participants by the pattern being so different compared to the previous haptic patterns. Furthermore, the number of vibrations it generated were also seen as less useful. When questioned all the participants ranked the fourth selection pattern (iOS Failure) very low. Only one participant understood the possible usefulness, with the comment that the fourth selection pattern should be changed to be more similar to the previous pattern.

In test five participants were introduced to a dropdown list, with haptic feedback patterns connected to every step of the microinteraction. In this case, the issue was not concerning the patterns themself. Rather, the number of interactions that generated a haptic pattern in the entire task was too many. The steps that generated a haptic pattern were opening/closing the list and selecting an item in the list. Participants felt that not every step they took in this interaction needed to generate a haptic pattern. Here participants' thought none of the patterns was useful and instead the whole interaction felt overwhelming and perplexing. Others thought that having a confirmation when opening/closing the dropdown menu and when selecting an item was useful, though only one of these steps should have a haptic feedback.

By analysing all these data points and comments a pattern that a short, simple pattern with a low amount of vibrations is preferred by the participants. Complex, long patterns with a high amount of vibrations are perceived as less useful. Furthermore, when to use haptic feedback is also part of this theme, by using haptic feedback everywhere the usefulness of the microinteraction decreases.

Haptic feedback needs to be simple and moderate. Only be implemented in moderation, when it serves a purpose and adds functionality. Using complex patterns or haptic feedback for every interaction easily overwhelms the user similar to other types of feedbacks such as sound or visual.

4.2.2. Multimodal preferred

Some of the strongest and unified responses collected from the participants were when visual and haptic work together. Which generates the most engagement, satisfying and highest perceived usefulness scores. A great example is the response from the participants in test number three. Where the correlation between the motion of the dot symbolising which selection had been made and the haptic made for the highest ranking of all scenarios. Haptic needs to be in balance and simulate what the participants visually perceive. Haptic does this by following the same rhythm and simulating the same metaphor as the visual feedback. With test three as an example, when the dot moved the haptic followed its rhythm. By simulating the movement of the dot through one vibration when the participants make a new selection and one vibration when the dot "lands" in that selection, haptic feedback is in balance with the visual feedback.

An example where the haptic feedback did not symbolize the same as the visual was in test five. When the participant pressed to open the menu, visually the menu slid down, the haptic generated a pattern that did not symbolize this. This caused many participants to explain that they saw the usefulness of the haptic feedback but would have ranked it higher if the haptic would have simulated the sliding effect.

Haptic needs to be in sync, follow and mimic the visual, not the other way around. Many participants agreed that haptic would work together with visual or sound. With haptic and visual being the most mentioned combination. Most participants think that haptic can replace sound but identified that they do not believe haptics can replace visual feedback completely.

Participants identified that visual feedback could be replaced in specific scenarios. In these scenarios, the user may not be able to rely on visuals, either due to low visibility or needing the sight for other tasks, as when driving a car. Here, haptic could serve as a replacement for simple interactions, such as confirmation that an interaction has been made on a touchscreen. Another example could be when replacing physical buttons with a touchscreen, as is common in many modern cars. Haptic feedback could also be generated when interacting with the wheel, stimulating a haptic pattern when changing lines. This interaction enables the driver to visually stay focused on the road while reaching feedback assisting in safe driving.

4.2.3. Haptic is individual

Through analysing this research, it is clear that haptic feedback communicates and affects a user on an individual level. Haptic feedback is very subjective and even two demographical similar individuals can perceive haptic feedback very differently.

The results are even more interesting when taking into account the patterns used and tested have been developed and named based on their perceived functionality by Apple. Through comparing the names of the haptic patterns with how the participants in this study described or perceived the haptic patterns. It is clear that none of the patterns perceived the functionality of the patterns the same way as Apple has. iOS failure was perceived as overwhelming and negative by some participants, others perceived it as notification, and some perceived it as a positive power-up or final level in a game. Similarly, with iOS Succes participants perceived it as everything from warning reaction to stimulating the sensation of a keyboard button or mechanical press. This shows that users perceive haptic very individually.

Basic parts of the patterns such as Amplitude (Intensity), Timbre (Sharpness), Granularity (Frequency) and amount were perceived very individually as well. Participants were rarely in total agreement concerning these basic building blocks. Some participants wanted more intensity while others wanted less in the same scenario and test. Even though this was a small group of participants no clear connection to any demographic could be made.

4.2.4. Accessibility

Accessibility was not specifically tested or studied in this study, however many participants suggested that haptic feedback could play a vital role in making more devices, products and services more accessible for more users. Several participants suggested that haptic can aid the visually impaired in interacting with touchscreen devices. Aid hearing impaired by alerting or reminding them of important events. Haptic could allow more products and devices to become more accessible to people with limited accessibility. In several of the tests and during the last questions participants argued that even though the haptic feedback might not be useful to them personally, haptic feedback could be vital for impaired users.

When analysing the data another aspect of accessibility was found. Participants stated haptic feedback might outright replace sounds or visuals. However, within certain situations where visual or sounds are limited, or not available haptic feedback could make a device previous inaccessible, accessible.

5. Discussion

The purpose of this research was to explore how haptic feedback and microinteractions can be combined to increase the perceived functionality and usefulness of a user interaction. A set of research questions were made to more clearly define this purpose. With the research questions serving as the framework throughout this research, the results discussion will therefore discuss the themes and previous theoretical framework through the scope of each research question.

The method for this research used a small group of realistic users to find qualitative data, through a usability lab study. The usability studies used specific haptic patterns together with common microinteractions to explore the usefulness of the haptic feedback. The research methods and analysis of coded data in this research identify crucial themes to consider when implementing haptics in microinteractions. The themes were created through analysing the collected data utilizing the Applied Thematic Analysis method. These themes allow the research to discuss and find connections between the themes and previously done research.

5.1. Result discussion

Through the discussion, the research found explanations to the research questions declared in chap. 1. The theoretical background illustrates that similar principles can be found in multiple research studies within HaXD (see chapter 3). These identified principles share similar fundamental reasoning when considering the design and implementation of haptics. When studying the themes generated by this research and existing studies, similarities can be evaluated.

This research's goal from the start was not to test previously stated principles, it was to explore how haptic can be functional within microinteractions. That the results of this research closely resemble parts of these principles are, however, no coincidence. This research wanted the haptic patterns tested in this study to be implemented as properly as possible, to prove that results generated by this study were as reliable and valid as possible. Therefore, these principles were taken into consideration when designing the prototype. However, this does not affect the results as the results are based on the thoughts and opinions made by the participants. The themes were based on the analysis of the data generated by the participants.

5.1.1. Haptics effect on microinteractions' usefulness

When discussing how haptic feedback affected the usefulness, patterns can be found in both this research data and in the theoretical framework. By studying the "Less is more" theme and "Multimodal theme", data shows that the participants found haptic feedback to increase the usefulness of the tested microinteractions through several ways. The participants preferred haptic patterns that were short and simple. Patterns using more than three pulses were found to be less useful. Haptic patterns that had a clear connection to the microinteraction were viewed as increasing usefulness. Participants found the use of haptic that simulated simple feedback such as confirmations, or failures to be an example of this. These findings are further supported by the principles found in the theoretical framework. The principle "keep the feedback short, simple and consistent" describes how haptic is most powerful when a user can react to the pattern intuitively (Muller 2020).

Furthermore, the number of interactions that generated haptic feedback played a vital role when investigating usefulness. As seen in test five, too many interactions generating a haptic pattern decreased the usefulness as the participants felt overwhelmed and annoyed. Similar findings can be found in the Punchcut and Apple principles.

A Punchcut principle focusing on simplicity is described as

"focus on delivering simple patterns that are easy to recognize and distinguish, at the right time and with the right amount. Do not overwhelm."
Punchcut 2020 chap. 10 Haptic Design Principles. Para. 1.

The issue with too many haptic patterns is discussed in Apple's principles,

"Use haptics judiciously. Playing haptics for a large number of trivial interactions can overwhelm people."
Apple Human interface guidelines 2021, chap. Designing with Haptics para. 4.

The use of so-called multimodal feedback was also found to increase the usefulness of a microinteraction. Multimodal feedback describes the use of two or more types of feedback. In the case of this study, the participants found that when haptic feedback simulated the visual feedback the usefulness increased. All the previous research mentions multimodal as a vital part of impactful and useful interactions. Muller (2020) describes it as making it easier for users to understand the metaphor that the, in this case, visual and haptic feedback tries to convey. With Schneider et.al (2017) pointing out that multimodal, when using multiple types of feedback, is a vital keystone in the holistic design of implementing haptic feedback.

However, in this research, it was found that when haptic and visual feedback are not in harmony, the usefulness dramatically decreased. Many participants found the haptic pattern annoying and disturbing in the best of scenarios. Apple confirms this by describing it as

"when visual, auditory, and haptic feedback are in harmony the user experience is more coherent and can seem more natural."
Apple Human interface guidelines 2021, chap. Designing with Haptics para. 3.

One final aspect of Haptics effect on microinteractions' usefulness is found in the "Haptic is individual" theme. This theme found data showing that the participants often perceived the same haptic pattern very differently from one to another. This does not mean that the principles and guidelines are useless, the same as guidelines for graphic design are seen as the foundation of graphic design. As discussed by Schneider et.al. (2017) and Müller (2020) implementing haptic needs to be done iteratively meaning: research, test, receive feedback, and improve. As became evident within this research with participants differ

5.1.2. Microinteractions benefiting from Haptic feedback

The purpose of the second research question was to identify if there were any specific types of microinteractions that would benefit from haptic feedback. This research was limited to only testing a small number of microinteractions. The limited number of microinteractions together with the small sample size prohibits any general conclusions about which type of microinteractions benefited from haptic feedback. However, conclusions can be made on the specific types of microinteractions tested within this research. Within this research microinteractions such as radio and checkboxes, were identified to benefit from implemented haptic feedback. In terms of usefulness and satisfaction participants ranked simple patterns connected to a single action higher compared to more complex patterns or patterns trying to convey complex information. An example is the unanimous response of the participants in test three, where the simple feedback generated when selecting, deselecting or changing selection was ranked amongst the highest in terms of usefulness and satisfaction. In the closing questions when asked which test was the most useful, several participants specifically picked test three. This due to the fact that the microinteraction had a clear purpose and the haptic pattern generated was well associated with purpose.

As found by these results, certain microinteractions and aspects were identified as beneficial when adding haptic feedback functionality. However, it was also identified throughout this research, an important theme is that users perceived haptic feedback as very individual. This theme first became apparent in test one, where participants tested eight different patterns with six being Apple's generic patterns. Almost no participant managed to identify known haptic patterns and Apple's intended use of these haptic patterns. Participants in this study identified iOS success were viewed as a warning, iOS failure was viewed as a power-up, etc. Although some participants connected iOS failure to error which is classified as an identified haptic feedback pattern. Even with a small sample, participants did not have a unanimous opinion of what type of functionality or symbolism the haptic pattern was to serve. As Apple states in one of its core principles

"Be sure to test the haptics. Different people have different preferences and levels of sensitivity to haptics"
Apple Human interface guidelines 2021, chap. Designing with Haptics para. 7.

This highlights the conclusion made by several participants, haptics needs to be customizable and optional. In essence, a microinteraction can be considered beneficial when adding haptic feedback if it can be adaptable, functional, and customised to participants wants and needs.

5.1.3. Haptic feedbacks effect on user interaction and engagement

To understand what type of haptic feedback increases and/or decreases user interaction and engagement this research explored how haptic affects the usefulness of a microinteraction and if this led participants to have positive reactions. According to research, the usefulness of a product or service is tied to the user interaction and engagement (Dovaliene, Masiulyte, & Zaneta Piligrimiene, 2015; Kim, Kim, & Wachter, 2013). When the usefulness increases so do the user engagement similarly if usefulness decreases so decreases engagement (Dovaliene, Masiulyte, & Zaneta Piligrimiene, 2015; Kim, Kim, & Wachter, 2013). The important themes already identified as "less is more" and "Multimodal preferred" illustrate important aspects to increase the user experience and engagement in haptic research. This is using haptic feedback judiciously, in tune with other feedback and a clear connection between the user's perceived functionality and the perceived metaphor the haptic represents is crucial for the future success of HaXD. To summarize, to increase the user interaction and engagement one must first increase the perceived usefulness of the haptic feedback interaction.

Visual feedback is used by users daily and has been refined over several years (Saffer, 2013). Therefore, microinteractions generated through sound and/or visual cues can be more complicated without decreasing the usefulness (Saffer, 2013). Similar conclusions as with microinteractions can be found by looking at console gaming. Within console gaming complex haptic patterns increase the user experience by enhancing the immersion of virtual reality with a physical reaction creating more realism (Deng, Chang, & Zhang, 2014). This is due to the fact that in console gaming haptic feedback and vibrations have been part of the experience for a longer time. By building on simple patterns by slowly adding more functionality and complexity, gamers have now gained an in-depth understanding of haptic functionality than non-console gaming average users (Deng, Chang, & Zhang, 2014). Today complex feedback patterns in games are commonly used (Deng, Chang, & Zhang, 2014).

5.1.4. Haptic Feedback - what causes decreasing user engagement

Even though all the participants agreed that haptic feedback would be useful in their everyday life, a few participants were claiming that they probably would not use haptic feedback. Adoption rates of microinteractions and haptic feedback among users may be hampered by several factors such as individual preferences and basic usability (Gonzales, et al., 2021). Therefore, haptic needs to be adaptable to the intended user, device and intended physical environment (Müller, 2020; Schneider et.al., 2017). Haptic needs to be customizable, the user needs to be able to change the intensity of the vibration, in what applications or scenarios haptic is to be used (Müller, 2020). Participants felt that some haptic feedback was deemed unnecessary when visual feedback was present. Haptic needs to be optional, the user must be able to disable haptic feedback without it affecting functionality (Müller, 2020). For example, if the user is operating the device in a cold environment, they might be wearing insulated gloves, this would dull the haptic feedback making it hard for users to perceive it.

During the opening interview, it became clear that few of the participants were accustomed to the use of haptic as a regular type of feedback. As stated in the previous chapter 5.1.1, microinteractions and haptic feedback that were complex in their function or purpose were perceived as less useful and leading participants to reject the user interaction. The lack of previous experience with haptic feedback could be an important aspect. Both Müller and Punchcut suggest that with haptic being newly implemented on a larger scale users need to be presented with simple haptic feedback within a clearly defined microinteraction (Müller 2020; Punchcut, 2020). For example, only one participant understood the more advanced functionality within test four. Most participants thought that the haptic patterns were unique to each checkbox. Only one participant understood the actual functionality, which was that for each selection the haptic pattern increased in intensity. This more advanced functionality could be missed due to the lack of previous experience of haptic feedback.

A possible solution to this problem is to help build users' haptic vocabulary through the use of simpler haptic patterns connected to more basic functionality (Müller, 2020; Schneider et.al., 2017). This to let the user understand more intricate haptic patterns and haptic functionality in the future. As mentioned in the Results section participants identified that haptics was perceived more useful when the haptic patterns made a clear connection to the function of the microinteraction. With haptic implementation still considered relatively new, many participants' only previous experience of haptic feedback were the intensive vibrations phones generated for an incoming call or text. Based on this discussion users might need time to increase their haptic understanding and vocabulary. Hapticians should start by creating a basic foundation that the users can use to build their haptic vocabulary upon (Punchcut, 2020; Müller 2020).

The usefulness of haptic enhanced microinteractions are affected by several factors discussed in this chapter, for example, the use of multimodal feedback, building a haptic vocabulary using simpler patterns, implementing haptics iteratively and test thoroughly, etc.

5.2. Method discussion

With the purpose to find answers to questions of more explorative nature, qualitative research methods were viewed as the most suitable type of method (Rorhe, 2013). During the data collection phase, it was discovered that haptic feedback is an opinionated topic with participants having preconceptions and opinions. Therefore, by using qualitative methods to both collect and analyse the data this research found ways to create valid and reliable data and results (Saunders, Lewis, & Thornhill, 2012). It did this through thorough research of different types of data collection and analysis methods, as well as relying on previously used UX research methods such as Usability testing, interviews and applied thematic analysis (see section 2).

5.2.1. Prototype discussion

The prototype was created using previous knowledge regarding user interaction and user experience design in combination with the principles described in the theoretical framework. The design process of the prototype revolved around the concept of limiting influences and feedbacks commonly found in a more realistic application. Feedbacks such as sound or visual were completely removed or kept to a minimum. The strengths of this approach lie in creating tests that could target specific microinteractions or haptic patterns. It was purposely decided to keep this minimalistic approach to generate the least contaminated data and to better understand how specific elements and feedback affect the participant.

Exceptions to this were made to make certain microinteractions functional, additionally, exceptions were purposely made to test the impact of other feedbacks in combination with haptic feedback. Such as with tests three, four and five, where visual feedback was added to both have the basic functionality of the microinteraction and test the connection between visual and haptic feedback.

Drawbacks from this approach were that the participants might not interact with the microinteractions in a way they would normally do, creating behaviours and opinions that might have been found in a more natural use of a similar application.

Another improvement that could have been made was in test one, which tested 8 different haptic patterns. This test could have been shrunk in terms of the amounts of patterns tested. With patterns four, five, seven and eight being too similar for any participant to differentiate them.

5.2.2. Interview discussion

The interview was a very valuable tool to collect the opinions and thoughts made by the participant. The choice to use both open-ended and closed-ended questions in a semi-structured interview allows the researcher to gather both generic broad answers, with the opportunity to probe and find more detailed answers. This led to many discoveries that aided in the analysis part and to find themes.

The interview contained a long list of questions that proved to be necessary to collect the needed data for further analysis. A drawback of this was the possibility that the interview could generate Respondent fatigue bias (Lavrakas, 2008). With many questions necessitated being of repetitive nature to cover the usefulness, disturbing, satisfying and annoying characteristics of each tested microinteraction and pattern. This led participants to sometimes shorten their answers when asked to reflect on additional functionality.

The participants believed to have already answered and described the functionality, and therefore had nothing to add.

A more streamlined interview to gather the same data could minimise the risk of Respondent fatigue bias, or testing fewer microinteractions/haptic patterns at a time using multiple occasions. Lastly, keywords used by the researcher to measure usefulness and satisfaction could have been improved by using simpler words, minimizing the risk of the participants having trouble differentiating between the different keywords.

5.2.3. Method discussion summarization

The two methods of data collection, prototype testing and interview, could not have worked without the other which is why it was found to be the most suitable approach to answer the research questions. Due to its laborious nature, a limitation on a feasible amount of participants had to be made. This limitation is compensated by the rich and detailed data generated and was therefore deemed to be worth its limitations. Other limitations such as preconception and biases were dealt with by the researcher neutrally asking questions, only asking the participant if they could be more detailed without asking leading questions. The participants aided in limiting this by expressing both their personal opinions and adding how it could affect people not sharing their opinions and beliefs.

6. Conclusions and further investigation

6.1. Conclusions

To conclude, haptic has the ability to increase perceived usefulness for users while strengthening the quality of interactions/engagement in microinteractions. With a unanimous group of participants agreeing that they perceive haptic as useful in their everyday life. The participants also agreed that haptic is deepening their connection to their devices through increased usefulness and satisfaction, leading to improved interactions and increased engagement. Participants also agreed that haptic work best when used together with other types of feedback, preferably visual, which is supported by research in the form being a key part of several principles. Haptic feedback has the additional advantage of not only increasing the usefulness, but also usability and accessibility for people with various sight or hearing impairment issues. This through allowing people with impaired sight to get feedback through haptic and sound, allowing them to in the future interact with touchscreens. It can aid hearing-impaired users to use devices and applications such as within navigation in situations where it is hard or impossible to use sight to get directions, for example using a navigation device while driving a car.

However, haptic needs to be perceived as useful and not disturbing for it to be thoughtfully implemented in applications and devices. This requires knowledge and testing as this research has proven haptic is perceived as very individual and can have completely different meanings depending on the users and their environment. To solve this hapticians and other interaction designers need to rely on principles and guides in the same way they rely on proven principles and guidelines for visual or sound design.

As further proven by this research haptic needs to be in balance with other types of feedbacks, something that was made clear by a majority of this research participants. Using a multimodal feedback approach is proven beneficial by previous research and many participants expressed their reason for ranking certain interactions higher because the interaction used both visual and haptic feedback that was in sync. When further asked the participants explained that the haptic was useful since they didn't have to focus on the screen to get visual confirmation, when they felt the vibration the visual feedback simply served as a marker of what they had selected. Meaning the haptic first confirmed that a selection had been made and the visual confirmed what had been selected.

RQ. 1 How is haptic feedback increasing or decreasing the usefulness of microinteractions?

Based on the valid qualitative collected data of this research it is concluded that the participants of this research viewed haptic feedback as increasing the usefulness of the tested microinteractions. With some types of haptic patterns, microinteractions and combinations of the two were more suitable than others, see RQ. 2. Haptic feedback was viewed as deepening the connection between the device and the user, further increasing the perceived usefulness, interaction and engagement.

Many participants described haptic feedback to increase the usefulness by serving as a basic feedback that the device had received the input. This allowed haptic to interact with the users by confirming that a selection had been made, an error was found or that the device needed more input. If needed the visual aspect of the feedback loop could then confirm to the user what had been selected, what went wrong or where extra input is needed. Haptic allows for users to focus on other tasks and could limit the need for the user to look at the device to be able to interact with it. Increasing the usefulness of devices in general and increasing the usefulness of touchscreen devices in scenarios where the user is limited or unable to use visual or sound to confirm their inputs.

RQ. 2 What type of microinteractions can benefit from haptic feedback?

The tested microinteractions that benefited from haptic feedback were radio buttons and checkboxes. The tested buttons could benefit from haptic feedback, but the specific patterns tested in this study did not increase their usefulness. Dropdown menus could benefit from haptic feedback, but further tests need to be done to find the most suitable type and amount of haptic feedback. With this research only testing a few microinteractions on a small group of users it cannot make a complete list of which microinteractions that would or would not benefit from haptic feedback. It is however possible, that with some modification and further refinement all of the tested microinteractions in this research could benefit from haptic feedback.

RQ. 3 What type of haptic feedback is perceived as increasing and/or decreasing user interaction and engagement?

Through the ATA themes found in this study, research concludes that simple, short haptic patterns are preferable. When purposefully implemented to create added functionality and value haptic feedback is generally viewed to increase the user interaction and engagement. Though this research only tested a few types of generic haptic feedback on a small participant group, it is clear that within this sample that short and simple type of haptic is perceived more useful.

Complex, long and intensive haptic patterns were perceived as less useful. Participants felt more easily overwhelmed, annoyed or disturbed by these patterns. Making them less likely to be perceived as increasing the user interaction and engagement, and more likely to decrease the user interaction and engagement.

6.2. Practical implications

This research shows that haptic has the potential to increase the usefulness of a wide variety of products that use microinteractions. This research shows that by implementing haptics into handheld touchscreen devices the perceived usefulness is increased, leading to increased engagement and interaction that a user has with their device. This study also shows that by incorporating the principles already existing in the development phase of haptic feedback a sound foundation is created.

6.3. Scientific implication

This research proves that more research is needed to make better use of the principles previously stated, that have been further legitimized by this research. It provides further legitimization of previously done research, as the findings made in this study points to similar themes, principles and conclusions found in previous research. This research adds to the scientific research of haptic by proving how haptic feedback can increase and decrease the usefulness of microinteractions. This research can be used as a preliminary study through the use of a small sample of interactions and participants. By proving what and how interactions can benefit from haptic feedback it allows for future research using larger sample sizes or other microinteractions to be conducted using similar methods.

6.4. Further research

There is still a large number of microinteractions that could benefit from haptic enhancement. These still need to be explored and tested as this study limited the test to only a common few. Furthermore, the limitations of this research meant that only a set of generic haptic patterns could be used and tested. This limited the types of patterns that could be created and tested, leaving other types of haptic feedback to be explored. This research was also limited to only testing on handheld iOS devices which eliminates a part of the realistic user sample and devices. It eliminates Android devices since too few patterns were available in the prototype tool. It also means that some users could be more accustomed to Android-based devices and systems. Further research could use the same methods proposed in this research and apply them to a different OS or types of devices. In conclusion, this research has merely scratched the surface of haptic research and there is much to still explore both within qualitative studies and quantitative.

It was noted during the usability studies that the participants held the device differently during the tests. This study was not able to further explore if this could have any implications on the way the participants perceived the haptics. Protective skins, shells or cases that many users have on their smartphones as protections could also have implications in terms of how the participant perceives the haptic. This study found out by mistake when the protective case was left on by accident on the test device for one participant. After removing this protective case the participant expressed that the haptic felt more intense, but even though the participant voluntarily retested the tested patterns it ultimately did not change the participants view on previous haptic tests or patterns. Further studies are however needed to research the implications protective cases may have on haptic feedback in handheld devices.

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Appendixes

Appendix 1 The Nielsen Norman Group framework - The Methodology explained

The Nielsen Norman Group framework contains three dimensions (Rohrer, 2014). The first dimension is termed behavioural versus attitudinal that assists in segmenting users' actions and insights (Baxter, Courage, & Caine, 2015; Rohrer, 2014). The second dimension focuses on the data collection process determining what type of data is going to be collected; qualitative vs quantitative data (Rohrer, 2014). Thirdly, the context of product use is added to decide if what type of research environment is suitable for the specific research (Rohrer, 2014). Lastly, by adding the product/service development timeline together with this three-dimension framework researchers can validate their chosen approach and find the most optimal tool for the product/service (Rohrer, 2014).

The first dimension

The first dimension is attitudinal vs behavioural. Here the researchers differentiate approaches by investigating Attitudinal what people say, or Behavioural, what people do (Baxter, Courage, & Caine, 2015; Rohrer, 2014).

Attitudinal approaches investigate the opinions of users towards a certain product or service. Do users view haptics as an important feature, would they be interested in having more implementation in their daily usage or simply do they like this technology or not (Baxter, Courage, & Caine, 2015; Rohrer, 2014).

Behavioural approaches focus more on the interactions with the technology, what do users do when faced with a specific task or problem (Baxter, Courage, & Caine, 2015; Rohrer, 2014). Examples of this when testing haptics interactions could be how the user reacts to different feedbacks. With this thesis focusing on the way users interact and react to tactile feedback, this thesis will utilize methods from the behavioural spectrum of the framework.

The second dimension

The next dimension is Qualitative vs Quantitative, which focuses on the type of data collected (Baxter, Courage, & Caine, 2015; Rohrer, 2014).

Qualitative data is gathered by directly observing and communicating with the user, often through interviews, focus groups or field studies. Researchers are mainly interested in rich verbal descriptions as people's thoughts, opinions and feelings towards a certain research question or area of research (Rohrer, 2014). This gives the researchers the possibility to ask users directly about their behaviour and attitude towards haptics. Qualitative data provides the opportunity (where open-ended questions are utilised) to ask follow-up questions that allow new insights or more descriptive information about haptics which is essential to this research paper.

The third dimension

The third dimension of this framework is the context of product use. This has to do with where and how users/people/participants interact with the product or service (Baxter, Courage, & Caine, 2015; Rohrer, 2014). There are four different contexts of product use:

Natural is the study of users when naturally interacting with the product or service (Rohrer, 2014). Scripted research methods are best represented by Usability lab studies, where the user receives a scripted scenario to examine a specific feature of a product or service (Rohrer, 2014). In a scripted study, the users are instructed to perform specific tasks or test specific functions (Rohrer, 2014). This helps researchers gain insights into specific usage patterns as they test a new function. A scripted study gives researchers more control and is often easier to get credible (Rohrer, 2014). However, decreases validity as some of the data might not be applicable in the natural use of a product or service. There is also a hybrid of the two, where the study is simply a combination of natural and strict methods for specific research (Rohrer, 2014).

Lastly, creating studies that focus on areas where a specific product or service is not used could give a broader understanding of issues that are beyond usage and usability (Rohrer, 2014).

By adding these three dimensions together Nielsen Norman Group created a landscape to illustrate the different methods and a course of action. This gives researchers a roadmap to quickly find what type of method is most suitable for their research (see fig. 3).

The product development timeline

If deemed inadequate researchers can add an aspect termed the product development phase, denominated as the "fourth dimension". This uses the aspect of time with the reason of adding the importance of the product development lifecycle (Rohrer, 2014). Time is divided into three distinctive phases: strategize, execute and assess (Rohrer, 2014). This displayed as a table (see fig. 4) explains these distinctive phases by the goal of the research, the most valid approach and the typical methods used to achieve this. HaXD is in the late strategize phase of the product development timeline. The strategize phase certifies the exploration and testing of new opportunities and allows the use of both qualitative and quantitative research methods (Rohrer, 2014). This allows new directions to be investigated and developed in haptic technology research.

	Product Development Phase		
	Strategize	**Execute**	**Assess**
Goal:	Inspire, explore and choose new directions and opportunities	Inform and optimize designs in order to reduce risk and improve usability	Measure product performance against itself or its competition
Approach:	Qualitative and Quantitative	Mainly Qualitative (formative)	Mainly Quantitative (summative)
Typical methods:	Field studies, diary studies, surveys, data mining, or analytics	Card sorting, field studies, participatory design, paper prototype, and usability studies, desirability studies, customer emails	Usability benchmarking, online assessments, surveys, A/B testing

Figure 11. The product development phase table (Rohe, 2014)