Master's thesis

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Prototyping, Implementing, and Evaluating Haptic Experiences in Mobile Phones

Master's thesis in Interaction Design
Supervisor: Giovanni Pignoni
June 2021

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Kunnskap for en bedre verden

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Abstract

Haptic feedback is a design element and microinteraction used in user interfaces to improve the user experience and provide tactile feedback to users. Haptic feedback is not currently embedded in the design process, meaning it is often left out and an afterthought in mobile applications. This study gains insights from interviews that explore smartphone users' perceptions, opinions, attitudes, and previous experiences with haptic feedback on mobile devices and the process of developers and designers implementing haptics in mobile applications. It reviews haptic feedback evaluation methods and guidelines through a literature review. It ends with an evaluation method for designers and developers to examine and evaluate haptic feedback in mobile applications. It also provides a quiz titled HapticFinder to aid designers in learning haptic feedback best practices and results in providing a system haptic based on the use case for the implementation status.

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3 List of Abbreviations (or Symbols)

DBR	Design Based Research
LRA	Linear Resonant Actuator
EMRV	Eccentric Rotating Mass Actuator
NSD	Norwegian Data Protection Center
GDPR	General Data Protection Regulation

1 Introduction

There are over 3.5 billion smartphone users worldwide, and 90% of users spend their time within mobile applications. (Statista, 2020). People are using mobile applications more than ever, and they play a crucial role in our daily lives. Smartphones are used for various functions, from starting a car to monitoring a heart rate to an alarm clock and so many other things. Smartphones today are on pace to replace over 50 objects we use every day (Gecko & Fly para. 1, 2021). With smartphones becoming more advanced with sensations and interactions, they can provide a richer user experience. Designers and developers provide a richer user experience through a component of a microinteraction called feedback. A microinteraction is the single-use case features that only do one thing; they can be the difference between a product we love and a product we hate. Feedback is the third part of any microinteraction, and it can be prominent or could go unnoticed by the user (Saffer, 2013). Feedback helps the user understand the system's rules, which the system communicates as either audio, visual, or haptic. Mobile phones provide us with and store a handful of information that the amount of feedback from different channels could be overwhelming. Haptic feedback or vibrotactile feedback recreates the sense of touch in the form of vibrations, texture rendering, simulated clicks, pulses, and buzzes (Haptic Technology, para. 11, n.d). It aims to enhance interactions and convey useful information to users through the sense of touch. Today's smartphones generate haptic feedback, usually by tiny motors.

Haptics is not a new technology and comes in many different forms. However, its most ubiquitous use first appeared in the early '70s in video game systems, with other applications being the automotive industry, medical field, robotics, virtual reality, and many others (Blenkinsopp, n.d.). Interaction with haptic technology has become more common steadily; haptic technology refers to any technology that can create an experience of touch while applying force, motions, and vibrations.

Haptic feedback in mobile applications is vibrational responses that are implemented when you tap, scroll, and slide on an app. Mobile haptic feedback can also enhance touch gestures and interactions, such as scrolling through a picker or toggling a switch. Today, the two types of haptic sensors used in smartphones are eccentric rotating mass vibration (ERMV) motors and linear resonant actuators (LRAs).

The rise of automation and robotics allows companies to explore haptic technology in different fields such as the automotive and healthcare sectors. Haptic feedback does have its drawbacks, as in a poll conducted by Westenberg (2019), when posed with the question "Do you use haptics while typing on your phone?" from 32,000 votes across four platforms, 59% of voters said they do not use haptics at all. The phone Westenberg (2019) was referencing was an Android. The first half of the study aims to address and identify the populations that use haptics and those who do not and then understand the motivation and cause of use or non-use. Current research does not delve into the user's experience of haptic feedback within mobile applications.

Another drawback to haptics is that the amount of information we get from touch is 1% of hearing, and most people can only detect three or four levels of vibration (Verrilo, Frailoi and Smith, 1969). Haptic technology is on the rise but still has a long way to go, with most implementations being in smartphones and pagers. People also perceive different vibration (haptic feedback) levels variously (Human Interface Guidelines, n.d.), which can be difficult when designing and implementing haptic feedback.

1.1 Motivation and Benefits

Haptic feedback is an important design element that can be used to convey meaning through vibrations and touch in mobile phones. It provides the user with a distinct way of feedback that is less blaring as audio feedback and less exigent than visual feedback. However, a significant issue with haptics in mobile phones is that a user has the ability to turn them off. This challenges the designer or developer who went to great lengths to implement haptic feedback in their mobile application. Every person is sensitive to vibration and touch in a particular way, and therefore, the feedback being creating by these developers and designers could be too much for one person to handle. This is why further analysis of mobile phone users and their experiences with haptic feedback is essential to the field.

The addition of haptics to an application can be beneficial, but context is vital. It is essential to understand when to apply just the right amount of haptic feedback to add value to an application, or else the user could become quite annoyed or, the opposite, disinterested. The addition of just the right amount of haptics to a mobile application can drastically improve the user experience and create new interaction levels. Developers and designers could benefit from understanding why smartphone users turn off their haptics because it allows designers to create experiences in a richer context and gives them the ability to connect with users beyond the screen. Also, designers are unaware of the pros and cons of adding haptic feedback as they are not used to sketching with haptics.

1.2 Research Questions

The thesis explores the following research questions:

- What role does haptics play in mobile phone users experience?
    - How have haptic experiences been evaluated in mobile phones?
    - What do current evaluation methods lack?
    - What could be a more effective evaluation method?
- Does haptic design play a role in mobile phone users turning off their haptic settings?
- How is haptics and haptic feedback currently incorporated in the design process?
    - How can haptics be more be more effectively incorporated in the beginning of the design and development process?

The research questions aim to understand how smartphone users utilize haptics on their mobile phones and, if they do not, why. It is essential in my project to explore the users who utilize haptics and those who do not. The goal is to understand the use of haptic feedback in mobile phones and how smartphone users perceive different levels of haptic feedback and in specific use cases. The thesis will also explore the other side of the table, the developers and designers who have implemented haptic feedback in mobile applications. The goal is to gain insight into how haptics is implemented into mobile applications and how the process could be done more effectively. As haptic feedback is so subtle and uncommon in mobile applications, the thesis will try to bring to light how a team should implement it and test it effectively.

2 Background

2.1 Touch

We extract meaning from the world around us through our senses. Humans have five basic senses which send information to the brain, allowing us to discover the world around us. Touch is the most complicated sense; the organs of touch are distributed throughout the body, embedded in our skin, muscles, and joints (O'Modharain, 2004). Touch is one of the first of our senses to be developed, and it is controlled by a large network of nerve endings, and touch receptors in the skin called the somatosensory system. All the sensations we feel, such as pain, touch, pressure, temperature, and motion, are responsible for the somatosensory system. The nerve endings in the body carry information from the spinal cord, which then sends messages to the brain where the feeling is registered (Science World, n.d.). Our sense of touch is constant and is also subconsciously how we regulate our physical comfort in a given environment (Park & Alderman, 2018). Learning more about touch can help us explore our senses in different ways.

The somatosensory system consists of four types of mechanoreceptors that respond to different touch-related stimuli. Mechanoreceptors sense stimuli due to the physical deformation of their plasma membranes. They contain mechanically gated ion channels whose gates open or close in response to pressure, touch, stretching, and sound (Somatosensation, n.d.). The four tactile mechanoreceptors are Meissner's corpuscles, Pacinian corpuscles, Merkel's disks, and Ruffini corpuscles. The Meissner's corpuscles in the skin respond to pressure and lower frequency vibrations, and Pacinian corpuscles detect transient pressure and higher frequency vibrations. In addition, Merkel's disks respond to light pressure, while Ruffini corpuscles detect stretch (Abraira and Ginty, 2013). The human body is covered with the largest and heaviest of all sense organs, our skin, where the average adult's skin weighs around 4 kg (9lb) (Jones, 2018). In addition, the skin is covered in touch receptors, which provide information to the central nervous system and the somatosensory system. The finger has around 3,000 touch receptors alone, primarily responding to pressure (Hancock, 1995). Mechanoreceptors respond to different ranges of vibration frequency when applied to the skin.

All in all, mechanoreceptors respond to vibrations on the skin from around .4 Hz to 1000 Hz. Different areas on the skin have denser collections of mechanoreceptors, which are more sensitive to stimuli than less dense areas. As mentioned, the fingertips have a substantial number of mechanoreceptors compared to the area such as the palm of your hand. This means that placing stimuli across different areas of the skin will not be perceived the same at different locations (Jones, 2018).

The sense of touch can be divided into two separate channels: Kinesthetic and Cutaneous. Kinesthetic perception involves positions, velocities, forces, and constraints sensed through the muscles and tendons. Cutaneous perception involves stimulating the skin through direct contact (Burdea, 1996). Cutaneous perception can also be additionally separated into different sensations such as pressure, stretch, vibration, and temperature.

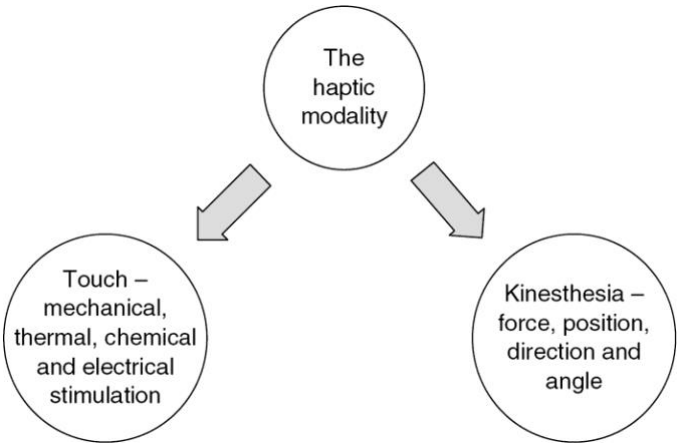


Figure 1: ISO, 2011 Definition of terms taken from Hoggan (2013)

The sense of touch can be classified as passive and active. Active touch or active haptic perception is the touch perception of the characteristics of an object through voluntary, intentional contact movement (especially by the hands), which is self-initiated (APA, n.d.). Active touch is goal-oriented behavior (Chapman, 2008). During active exploration, the finger pads are used to convey information about texture and shape. The sense of touch is the most adaptive as we can quickly tune out certain sensations. In humans, the hand is the most important tactile organ for object identification (Darian-Smith, 2011).

Touch has many different motivations, but most often, touch is associated with the intention of doing a task, probing an object for its state or qualities, communicate a message, poke something to elicit a reaction, or verify that an action is completed (MacLean, 2000). The motivations of touch allow us to recreate these feelings in haptic interfaces. The act of touch allowing us to determine and identify the properties of objects which is called haptics or haptic sensing (Jones, 2018).

2.2 What are Haptics and Haptic Feedback?

Traditionally, the term haptics describes the sense of touch and the ability to perceive properties of an object relying on touch (vibrotactile feedback). Haptics is derived from HAP-tiks, which from the Greek haptikos, meaning "tactile, pertaining to the sense of touch"(Blenkinsopp, n.d.). The field of haptics is a multi-disciplinary field with beginnings in psychology and has since expanded to art, wearables, the medical field, and many other adaptations. The table below lays out the different definitions of haptics pertaining to the field that they belong to.

Reference	Fields of Knowledge	Definition
Klatzy & Lederman (2003)	Psychology	The active touch
Gibson (1962)	Psychology	Goes beyond the classic modalities of kinesthesis and cutaneous senses but, the experiences and objects or patterns.
Jones (2018)	Engineering and Computer Science	The ability to identify and perceive the properties of objects relies on the sense of touch.
Hayward, V. Astley, O. R. Cruz-Hernandez, M. Grant, D. & Robles-De-La-Torre, G. (2004)	Engineering	Capability to sense a natural or synthetic environment through touch.
International Organization for Standardization, 2009		Sensory and/or motor activity based in the skin, muscles, joints and tendons.
Material Design (n.d.)	Technology	Haptics refers to the sensation delivered to users through a touch UI.
Human Interface Guidelines (n.d.)	Technology	Haptics engage people's sense of touch to enhance the experience of interacting with onscreen interfaces. Haptics can also enhance touch gestures and interactions like scrolling through a picker or toggling a switch

Table 1: Adapted from Almedia (2020) and improvised

The variation of definitions show haptics is a multi-disciplinary field composed of scientific and artistic layers. The scientific layer is built on structured knowledge of biological receptors, a vast number of testing methods and perceptual studies, and a set of well-investigated parameters in both hardware and software domain for signal processing and programming. The artistic layer is composed of Haptics also has an artistic layer that uses scientific knowledge, directly or indirectly, to enable the creative expression of information and the induction of feelings through skeuomorphic or abstract somesthetic (i.e., tactile, thermal, pressure, and pain) sensations (Almedia para. 3, 2020). As stated previously, the field has drawn psychologists, designers, engineers and artists.

The term haptic interface has many definitions as well as the term 'haptic' is included in the term itself. Like the definition of 'haptics,' the term haptic interface is used throughout many different fields and in different contexts. In Human-Computer Interaction, one definition of haptic interfaces is that it comprises of a robotic mechanism along with sensors to determine the human operator's motion and actuators to apply forces to the operator (O'Malley and Gupta, 2008). This is a mechanical definition of haptics interfaces as Park & Alderman tie the term haptic interfaces to the tactile, proprioceptive, and vestibular systems (2018). They describe that most interfaces are haptic, whether it is mechanical products or computing. They also state haptic interfaces as what we use our hands to touch and explore our environment, and they have a robust blend of sensory and motor capabilities. Some examples of haptic interfaces are touchscreens, keyboards, keypads, paintbrushes, pencils, and knives. The term haptic interface has many definitions, as there are many different definitions of the term 'haptics' and the term 'interface.' Another definition of haptic interfaces from the design perspective involve haptic feedback, where they state haptic interfaces provide tactile feedback by applying vibration and forces (Rogers et al, 2011). The definition that will be used throughout this paper is Park & Alderman's 2018 definition.

Haptic sensing is how we are provided with information that enables us to use the right amount of force to lift a glass of water from the table or find the light switch on the bedroom wall in the dark (Jones, 2018). Haptic sensing is closely reliant on our hands and vision because we receive ongoing feedback from sensory receptors in the skin to adjust our hand movements or placements. Haptic sensing differs from other senses as it is bidirectional; therefore the information, we can obstruct about the properties of an object is linked to the movements made to perceive those properties sensing (Jones, 2018). We do not realize how reliant we are on our hands until we cannot use them in specific situations, such as when it gets too cold outside, and you lose feeling in your hands.

Haptic feedback is used to communicate touch with the user. Haptic feedback is also considered a microinteraction when referring to feedback methods in digital products or user interfaces (Saffer, 2013). Microinteractions consist of a trigger, rules, feedback, and loops and modes. Using haptic feedback in an interaction is a microinteraction. As the user interacts with the system, which triggers a microinteraction, that has a rule, based on that rule; the user receives feedback. Based on the extent the user uses the microinteraction, a mode or loop is established. The figure below represents a process flow of a microinteraction from NNG, 2018.

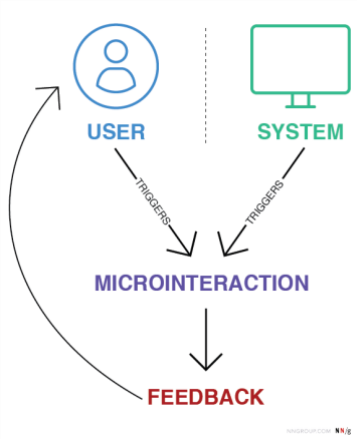


Figure 2: NN/G, 2018 Process flow of microinteractions

As stated above, haptic feedback is used for communication. It is also used to simulate the sense of touch to the user. It allows designers and developers to communicate physical metaphors (Baker, 2019). The term haptic system is used throughout the industry and refers to the systems that deal with haptic feedback. Haptic feedback is being used throughout many industries to provide feedback to users when visual or audio feedback is not helpful.

Haptic feedback patterns are often learned over time and connected with real-world physical experiences. Haptic feedback can also be used to make small digital transactions physical (MacLean, 2005). These patterns and roles can be constructed to what Maclean (2005) calls haptic icons. She defines haptic icons as "short, synthetic, abstract, haptic signals that convey information, such as event notification, identity, content or state." Haptic icons are closely related to haptic language. As haptic language is the meaning, we create from the brief haptic signals. Maclean (2005) discussed when creating a new haptic language; we begin with our social and experiential norms for manipulating tangible objects and interpreting physical feedback. We can drive new models for association when communicating physical metaphors and bring new meaning and affordances to haptic icons.

When creating custom haptic patterns, sharpness and intensity are intertwined to convey information to the user (Human Interface Guidelines, n.d.). Sharpness is defined as the perceived rigidity or hardness of the impulse. When the rigidity decreases, it is more difficult to tell the difference between the vibrations. Baker (2019), a design lead at Netflix, states the sharpness of a vibration pattern should increase when

conveying an important semantic pattern, he suggests such as correctly depositing a check in your bank app. In addition, he suggests that one should reduce the sharpness to convey subtle feedback such as continuous feedback, as one experienced while playing a mobile game. The intensity in haptic patterns refers to the perceived strength or magnitude of the impulse. For controlling intensity in haptic patterns, Baker (2019) recommends that one should increase the intensity when providing salient feedback for transient events, such as when you pay for an item or the purchase fails. The intensity should be decreased to provide complimentary feedback for neutral events such as opening an app or adding an item to the shopping cart. Using these rules can help create better haptic patterns that are easily perceived based on the physical metaphors we have created.

There are two types of haptic feedback: transient and continuous. White (2020) defines Transient haptic feedback or transient events as "the feedback we are most aware of as it addresses the brief little events that come and go and they are minor events such as success a haptic when a payment goes through or an error vibration when a page fails to load. Continuous haptic feedback or continuous events are pattern-based as the haptic patterns with a specific duration that keeps going for as long as the user needs. Continuous haptic feedback is common throughout games where the user needs continuous feedback such as slowly increased vibrations to show the car is slowly accelerating. These feedback methods can help designers control the types of vibrations that occur and how long.

Haptic feedback can be split into two different categories: active and passive. Active and passive haptic feedback closely correlate with active and haptic touch described in the previous section. Hoggan (2013) describes mobile phones as having both active and passive feedback. Without any prior user input, the phone vibrating, as when the user receives a call, would be qualified as passive feedback. For example, the vibration triggered by the user typing on the keypad is instead considered active feedback. As stated previously, active touch is goal-oriented, same with active haptic feedback. This is because the user initiated the event itself and was given feedback according to intentional movement. Throughout the rest of this paper, the researcher will predominately be addressing active haptic feedback, as designers mainly add tactile cues to mobile applications in combination with other types of feedback such as visual or audio to confirm or deny that an action has been completed.

2.3 Designing with Haptic Feedback

Current devices engage two primary senses: seeing and hearing. Our senses are the only way we experience the world (Park and Alderman, 2018). Designers need to understand how our senses help us experience the world around us when designing new interfaces. In addition, designers have to take into account the different modalities when approaching user experience design. The term Modalities are how we use our senses; the patterns develop throughout our lives and encompass how we use information (Park and Alderman, 2018). With the different modalities, people can have their preferences and rely on certain modalities more than others, but we depend on modalities to experience the world. The key interface modalities consist of: Visual, Auditory, Haptic, and Proprioceptive (Kinesthetic). Modalities are also a way to multiply how information is experienced and controlled from the interface through the different modalities (Rogers et al, 2011).

O'Modharain says the sense of touch holds the key to the design of truly embodied mobile applications (2004). For example, visual imagery carries a lot more information that haptic vibrations cannot. In the physical world, touch is used many different ways, and much of haptic perception relies on active exploration (Lederman, Klatzky and Metzger, 1985). Active exploration allows us to create gestures and develop responses to haptic stimuli. Unlike audio and visual feedback, haptic feedback cannot be turned off.

2.3.1 Modalities in Design

Haptic interfaces are rarely uni-modal. When we are dependent on a single sense solely, it is unnatural because, in the real world, we receive information from many different modalities as we can feel, hear, and see a button being pressed (Hoggan, 2013). Devices that use many modalities can help us explore and develop new ones for us to learn; using one modality over another can help improve the experience (Park and Alderman, 2018). Multimodal design is the art of creating user interfaces across multimodalities, and multimodal interactions consist of when the user is provided with multiple modes for interacting with a system. Park & Alderman, 2018 states that "Good multimodal design can help us stay focused on what we are doing. Bad multimodal design distracts us with clumsy or disjointed interactions and irrelevant information."

Multimodal feedback is providing feedback through a combination of different modalities. Using multimodal feedback compared to no feedback can significantly improve the user's experience. Lee and Hwang investigated smartphone interaction models for large displays where they found that auditory and haptic feedback combined are just as useful as visual feedback (2015). Multimodal feedback can also aid in different ways, as Campbell & Feldmann investigated the power of multimodal feedback when grading student's papers and how the use of speech and video feedback helped teachers connect to their students and spend more time reading their feedback (2017).

In the current industry, designers have no way to prototype haptics in the typical design process. In the current industry, designers are not trained to include haptics in their design process and or "not trained to sketch with haptics" Because design tools cannot prototype haptic feedback, which could be explained by the implementation of haptics in commercialized products is low (Bjelland and Tangeland, 2007). Before thinking about implementing touch feedback in a mobile application, O'Modharain (2004) suggests that looking at the purposes of touch as existing interaction models can help provide valuable information about existing models to recognize where interactions should be built. He explains that the primary purposes of touch are for actions and communicating expression. When communicating expression with haptics, you are communicating motion. Designers often focus on visual feedback when designing for phones, as that is how they are currently interacting with their users. He also states that we should reflect on when touch plays a significant role in existing interactions. Starting from experience can help provide valuable information to designers so novel interaction can be built.

2.4 Haptic Feedback Design Approaches

Feedback is defined as an intermittent reinforcement of behavior and can be extremely powerful and can make or break a microinteraction (Saffer, 2013). Feedback can be applied as visual, audio, or haptic. Our individualized haptic feedback experience began with pagers and mobile phones, which allowed humans to experience vibrotactile feedback in the palm of their hands. Nowadays, mobile phones have built-in actuators where developers can take advantage of our haptic imprecision to create the illusion of human contact through haptic feedback (Park and Alderman, 2018).

Touchscreens have relied previously on visual feedback but, touch feedback has been explored throughout the growing age of technology and is getting better and stronger. Tactile feedback plays a key role in improving interactions with touch screens (Brewster et al, 2007). There are advantages and disadvantages to haptic feedback. Hoggan (2013) describes them in-depth, and they are laid out in the table below.

Advantages	Disadvantages
• To reduce the amount of visual information on the display • It helps to aid situational impairments • Enhance the usability for those with visual impairments	• Haptic modality is relatively low resolution compared to vision • Not able to present absolute data, as it is difficult to feel the difference between two different vibrations • Changing one attribute of a haptic cue may affect the others

Table 2: Advantages and Disadvantages of Haptic Feedback

Adding tactile feedback to touch screens allows for a different form of communication when audio and visual feedback are inoperative. Additionally, input/output devices can help users receive feedback from computer applications in the form of sensations delivered from their hands or other parts of the body (George, 2015). Designers must create accessible interaction methods that allow the user to understand interactions, whether in a crowded, noisy coffee shop or simply on their couch. Haptic feedback is how designers communicate with humans. Embedding haptic feedback into an interface allows for the communication of touch to the user. In embedding haptic feedback in an interface, MacLean (2000) suggests that designers first need to provide an effective interface to a given application. When going about design, designers should have a start goal to create a successful interaction rather than the goal to use haptic feedback. MacLean (2000) provides examples of the possible uses of haptic feedback such as:

- **For reconfigurability**: she suggests haptic interfaces can change their feedback in response to the environment they display and control
- **For handling for continuous control and monitoring:** the ability to provide continuous analog user guidance or intervention which can reduce motor or visual strain when the manipulation is prolonged
- **Buttons for discrete control and information:** for differentiation and identification, imposing continuous discretization on continuous input
- **Affect and communication:** haptic feedback can add social context to a socially sensitive or impoverished situation and create the sense of a shared experience
- **Comfort and aesthetics:** for pleasant tactility and satisfying motion and dynamics
- **When dealing with complexity:** haptic can help offer clues to what a user's options are, through constraints and gentle guidance

When specifically designing using haptics for mobile phones and applications, it is crucial to address the operating system itself, as they have their own rules and guidelines. For Android, Material Design is the guidelines developers and designers follow, and for Apple, the iOS Human Interface Guidelines are what designers and developers' reference. These guidelines are widely available online, and the failure to follow these rules in some cases could have an application rejected from the app store. These guidelines operate in similar senses as they are meant as a documentation style so that the user experience is consistent across different devices. Without rules and guidelines, mobile phone users would not have any way to build a mental model and have a consistent design experience.

Material Design by Google Design is a design system that aims to build high-quality experiences. Material Design encompasses everything such as visual, iconography, layout, typography, etc. The guidelines help simplify the process and help create building blocks that make a product useful and functional (Material Design, 2021). It is important to note that Material Design is being refreshed as this paper is being written. The Human Interface Guidelines, or the HIG for short, are Apple's documentation guidelines for all developers and designers of iOS applications to follow.

2.5 How much is too much?

Previous research regarding haptics and mobile phones has focused on many separate areas. Payment is a common form of smartphone usage Google Pay, and Apple Pay allow phone users to purchase items from stores or online through their smartphone. Manshad et al, (2019) explores the addition of haptic feedback to "pain of payment," a physical sensation to accompany the use of payment in mobile devices. They explore the user's grip of mobile phones where they identified a heat map that revealed that participants were most likely to grip the phone in the middle of both edges with additional contact along the center of the phone's backside. They were able to induce the "pain of payment" by testing five haptic sensors with five vibration motors along with a custom-built application. They found "a configuration of vibration motors located around the right and left edges of the phone, which give high frequency, short duration vibrations upon payment is the most effective way inducing the pain of payment."

To understand where to place haptic feedback, the interaction process can be separated into three stages: locating, navigating and, interaction (Yang et al, 2011). Locating refers to when users want to interact with a GUI (Graphical User Interface), and haptic feedback can help the user locate the GUI on touch screens. Navigating in the interaction process is when the user needs to move the input interface (towards the GUI, to cross its boundary and finally reach the inside of the target. Adding haptic feedback while the user is navigating can assist them in reaching the correct target. The last stage in the interaction process is the interaction, where the user reaches the target GUI. Implementing haptic feedback after an interaction has occurred has little effect on the user's performance. If the feedback occurs after the interaction, it will not reduce completion time, but it could provide additional input and information to the user. Yang et al (2011) suggest adding haptic feedback at the beginning of the interaction process so the user will react to the event sooner. They also suggest adding haptic feedback at the user's expected destination on the target. To begin with, most vibrotactile stimuli used in mobile phones transmitted very simple information, such as alerts. However, with newer models of phones and more powerful Taptic Engines' (Apple), developers are able to add complex vibrotactile stimuli to smartphones. This is an advantage for users with some sensory deficiency, like deaf or visually impaired (VI) (González-Cañete et al, 2019).

2.6 Haptics in Mobile Phones

Haptic technologies are installed in about 200 million mobile phones, but the capabilities have not been fully utilized (Immersion, 2017). Mobile phones today have haptics, but they can be provided in a few different ways. Vibrations aren't just created by magic; tiny motors in our devices power them. Mobile phones have used haptics for different use cases, beginning with notifications (calls, text messages) to now being embedded in our everyday applications.

Haptics began with devices in the '90s that used an eccentric rotating mass (ERM) actuator. It consists of a rotating electric motor with an off-center mass. As the ERM rotates, the force of the offset mass becomes asymmetric. This results in a net centrifugal force, which causes the motor to become displaced. As it rapidly spins, the motor is constantly displaced, which creates the vibration feeling (Precision Microdrives, n.d). ERM's are not found in many mobile phones nowadays due to their size and need for a large amount of power. ERM's were a cost-effective solution because the only haptics they needed to provide were for notifications (Boréas Technologies, 2020).

To further the haptic experience, mobile phones began using LRA's. A Linear Resonant Actuator (LRA) consists of a magnet attached to a spring, surrounded by a coil, and encased in a housing. It is driven by an energized electromagnetic coil, and then the mass moves back and forth within the coil, which causes the vibration. LRA's provide firmer and crisper tactile effects while consuming less power (Boréas Technologies, 2020). Precision Mircrodrives (n.d) cites the advantages of LRA's as:

- Longer lifespan, as they do not have internal brushes, although they state that the springs will wear over time
- Shorter lag and rise times makes for a faster haptic performance
- Consume less power than ERM's
- Compact size
- Input signal's amplitude and frequency are independent of each other, which allows for a more complex waveform to provide a richer user experience

These are the two main types of technologies providing haptic feedback in mobile phones today. There are other options available on the market but serve for different industries and product, such as VR and physical products.

2.6.1 Apple's Taptic Engine

Apple introduced their own version of an LRA in 2016 they call the 'Taptic engine.' They created the Taptic Engine to provide a localized haptic experience in which they placed under the home button to replace the feeling of a mechanical button click (Boréas Technologies, 2020). The Taptic Engine is notably large compared to the Android equivalent, taking up the bottom section of the phones, but it has been reduced in the newer models. Apple controls the hardware and software of their devices, so they have control of their experiences across the different devices.

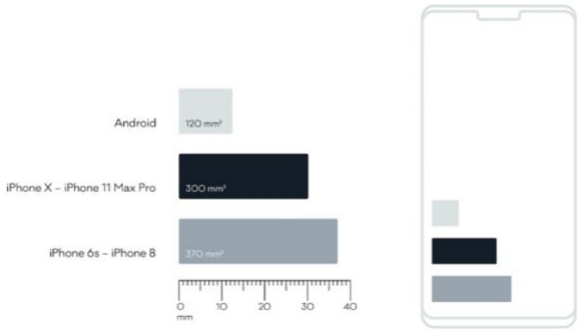


Figure 3 Actuator comparison Berrezag & Jayawardana (2021)

Apple provides guidelines to designers and developers, the Human Interface Guidelines or often referred to as the HIG. The HIG covers many essential topics regarding designing on iOS, but most importantly, it has a section regarding haptics and designing with haptics. The section is located under 'User Interaction.' Apple mentions haptics again under 'Technologies,' then under 'Accessibility,' and finally under 'User Interaction.' Apple also has system haptics embedded for developers and designers to use and take advantage of without becoming a haptic expert. There is also an option to create custom haptic patterns. For iOS, there are eight system provided haptic feedback options:

- Light: A single thud with light intensity
- Medium: A single thud with medium intensity
- Heavy: A single thud with heavy intensity
- Rigid: A single thud with rigid intensity
- Soft: A single thud with soft intensity
- Success: Signaling a task has been completed
- Warning: Signaling a task has produced a warning
- Failure: Signaling a task has failed

The system-provided haptics are used throughout Apple's system user interface. Therefore, users may have a mental model of the different haptics based on Apples' use. So, when using the system provided

haptic patterns, Apple recommends that "People recognize the system-defined haptics, so it is important to use them according to their documented meanings." (Human Interface Guidelines, n.d.)

2.6.2 Android's Haptic Experience

With Android being an open-source operating system, the device manufacturers can choose which haptic actuator they can implement into their devices. Since the companies have all the control when it comes to haptics, device manufacturers can choose where to spend their money when it comes to the different components.

The difference in actuator size across the different devices provides different haptic experiences even if they use the same code. Berrezag & Jayawardana (2021) compared the different sizes of eight Android actuators and two generations of iPhones. The size of the Taptic Engine was decreased in the iPhone X, which is why they are split from 370 mm^2 to 300mm^2. He found that the average Android actuator was 120 mm^2, with the two-generational chucks of iPhone being: 300 mm^2 and 370 mm^2. As explained at the beginning of this section, a force is required to accelerate a mass and produce a strong vibration. In addition, the size of the actuator in relation to the weight of the phone determines how much force the actuator can provide. Some Android phones can have strong haptic vibrations, such as the Google Pixel 4 and Samsung Galaxy Note 10.

While Android might lack the size and precision as Apple's Taptic Engine, there are many resources for Android developers and designers to look at. Since Android device manufacturers choose their display, screens, and speaker components, it has been harder to emulate a localized, similar haptic experience across devices.

2.6.3 Haptic Comparisons between systems

An overview of Android and iOS haptic systems in their mobile phones can be summarized in the table below.

	iOS	**Android**
Haptics powered by	Taptic Engine	LRA (depending on the manufacturer)
Built with	CoreHaptics, XCode	Android 10/11, Android Studio
Ability to control Amplitude	✓	✓
Ability to control Frequency	✓	✗
Audio Haptic Synchronization	✓	✗
Average Haptic Engine Size	300mm^2 / 370mm^2	120mm^2
Resonant Frequency	110-130 Hz	200-300 Hz

Table 3: Comparison of Apple and Android's haptic systems

2.7 Prototyping Haptics

In the design process, prototyping is often a method designers use to develop, communicate and test their ideas with other colleagues, stakeholders, and users. When prototyping, there are different fidelities, which means how far away the prototype is from the final product. The fidelity is determined by a few factors such as: stage of the design process, the available resources, and the goals for the prototype (Smith, 2019). High-Fidelity prototypes are created further along in the design process when the team knows what they

want the finished product to look like. If the prototype needs to be tested with users, high-fidelity prototypes are often the answer. The types of High-Fidelity prototypes include interactive, digital, and coded. When the product's flows are well thought out, digital prototypes created with prototyping software are the most common type of high-fidelity prototypes.

Currently, most widely adopted design tools do not support the prototyping of haptics. Bowman and Palmer, 2020 are the creators of the UX Tools survey, which they send out to designers in their network and email list, where they have collected over 10,000 responses. The survey shows that the top three tools designers used to prototype in 2020 are: Invision, Adobe XD and Figma. All these tools lack the ability to prototype haptics as they are primarily visual programs. According to UX Tools, when approaching the designer-developer handoff, the most common tools are Figma, Zeplin, and Invision. Again, neither of these tools has the ability to prototype haptics. Designers have to find creative ways to prototype haptics within mobile applications as the current market of design tools being mainly used for wireframing, visual design, and clickable prototyping. A designer had asked how to indicate a vibration for error in Invision. A representative from the company recommended they take it into a whole other program to show the idea that there was a vibration visually.

There are many tools on the market that have the ability to prototype haptics but are not commonly used in the industry. Flinto, a web-based application design tool, recently allowed designers to add haptic feedback to links. The eight haptic patterns for iOS are preinstalled. Even with the ability to prototype haptics Flinto is not a top-tier tool used by designers. However, different tools have strengths and weaknesses and depending on the designer's use case, prototyping haptics might not be strong enough to use haptics. Origami Studio is a web-based prototyping tool that allows for iPhone and iPad haptic engines where they can play pulses and prototype haptic feedback. Haptique is an iOS application that allows designers and developers to break into the field of haptics and haptic feedback. It allows for designers to have the ability to prototype and experience the different iOS haptics before implementation with the goal to reduce the developer-designer handoff.

2.8 Testing and Evaluating Haptic Experiences

After creating prototypes and solutions using the tools described previously, designers test their applications. Improving performance and understanding their user's needs can only be solved by testing with users. When performing a user test, designers have guidelines and checklists that they follow to maximize performance and ensure clarity. When it comes to testing haptics, there are few resources for designers to look to. In addition, when conducting remote user test sessions, it is harder to evaluate haptic experiences. As mentioned in section 2.4 there are many different rules and guidelines to follow when implementing haptics, but many do not involve the user directly.

In Apple's Human Interface Guidelines under haptics, they recommend to "Be sure to test the haptics in your app. Different people have different preferences and levels of sensitivity to haptics, so you need to test the haptics with as many people as possible." When going about testing haptics, there are no specifications or rules to follow to make sure the correct haptic was chosen for the specific interaction or a way to validate the haptic experience. Though there is never a correct haptic to use in a specific instance, testing the haptic with as many users as possible allows the designer to gauge the perception and urgency of the haptic relating to the strength.

3 Mobile Phone User's Experiences

3.1 Methods

The remaining portion of the study will be divided into two parts to address different research questions regarding haptics as different approaches were taken. The methodology used in this section will be used answer the following research questions:

- What role does haptics play in mobile phone users' experience?
- Does haptic design play a role in mobile phone users turning off their haptic settings?

The first and second research questions will be answered through semi-structured interviews with mobile phone users. Interviews were chosen as the primary data collection source instead of other methods. They provide firsthand accounts of mobile phone users' thoughts, feelings, and experiences, in discovering the role that they play in the mobile phone users' experience, who better speak with them than the users themselves. When approaching the second research question, it was important to interview mobile phone users who use haptics and those who do not use haptics on their mobile phones. This was a requirement to inquire if design plays a role in mobile phone users turning off their haptic settings. The interviews were then analyzed using thematic analysis to identify key themes to answer the stated research questions. The thematic analysis is the basis of this portion of the study and will be discussed in depth how the analysis was conducted. In conducting a good thematic analysis, the researcher should always disclose how they analyzed their data or what assumptions informed their analysis, then evaluating the trustworthiness of the research process is difficult (Nowell et al, 2017).

3.1.1 Semi-Structured Interviews

In preparation for the interviews, an interview guide was crafted, which can be found in Appendix Blah. The researcher decided the interviews would be semi-structured and discussion-based as the goal was to gain insight into current experiences. The interview guide was thirteen questions long, with a few questions omitted and asked depending on the participant's answers. The interview guide was followed so that the interviews would stay on track and allow for basic conversation. In addition, the interview guide aided the researcher if the discussion comes to a stall. To test the questions in the interview guide, one pilot test was conducted in person with a mobile phone user. The pilot test was timed to see the amount of time it took to answer the questions to inform future participants. In addition, the pilot test was also conducted to confirm the order of the questions, check for potential leading questions, and get an overall feel of the participant's understanding of the questions. The pilot test was conducted in person. The researcher took into account the timing of the questions could vary in person versus over a video conferencing software such as Zoom.

The researcher chose to conduct semi-structured interviews for mobile phone users. The purpose of conducting semi-structured interviews was to get more comprehensive experiences from mobile phone users and their thoughts and opinions. The goal was to discuss the haptic interactions that they have experienced and gain different points of view with users with different models of mobile phones. The majority of the data collected through the interviews is qualitative, but a handful of qualitative information was collected. The interviews conducted allowed for open-ended discussions about the haptics on their mobile phone and where they see benefits or improvement.

In conducting the interviews, the participants were given a consent form to read through and sign. The consent form contained details regarding the research project and informed the participants of how their

data would be used throughout the research project. The consent form also stated the participant's rights according to the Norwegian Center for Research Data. To collect personal data, the researcher got permission from the Norwegian Center for Research Data. The consent forms were signed over email and kept on NTNU's OneDrive.

The interviews followed the structure: opening questions, discussion, and closing questions. The opening questions of the interview are where the personal data was collected and to gather foundational data to establish the further conversation in the discussion part of the interview. The opening questions included gathering the participant's age, type of mobile phone, familiarity with haptics, and whether or not they use haptics or not. The opening questions determined whether or not to omit a few questions in the discussion. In the discussion portion of the interview, the questions were based on the user's recent experiences and encounters with haptic feedback, how it adds to the experience, and how their experiences could be improved. The closing section of the interview contained only one question aimed at users who do not use haptics and posed to the participants what would make them turn on their haptics. The closing question closely relates to the research question to understand if design is a factor when user's turn off their haptics. The questions were checked for bias by sharing the interview guide with their supervisor, in which they looked over the questions. The interview guide also followed Baxter's Dos and Don'ts of question-wording (2016). One of the dos on Baxter's list is using terms that are familiar to the user. Even though haptics is not a well-known word outside of Human-Computer Interaction, the researcher made sure to ask the participants if they were familiar with the topic, and if they were not, it was explained to them. In addition, the researcher only asked personal questions where necessary, as stated to NSD.

3.1.2 Sample

The intended sample for this study was all mobile phone users, as the research question wants to investigate what role haptics plays in the user's experience. A majority of the population has a mobile phone with haptics; the sample would be nice to reflect that. Initially, the study was aimed to investigate different age groups and their perception of haptics, but due to COVID, that idea was scrapped. The intended sample would collect mobile phone users:

- who are familiar with haptics
- those who are not familiar with haptics
- who use haptics
- who have their haptic settings turned off

In addition, the participants would be spread out across a wide age range to gather different experiences related to age. It is essential to meet these criteria because when answering the second research question, "Does haptic design play a role in mobile phone users turning off their haptic settings?" as it is essential to speak with the mobile phone users who do not use their haptic settings because they are the ones who can provide a first-hand account of their experiences and provide the why.

The sample the researcher collected was seven participants with ages from 22-35. This portion of the study used nonprobability sampling as they have no way of predicting that the sample collected represents the population. Participants interviewed were connected with the researcher who used the people that there is access to, which is students and faculty, and reaching out to people through their network, butterfly sampling. Considering there is still a global pandemic occurring, convenience sampling is the only way to include participants in the study. Convenience sampling is never an ideal option because it does not provide a representative sample of the population. But in this case, there are 3.5 billion smartphone users worldwide, so it would be challenging to have a representative sample of smartphone

users worldwide. For the sample of smartphone users, participants were found from the researcher's direct network.

3.1.3 Ethical and legal considerations

Ethical approval for the entire study was gained from the Norwegian Data Protection Center. The study was outlined how personal data is collected and synthesized to follow along with the General Data Protection Regulation (GRPR). The personal data that was collected was age, gender, occupation, and field of work. The study was not aimed at or came into contact with any vulnerable user groups.

The study was conducted and followed the professional code of ethics as the participant's protection, and conformity was of the utmost importance to the experiment. The professional code of ethics was addressed, and the study followed the ethical issues: protection from harm, voluntary and informed participation, right to privacy, and honesty with professional colleagues (Leedy & Ormrod, 2015). The participants were not placed into any harmful situation and were treated with respect. The interview questions were a free discussion so the participants could lead the interview in any direction they wanted, focusing on the topic at hand. Since it was possible to gain informed consent without influencing the study results, the researcher got the participants informed consent as they sign the consent form. The consent form described the nature and scope of the research project and the nature of one's participation in it. The participants were also read their rights in the introduction of each interview. The researcher explained that the study was voluntary. The participants could remove themselves and their data from the study at any point and refuse to answer any question.

A portion of the interviews was conducted over video conferencing software, and a portion was conducted in person. In the in-person interviews, the participants were able to be seen and made sure they were physically comfortable and emotionally comfortable. In the video conferencing interviews, it was harder to gauge if the participants had become uncomfortable but were always allowed to speak their mind and were never interrupted and always allowed to finish their thought. Also, at the end of each interview, participants were asked if there was anything else they wanted to add, so they knew that all of their thoughts were being heard and taken into account.

3.1.4 Data Analysis

In analyzing the data from the semi-structured interviews, a thematic analysis was conducted. The thematic analysis followed a six-step approach by Nowell et al. (2017) to conduct a trustworthy thematic analysis. The steps included: familiarizing with your data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. A thematic analysis is typically conducted with more than one researcher to ensure that the themes being defined are consistent and reflect the research questions posed. Due to the study being a master thesis, the thematic analysis was conducted alone. Therefore, the researcher used Nowell's et al steps to ensure the analysis was as trustworthy as possible (2017).

In following Phase 1 of Nowell et al.'s step-by-step approach, the researcher familiarized themselves with their data by jotting down notes and key points made during the interview and transcribing the discussions so that the researcher has complete raw data (2017). The raw data was then transcribed into an edited transcript, where the researcher takes out the word crutches and misstatements such as the um's and the ahh's (Baxter, 2015). In Phase 2, generating initial codes, the researcher debriefed and reflected with themselves after the interviews ended. The debriefing after the interview is where the researcher wrote down key points they remembered from the interview because they stuck out to them and drew their attention. In this phase, the researcher also began to think about potential themes and what stuck out to them regarding answering the research questions in the initial interviews. Phase 3 and 4 were conducted simultaneously as the researcher reviewed the data and searched for the themes together to make sense of

the theme collections. In searching for the themes, every participant's statement was placed onto a sticky note in Miro. The statements were pulled from the edited transcripts and anonymized so the data could not be traced back to a single participant. A large portion of Phase 4 is to vet the found themes with team members so that they can be matched for accuracy and checked for bias. In choosing to review the themes alone, the themes were revealed more times and checked for accuracy. In Phase 5, defining and naming themes, the researcher organized the post-it notes into five different categories. Within the five different categories, the researcher identified key themes throughout, which are discussed in the next section in the Results. In the last phase, Phase 6, the researcher produces the report and describes the process and coding analysis in significant detail, which this section aims to do.

3.1.5 Assumptions

In investigating how haptics plays a role in the user's experience, the researcher had a few assumptions of note to the study. After having many positive experiences with haptics and haptic feedback, the researcher had similar assumptions that many others would as well, which is why the researcher chose the topic in the first place. The researcher also assumed haptics play an important role in design, and it is not often discussed among designers. The researcher thought this because as you learn the basic principles of design in school, you learn many other aspects of design through experiences and constraints, such as microinteractions and haptics. In addressing these assumptions, the researcher ordered the interview questions so that the participants were introduced to haptics and asked if they were familiar with the topic, which was crucial in gauging their responses.

3.2 Results

As stated previously, the seven semi-structured interview statements were placed into five different groups of insights. The groups were loosely titled as they had reoccurring themes. The data were sorted into five categories: identifiers, mobile phone experiences, opportunity areas, why haptics, and user's experience. In this section, the results will be addressed pertaining to these five categories. Seven interviews were conducted with mobile phone users. Those interviewed were all mobile phone users ranging from ages 24-34, with a mean age of 28. The mobile phone users were students at NTNU i Gjøvik in Norway. The sample consisted of four females and three males. The Miro board with how the insights were grouped and categorized are shown in the figure below.

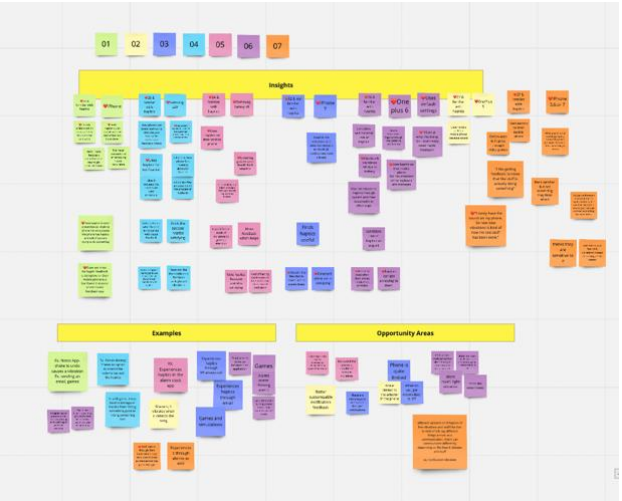


Figure 4: Miro Board of Insights

3.2.1 Identifiers

The identifiers section describes the sample with the participant's familiarity with the haptics and their use of haptics to categorize the data better. Six of the participants were familiar with haptics, and five use

system haptics on their mobile phones. One participant was unfamiliar with haptics but knew the term when it was explained to them. The participants had a wide variety of mobile phones, with three of the seven being iPhone. A handful of participants also stated that they know about haptics through games and gaming. One participant stated that they "Were introduced to haptics through the system haptics and then observed it in other apps." The type of phone of the participants and the coded reference they will be referred to throughout the results are listed in the table below.

NH1	**NH2**	**H1**	**H2**	**H3**	**H4**	**H5**
OnePlus 5	Samsung s20	Samsung Galaxy s8	iPhone 7	OnePlus 6	iPhone 7	iPhone 6
Does not use haptics	Does not use haptics	Uses haptics	Uses haptics	Uses haptics	Uses haptics	Uses haptics

Table 4: Participant Overview

Two of the seven participants stated they do not use system haptics on their mobile phones. Both of the participants who manually turn off their haptics are Android phone users.

3.2.2 Why Haptics

One of the first questions the interview participants were asked regarding haptics is 'why or why they not use haptics on their mobile phone.' As stated in the previous section, two mobile phone users do not use haptics on their mobile phones, so the question was posed to them "Why do you not use haptics on your mobile phone?" The two participants (NH1 & NH2) both agreed on their dislike for sound, but they differed when it came to turning off their haptic settings. NH2 participant declared that they had switched phones, and the settings came pre-embedded, and they have not turned haptics back on. The other participant who does not have their haptic settings turned on (NH1) discussed their battery life and how haptics and haptic feedback affects their phone's battery life. They also said, "I look at what I'm doing, so I don't really need haptic feedback." They were addressing the fact that their phone provides them with visual feedback therefore, they do not need haptic feedback, and it can save battery life. In addition, both participants brought up the continuous vibrations on the keyboard for when they are typing and how they have that setting turned off specifically. Another essential point that arose was that a participant claimed the phone was quite large. In combination with the constant feedback texting with one hand, it was constantly shaking and unbearable.

Five of the participants said they used haptics on their mobile phones, so the question posed to them was: "Why do you use haptics on your mobile phone?" Some participants discussed their physical reasons, such as being hard of hearing and always being on the move, being a good way to get their attention. There were discussions about distaste for sound feedback and, as a participant described, sound annoying and another as "it scares me." Another point was made that already embedded in apps and too troublesome to disable. Some participants explained that it depends on the application where they use haptics and do not. A participant who plays many video games said that they use haptics because "It is just confirmation mostly for me it is confirmation to tell me that like stuff is working as it should and that something has been done." They explained why if they did not have it, they would feel like their phone is broken or not working properly because if they did not get haptic feedback, they feel something is wrong.

3.2.3 Mobile Phone Experiences

When addressing mobile phone users' experiences and asking participants to describe their last encounter/ instance with haptic feedback, the participants had a wide variety of answers. The researcher did not ask specifically for an in-app haptic occurrence but just asked the participants for their last encounter. The participants answered: notification, alarms, the notes app, games, banking applications. One of the participants had to think for a while about a haptics occurrence and eventually came up with Shazam.

After some of the participants gave their answers to provide a system haptic, the researcher asked them to describe their last haptic encounter through a mobile application. This was asked to steer the discussion closer to the researcher's topic, which is focused on haptics in mobile applications. One participant could think of many instances for haptics in mobile applications, as they mentioned their notes app, YouTube when they pull down to refresh, sending an email, and games. The discussion of haptics in their mobile application went into deeper detail. Two participants had gaming backgrounds and compared their experiences from their mobile phones to those while gaming. The participants mentioned games with controllers and VR games because the haptics on those two devices is refined.

3.2.4 Likes and Dislikes

Another question that led from the previous one asked participants to describe their thought process when encountering haptic feedback and what they like and dislike about haptics. A participant stated how haptics is a comfortable way to get their attention and an excellent way to show that an action has been done/recorded. Another discussion of error prevention came up, as a participant mentioned that they have never had annoying haptic feedback. The same participant also discussed their dislike for sound and said, "I do not think the haptic feedback is disruptive on my mobile phone but has found instances where sound feedback was" One participant stated how they like haptics for notifications. They specifically like how their phone has a slider so that they can control the intensity. Another participant broke down their process when encountering haptics feedback as "something goes brr so I should check what it is."

One of the participants who does not use haptics explained how they believe the use of haptics to be urgent and that haptics can get annoying to them. But they also said they use haptics to know when their phone needs attention. Another participant finds the success haptics satisfying but get confused when the haptic feedback is not paired with visual feedback. In addition, they do not like the continuous harsh feedback from the keyboard vibrations. Another participant likes haptics because sound is annoying to them and they are hard of hearing, so it is easier to feel a vibration rather than a sound notification. They also like that it is more feedback than just visual so it helps when doing different tasks on their phone. They also discussed how their phone has different vibration levels which they enjoy because it is a different way to get their attention.

3.2.5 Opportunity Areas

The last questions of the interviews aimed to get the participants to summarize on their thoughts and discuss opportunity areas for haptics and haptic feedback. The participants were asked how they think the haptic experience could be improved on their mobile phone. Five of the seven participants agreed that they wish their mobile phone had more customizable feedback. One participant wanted their phone to be able to sense how silent the room is so they wouldn't get strong vibrations when the room is quiet so everyone will stare at them. Another participant proposed the haptic experience could be improved adding different types of vibrations. They were not sure if the phone is capable of such strong vibrations though. One participant mentioned that there are other ways to use haptics, rather than just notifications. A participant with a gaming background suggested that the phone should have different varieties of haptics that tell more of a story and communication.

3.2.6 Outliers

In a few of the interviews the topic of sensitivity arose, as one participant had difficulty providing an example of when they come into contact with haptic feedback. The participant was unfamiliar with the concept and term haptic feedback, but constantly has their vibration settings on. The researcher posed a few examples of when the participant might come into contact with haptic feedback and they were still not sure or unaware of the vibration. The researcher posed the question to the participant: Do you think you are sensitive to haptics and haptic feedback? The participant stated that they were not sensitive at all

and explained how they had their vibration settings always on where their phone would constantly be buzzing on the table. In another discussion, a participant was then also posed with the question of sensitivity, as the participant stated that they rarely looked at their phone for confirmation but feel the vibrations. The participant believes they are sensitive to vibration, as they said: "I rarely have the sound on my phone. So now vibrations are kind of how I'm told stuff has been done."

3.3 Discussion

3.3.1 Mobile Phone Users Interviews

Within the five key themes that appeared from the interviews with mobile phone users. A common issue for the interviewer was steering the discussion away from mobile phone system haptics. When asking the participants about their last instance or experience with haptics in mobile applications, many participants first mentioned a haptic experience through a system application with some of the answers included: alarm clock, switching their phone from vibrate to silent, and games (not a system haptic but common answer). The common theme throughout the semi-structured interviews was a lot of participants' ability to state an example of a non-system application, other than a game or an alarm. The system applications are where most phone users are introduced to haptics which participant NH1 stated. As stated in the background, we learn about haptics through our system haptics such as notifications. The association with notifications where some of the participants stated that they liked. This is not necessarily a bad thing as Apple's Human Interface Guidelines state, "Prefer adding haptics to a small number of significant, consequential interactions." As haptic experiences should be subtle and just give the user a little extra confirmation that an action has been done. Usually, with phone calls and notifications, the vibrations are meant to grab our immediate attention as someone is trying to contact us or tell us something via another application.

In answering the research question of "What role does haptics play in mobile phone users' experience?" the participants stated their opinions on haptics and haptic feedback, both positive and negative. From the interviews, the researcher was able to draw out the engine itself, and the setup of the system haptics play an essential role in mobile phone users' haptic experience. The two participants who have their system haptics turned off stated that their Android phones' constant vibration is very disrupting to their experience because of the continuous vibrations. The continuous vibrations are quite controversial because it again depends on the sensitivity and mobile phone user's preferences of constant feedback. The three iPhone users commented on the subtleness of the haptics as pointed out that one iPhone user said they "have never had a bad haptic experience." The participants with a non-Apple mobile phone were quick to bring up the keyboard haptics, vibrating after each letter they type. A participant described the constant feedback as quite annoying.

3.3.2 Opportunity Areas

When posed with the question "How might the haptic experience on your mobile phone be improved?" multiple participants mentioned the different types of vibrations should be possible. The current phones have limitations when customizing vibration patterns. One participant mentioned that haptics is a good way to get attention, and the different haptic patterns would allow for a different message to be sent. A few participants mentioned the relation to games and how they provide complex vibrations.

The discussion of the topic of sensitivity to haptics arose in multiple discussions. This led from discussing the experiences that were encountered on their mobile phones. One participant claimed they were not sensitive to the vibrations on their mobile and hardly noticed them as they occurred. The participant had all of their vibration settings on ex. for calls, text messages, and notifications, so there could be a correlation to their sensitivity with haptics. Another participant claimed they were severely sensitive to haptic feedback, which is why they have their keyboard haptics turned off. Another critical point that

arose was that a female participant claimed her phone was quite large. Combined with the constant feedback texting with one hand, it was constantly shaking and unbearable.

3.3.3 Sensitivity

An important topic to investigate that came about through the mobile phone user interviews regarding haptics is sensitivity. Since haptics are used to communicate a message, sensitivity is a large part of how users perceive the messages designers are trying to send. Investigating different sensitivity levels would be a topic for further investigation to see whether age or gender affects sensitivity in haptics in mobile phones. As mentioned previously, Apple and Android's haptic engines have different strengths of vibrations. Android's resonant frequency is around 200-300 Hz, whereas iPhone's resonant frequency is around 110-130 Hz, which means that iPhones tend to have less subtle vibrations than those of Androids.

Regarding preference of liking or disliking haptic feedback, it also depends on the mobile phone user's hand sensitivity level and the device itself. The ability for customization of haptic sensitivity is an option that mobile phone makers should explore. Android phones currently have intensity sliders, as one of the users had described how they like that they can adjust the intensity. Currently, with iPhone's the only options are to turn the system haptics on or off. The haptic experience of a phone can make a difference in the smartphone user's experience.

Another topic regarding sensitivity that would be interesting to investigate is based on the mobile phone user's previous habits (use of system vibration settings) and how that affects their sensitivity level of the haptic experience on their mobile phone. As addressed in the background, mobile phone users were introduced to haptics through system vibrations such as phone calls and notifications. Then when actuators became more complex, and developers were able to access them, they were implemented into mobile applications. The question to be investigated could be 'Do previous habits with system haptics affect the sensitivity of haptic experiences in mobile applications?' As stated, one participant became very acclimated with vibrations to the point where they would not notice the fundamental vibrations that their phone was omitting. Based on their constant use of vibrations that they have for every application, the researcher was able to deduct that the sensitivity decreases over time when most notifications use vibrations. Do you become more sensitive to haptics as you age? Or do you become desensitized to haptics as you age? Because previous research has investigated hands as you age and how your motor functions tend to decrease as you age. It would be interesting to investigate this topic in thirty or so years as the generations who grew up with phones in their hands start to lose motor functions.

3.3.4 Limitations

The study was limited due to the sampling method, and therefore it would have a high sampling bias. The researcher found strong data points in their results but, the results would not apply to the entire population. As stated in the Methods section the researcher used, convenience sampling was prone to sampling bias. To appropriately answer this research question with results that could apply to an entire population, refer to section 3.1.2.

To better answer the research question "Does haptic design play a role in mobile phone users turning off their haptic settings?" a more varied perspective would be valuable as the researcher should aim to find a large group of non-haptic users. However, speaking with the two participants who do not use haptics on their mobile phones, they have other reasons for not turning on haptics on their mobile phones. With the previous point of the user only being able to recall system haptics, application design does not seem to play a role. However, it also would depend on the phone that the users have. Users turning off haptics settings could vary widely depending on other things than bad design, such as physical condition. Bad design could play a role, but according to the sample, it is not largely conspicuous. As haptics gains more popularity with designers, bad design and implementation could play a role in the future of mobile phone

users turning off their haptics. Nevertheless, currently based on the user interviews, haptics is not often implemented enough to where the user can point out natural haptic occurrences outside the system haptics. In addition, Android device manufacturers are currently working on improving their haptic engine, so haptic use in applications on Android could grow increasingly in the future.

To get more varied perspectives on mobile phone user's experiences with haptics, speaking to those who do not work in the tech industry would be valuable. Speaking with those unfamiliar with technology and haptic feedback would be valuable to get their perspective and investigate their perception and feelings. In addition, getting experiences from those unfamiliar with the technical aspect of haptics could provide designers and engineers with new insights about haptics. There are many different types of mobile phone users with many different types of phones. Therefore, it is hard to design for all of them at once. Neglecting these groups of people could be missing contrasting experiences, which could lead to more insight.

4 Designers and Developers

4.1 Methods

The methodology for the second part of this study consists of a design-based research (DBR) approach in which the researcher: analyzes practical problems, develops a solution with a theoretical framework, evaluates and tests the solution and documents, and reflects to produce a set of design principles (Reeves, 2006). The choice of doing design-based research with a prototype was to tackle a fundamental problem of designers not having a way to easily implement haptics and haptic feedback without becoming a haptic expert. In choosing design-based research, the goal was not just to prove that designers and developers have no transparent process for implementing haptics and haptic feedback into their designs but also to design a solution and instruction for the future. In addition, with the goal that the solution and or instruction will get refined. Another reason for creating a prototype and website solution is that designers and developers are used to documentation, whether using a design system or material design, human interface guidelines, or many other things. Hapticfinder gives designers a fun go-to when designing with haptic feedback so that they do not have to guess where a haptic should go but give them a confirmation and suggestion of where it should go. In performing research and creating with designers, the goal was to create a tool to use and incorporate it into their design process. The goal was also to promote haptics, and haptic feedback as a new way designer can communicate with their users beyond the screen as DBR typically has an explanatory and advisory aim, mainly to give theoretical insights into how particular ways of teaching and learning can be promoted (Van den Akker et al, 2006).

The methodology combined with the creation of a prototype and guidelines will be used answer the following research questions:

- How is haptics and haptic feedback currently incorporated in the design process?
- How can haptics be more be more effectively incorporated in the beginning of the design and development process?
- How have haptic experiences been evaluated in mobile phones?
    - What do current evaluation methods lack?
    - What could be a more effective evaluation method?

The first research question will be answered through a combination of the data from the semi-structured interviews and secondary research. The interview was conducted with one expert in the field as it was proven difficult to find experts on haptics in mobile phones. The second research question will be answered through the use of prototyping with the goal to create a solution that helps designer's more effectively incorporate haptics in the design process. As through desk research, it was discovered that current design teaching methods do not involve haptics or a way to protype and sketch with haptics and haptic feedback. The third research question will be answered through secondary research where the researcher will review on what other people have done and propose a refined solution for evaluating haptic experiences for designers. Secondary research was used to answer the third research question because asking mobile phone user's and designers in the field would not suffice as they are not the ones evaluating haptic experiences. To answer the research question, the researcher had to turn to scientific literature.

In regarding the second research question, after the prototype was created, Hapticfinder was tested given designers a use case and a fake mobile application. They then took the quiz and to see what haptic Hapticfinder recommended and if they felt that Hapticfinder recommend them a good haptic to use. The

involvement of the user's (designer's) is key to research-based design as when creating a tool for a specific user group, it is essential to have them involved from the beginning with iterations being constant.

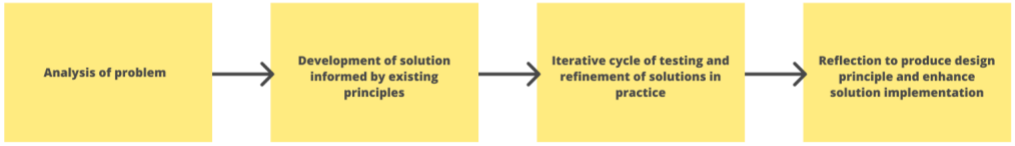


Figure 5: Reeve's (2006) Design Based Research

The following section, follows Reeve's (2006) structure of Design Based Research where the researcher begins with analysis, develops a solution, then iterates and reflects upon the solution.

4.1.1 Desk Research/Secondary Research

To better understand how haptic interfaces are being evaluated and to gain insight into how haptic experiences have been evaluated in mobile phones and the current guidelines that are out in the industry an initial desk research phase was conducted. Desk research was chosen as a method to answer the research question "How have haptic experiences been evaluated in mobile phones?" to understand and to investigate into the field of current haptic evaluation methods. Desk/Secondary research can also help identify gaps in the current knowledge in a field and highlight future directions (Shah, 2018). In addition, the desk research is aimed to inform the overall study and aid the creation of the interview guide for the expert designer interviewed. The desk research for this portion of the study consisted of:

- A review of scientific literature regarding evaluation methods and guidelines in haptic experiences
    - Keyword used in Google Scholar was "Haptics for Usability" and then used the sources from the main article

In the review of evaluation methods regarding evaluation methods in haptic experiences, the researcher initially found the one paper through searching 'haptics for usability' on google search engine but then used the same search words on Google Scholar. The search was then performed on Google Scholar where 'Haptics for Usability' queried 24,600 results. The search was then narrowed to 'haptic feedback usability evaluation' but still queried 30,000 results. The search was narrowed down even further by year and to those with evaluation methods as their end result. One paper was found with an end result of an evaluation method of haptic experiences. The paper was found on IEEE and then the researcher dove further into the database. Next, the researcher searched IEEE, where they searched 'evaluating mobile phone haptic feedback' which queried only 5 search results. The researcher checked to see who had used the paper as a source as well.

In assessing the quality of the results, the researcher followed Leedy & Ormrod's checklist of evaluating a research article (2015). The checklist covers reliability of sources, procedures, data analysis and conclusions. In addition, the researchers of the articles background were also explored and evaluated their previous published papers relating to the industry.

4.1.2 Semi-Structured Interviews

To first uncover the problem designers have in implementing haptics the researcher spoke to a senior designer who has previous experience and interest in haptics and works at commodity marketplace company. To uncover the experiences and go to a further in-depth discussion about the implementation methods the researcher chose to conduct semi-structured interviews. Interviews were chosen over other methods because it allowed for a more personal conservation as speaking face to face with someone

interested in their projects and subject matter allowed for a more open and impartial conversation. Interviews were also used over surveys and other methods because the researcher could gain more context of the designer's team structure rather than through a survey where only thoughts and opinions would be collected. In addition, if the researcher had some follow-up questions about the participants answers, they could ask and go into further clarification or steer the conversation in a certain direction.

The expert interview was quite casual but still followed an interview guide. The interviews were structured similarly to the mobile phone users as they were composed of opening questions, a discussion and closing questions. The questions that were asked to the experts, allowed for a discussion on their work and the opportunities they see for haptics in the future. The discussion was guided for the designers to talk about their work and what they were excited about in the field. The expert interviews were also read the introduction and sent the consent form ahead of the interview where they signed the document and returned it to the researcher. The consent form was provided by the Norwegian Center for Research Data and contained details regarding the research project and also informed the participants of how their data was going to be used throughout the research project, as well as their rights to their data. The audio was recorded with the participants permission as well as disclosed to NSD so that it could be transcribed and listened to at a later date.

In selecting experts to interview, the researcher initially asked friends and family and looked through LinkedIn to find experts who have experience implementing haptics. Finding expert designers and developers who have implemented haptics in a mobile application was difficult, as very few mobile applications have haptics implemented in them. The researcher had to then turn to a different strategy and look in another place. Finally, the experts were found, searching through Medium articles and scientific papers. Participants interviewed were chosen because they have previous experience and work published that dealt with haptics. The experts were contacted through email and LinkedIn, where they then set up a time to chat and discuss their work. It would have been beneficial to compare the different implementation methods at small and large companies but due to the small sample size this could not be done.

4.1.3 Data Analysis

Since the sample size for the interview was one interview the researcher was unable to conduct a thematic analysis across multiple interviews. But the researcher could still pull out themes and points made within the same interview and reference it with secondary research. The interview with the expert was transcribed and coded for reoccurring themes. In addition, secondary research was conducted in tandem with the expert interview so that there would be foundational data to back up the claim. The details of the review of the literature can be found in section 4.1.1.

4.1.4 Problem Analysis

In uncovering the problem in the semi-structured interview and through desk research two problems were discovered. The first problem based on the interview data and desk research; the researcher was able to identify that there is no current structure in the design process in adding haptic feedback to mobile applications. The interviewed participant stated that it is normally a discussion when adding a new feature that haptics arises. They stated that it is normally the developer who starts the conversation about haptics as they have more familiarity with haptics as they are the ones that write the code. The second problem that was uncovered was the lack of evaluation guidelines for testing haptics in mobile phones.

4.1.5 Development of Solution-Prototyping

To answer the research question of "How can haptics be more be more effectively incorporated in the beginning of the design and development process?" and "What could be a more effective evaluation method?" a prototyping approach was taken. In assisting designers when adding haptic feedback to

mobile application, the initial goal was to create guidelines which designer could follow best practices in implementing haptics. The researcher discovered there were many different guidelines by a handful of researchers that all say the same thing. Ultimately Apple's Human Interface Guidelines are the guidelines that should be followed as they have the power in deciding on whether or not an app can be in the app store or not. The guidelines were created through sketching and analyzing the evaluation methods in the literature review.

4.2 Results

4.2.1 Literature Review

To answer, "How have haptic experiences been evaluated in mobile phones?" a literature review was conducted, and the results are summarized in the table below.

Author	Source	Type	Guidelines
Android source (n.d.)	Implementing Haptics	Assessment	Providing an observation and assessment of mobile phones to determine if the amplitude of haptic patterns is perceptible by humans.
Material Design (n.d.)	Android haptics	Guidelines	Follow system patterns, focus on user need, design holistically, combine haptics with audio and visual, avoid unpleasant haptics, use patterns predictably
Apple (n.d.)	Human Interface Guidelines	Guidelines	Haptics should have a clear cause and effect relationship, they should be used consistently and judiciously, in combination with other feedback, avoid overuse, be optional, tested with users
Khan et al. (2011)	Development of Usability Evaluation Framework for Haptic Systems	Scoring system	Efficiency, effectiveness, satisfaction, learnability, safety, operability, time behavior, accuracy, navigability, consistency, flexibility, familiarity, simplicity, user guidance, resource safety
Sinclair et al. (2012)	Towards a Standard on Evaluation of Tactile/Haptic Interactions	Guidelines	Validation of system requirements, the verification that the system meets the requirements, and the overall usability of the system
Müller (2020)	Designing with haptic feedback	Checklist	Current information, functional opportunities, feedback opportunities, body interaction, context, object, advantages, challenges, character, importance, learning, advantage, and technology

Table 5: Literature Review

4.2.2 Expert Semi-Structured Interview

One semi-structured interview was conducted with an expert designer who has worked with haptics and has previous work in the field. The interview began with the expert describing themselves and how they got into the field of haptics, and how they work as a designer/developer team in their company. The expert designer works at a commodity marketplace company in Norway. They are a senior designer and are responsible for various projects but are primarily responsible for iOS and Android applications. In addressing the topics that the researcher had prepared, there was a natural flow to the discussion, and the interview guide was not followed. The expert designer spoke about their interest in mobile applications,

stemming from being very interested in different technologies. Since they have been working in applications since the early adoption of the Apple app store, they have extensive experience in mobile applications.

As an expert in haptics, they explained that they were self-taught designer, and their interest in haptics stemmed from their mobile app interest. They described haptics as "the soul of the product." At their current company, the approach to design they stated is like a speedboat, and they get to go around to the different islands and see what cool things they can do to improve and enhance the user experience. When discussing how haptics gets implemented, the expert designer brought up the fact that they have worked at a communication agency previously where they worked on mobile apps. They described the experience of implementing haptics as different than where they are at now. With the consulting agency, they described that they were hired on a project basis. As a design consultant, they described that they would be assigned to a project where they had one month to design. Then they would hand off their designs to the developer where they do not know what the project is. The whole point of this discussion was that the developers were on a time crunch and had little to no time to care about tiny details such as microinteractions and haptics.

When asked about the haptic implementation process at their current company, the expert designer explained that they work very closely with their developer on the same feature. They talked about how they work closely with their developer and can pop over to their desk if they have a question or comment. When deciding when to implement a haptic, they stated that the most challenging thing about it is talking about it and deciding which haptic to go with. In talking about haptics, the designer described that you feel and experience haptics, which means it is hard to put into words. They stated that as a designer, they wanted to limit the back and forth between the developer and designer to settle on a haptic. It was mentioned that it takes much time for the developer to prototype a haptic, and then they would bring it to the designer, and they would play around with the prototype.

In addressing how haptics comes to implementation, the expert designer stated that it is part of their design process because when they are designing the screens in Figma, they keep haptics in mind. They also mention that the developer has access to the Figma files, which is the tool they use for the handoff. When working in the Figma file, the designer makes small annotations or comments where there should be a haptic ex. Long press. Although, they admitted that sometimes they do forget to annotate it and point out where a haptic occurrence should go. Bringing it back to the design process, they mentioned that when they are discussing a behavior, the discussion of haptics comes up and would use the app Haptique (that they created) to test out the different haptics. The expert designer brought up that they would say the coming about of haptic implementation is mostly brought on by the developers. This being because they know the latest technology available and are eager to implement it. The expert designer pointed out that developers have as much say in the product as the designers do. They mention that the product is built by developers and designers because developers also have the opportunity to add to the design.

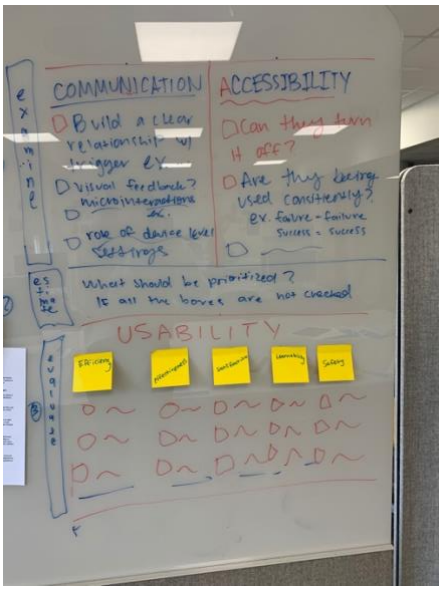
As far as testing haptics, the expert designer would use the screens created in Figma and pretend to tap the screen and then use the app Haptique to test different haptic patterns. When asked if they test haptics in their applications, the expert designer said they have not had a significant enough haptic experience that it needed to be tested. They said they would only test a haptic if it was a custom haptic pattern for a more significant occurrence, such as a celebration screen. They have not made any custom haptic patterns yet but are excited to go down that road at some point. The expert designer also stated that they do not test any visual feedback unless it is spinning and doing a lot of stuff with moving parts.

Throughout the interview, the expert designer brought up their love and appreciation of Apple's approach to technology. They point it out throughout the interview because when implementing haptics, the main focus is on iOS. They mention that it is not worth the designer's time as a designer working on haptics for

Android. Because none of the Android phones have a standard haptic engine, so the result you get on each device is very different. They put it into terms of fonts across the web and how they can be rendered differently on different browsers. This is the same for Android's haptic experience. The expert designer states that they prefer and invest more time into iOS haptics as Apple controls their devices. They also mention that Apple's devices are very controlled down to screen size, making it easier to design for with the experiences being the same across all iOS devices. The expert designer compared the haptic experience on Android as a guitar having only one string, with iPhones having all six strings.

4.2.3 Evaluation Proposal

In answering "What could be a more effective evaluation method?", the researcher pulled valuable insights from the literature review and formed new evaluation guidelines. These guidelines are specifically for designers and developers where the top portion acts as a pre-test check, and the bottom flow chart is meant to be used during a user testing session. The evaluation method was sketched out based on the information acquired from the literature review. It was first illustrated on a whiteboard, then taken to a paper prototype, and then refined in Figma.



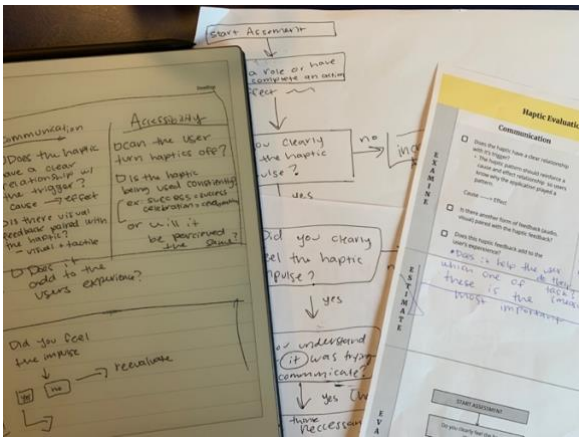


Figure 6: Sketches of Evaluation Prototypes

The evaluation method proposed is a tool for designers to use and learn from to improve their knowledge of haptics. The evaluation proposal is divided into two sections: Examine and Evaluate. The 'Examine' section is a checklist for designers to perform before evaluating their haptic feedback with a participant. The 'Evaluate' section is for designers to use when performing a user testing session with a coworker or anyone they can get a hold of. The evaluation method can be found on the next page.

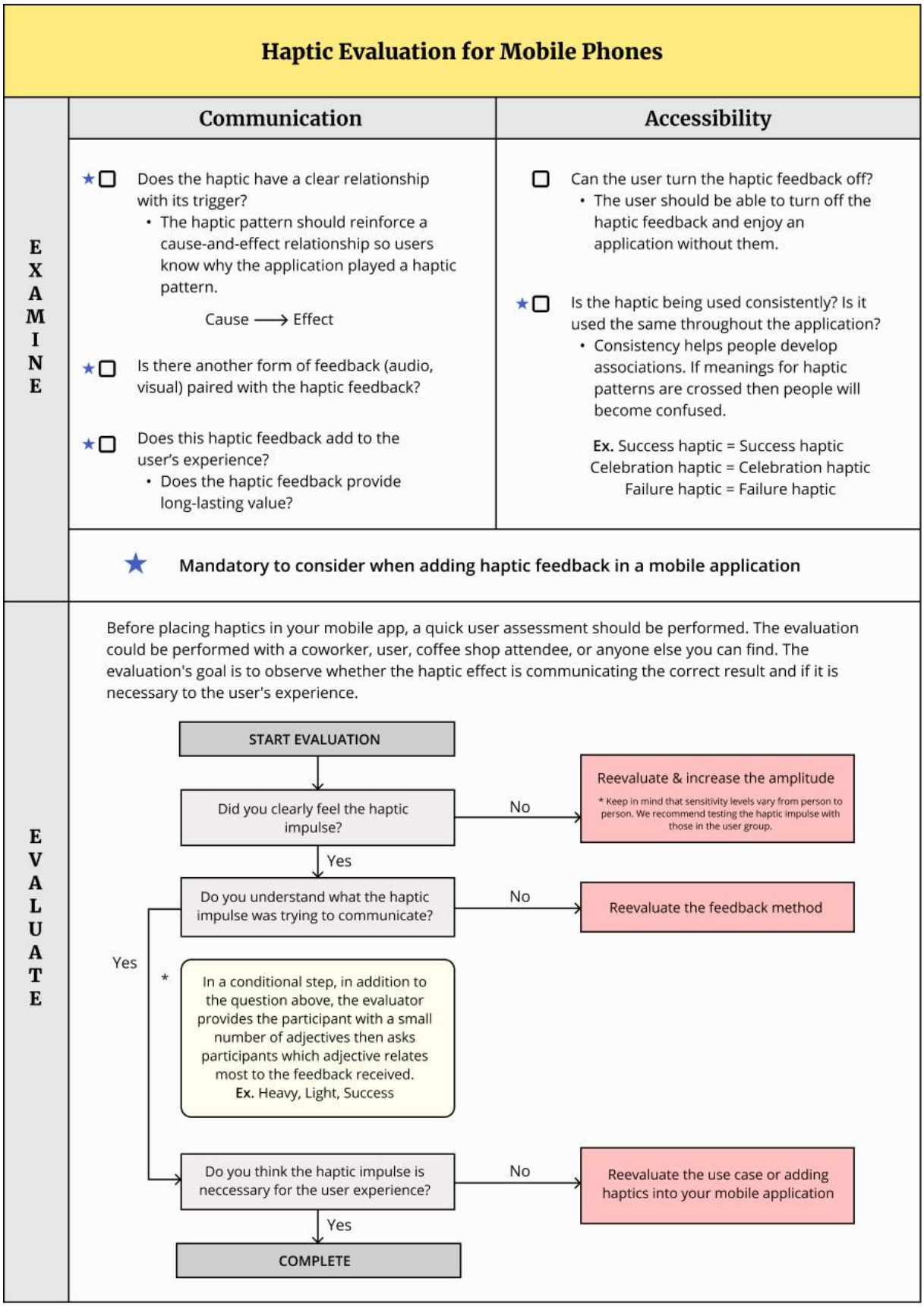


Figure 7: Evaluation Method

4.2.3.1 Examine

The 'Examine' section of the evaluation proposal is divided into two sections: communication and accessibility. The two sections have five questions in total for designers. To better understand the evaluation proposal, an explanation of each step is as follows:

Communication

1. Does the haptic have a clear relationship with its trigger?

   Making sure that the user is aware of the cause and effect relationship with the haptic feedback is essential. Feedback is used to explain information to the user which indicates haptic feedback should be used when a message is meant for the user. If the user completes and action and receives feedback based on the action and is unable to associate the feedback with the action, the feedback is ineffective. The relationship between the trigger and the haptic should feel natural and should not be experience too often. This is important for designers to be aware of as haptics are

2. Is there another form of feedback (audio, visual) paired with the haptic feedback?

   Haptic interfaces are almost always multimodal. This question is to confirm that the designer has visual or audio feedback in tandem with haptic feedback. If the phone starts buzzing randomly without visual or audio feedback, the experience becomes unnatural. The user is able to learn more through multimodal feedback and is able interpret it in different environments.

3. Does this haptic feedback add to the user's experience?

   Haptics should only be used to improve the user's experience. If they do not improve the experience for the user's, then there is not point adding haptic feedback into the mobile application. Haptic feedback should provide long lasting value so that the user will be able to associate certain action with a specific type of haptic feedback.

Accessibility

1. Can the user turn the haptic feedback off?

   Having the ability to turn haptic feedback off gives the user more control. Everyone uses their phone different and has different conditions when using it, giving control gives the user more freedom. More freedom makes it more likely that they will keep using your app in the future. The haptic feedback is not the main feature of the app and should be able to enjoy the application without the haptic feedback.

2. Is the haptic being used consistently?

   When building relationships between the haptic and their trigger, they should always be consistent. Consistency is how we build mental models and are able to make associations. Designers are normally familiar with associations and building mental models, but it should always be checked. A success action should always trigger the same haptic. If this is not the case, then the haptic is not being used consistently.

4.2.3.2 Evaluate

In the 'Evaluate' section of the evaluation proposal, the researcher created a flow chart based on Android source's subjective assessment. The flow chart is aimed for designers to use when performing a user test. The flow chart can act as a loose script when user testing. The flow chart evaluation consists of three yes or no questions with one conditional step that could be added.

The flow chart evaluation begins in the user test session after the participant has completed a task on the application that they are testing. After the participant has completed the task with the haptic feedback, the evaluator then asks the question in the first step, "Did you clearly feel the haptic impulse?" The participant then has the option to answer yes or no. Depending on either answer, the flow chart will lead the evaluator to the next step. If the participant answers no to feeling the haptic impulse, it leads the evaluator to reevaluate the haptic and increase the amplitude.

If the participant's answer is yes to feeling the haptic impulse, then the evaluator is able to move on to the next step. The next step in the evaluation proposal is to ask the participant if they understood what the haptic feedback was trying to communicate. As with the previous question, if the participant were to answer no, then the evaluator would be led to reevaluate, but in this instance, the feedback method should be reevaluated. This is because the participant says they cannot understand what the feedback is trying to communicate. For this question, there is a conditional step. The conditional step is to aid in the confirmation of the combination of the haptic feedback. The conditional step is an exercise that can be done with the participant to confirm that the feeling of the haptic feedback was what the evaluator or designer was trying to convey. The exercise would consist of the evaluator providing the participant with a series of adjectives. The participant would have to select the adjective they believe relates the most to the received vibration pattern. The researcher does not recommend more than three adjectives. If the participant does not select the correct adjective related to the feedback received, the evaluator can then ask the participant to explain their answer and justify.

Figure 8: Example of the conditional step in the 'evaluate' section

After completing the conditional step, the evaluator then would ask the participant, "Do you think the haptic feedback is necessary for the user experience?" If the participant answers yes, then the assessment is complete. However, if the participant answers no, then the evaluator is led to reevaluate the use case or the need for adding haptics into the mobile application. After the evaluation has been completed, the designer can give the developer to implement the haptic feedback in the app.

4.2.4 HapticFinder

The insights gathered from the interviews led the researcher to create HapticFinder, as the expert designer stated that the hardest part in implementing haptics is choosing the right haptic and talking about it with the developer. HapticFinder is a quiz made for designers and developers to help them decide what iOS system haptic works perfectly for their implementation status and ensure that they are following the best practices. The best practices being the Human Interface Guidelines. HapticFinder was based off of early 2000's teen magazine quizzes where the reader would answer different questions and follow a flow chart to end at a result. The researcher decided to keep the structure as a tree behind the scenes but present it as a quiz. This being that the results could have been influenced if the users were able to see the path that could lead them there.

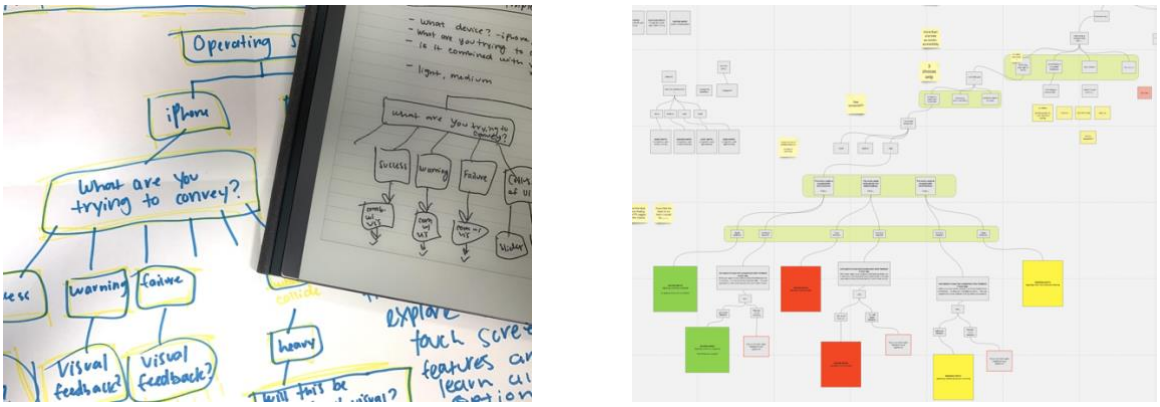


Figure 9: Prototyping HapticFinder

The choice to focus on implementing iPhone haptic feedback and building HapticFinder to aid the process was that the iPhone has nine preset system haptics. The nine preset system haptics allow designers and developers to implement haptic feedback into their mobile applications without creating a feedback pattern from scratch. There is an option to create custom haptic patterns through haptic API, but it should also still follow the rules in the Human Interface Guidelines. In addition, iPhone haptics are quick and smooth. As previously mentioned, Apple has created its own LRA, the Taptic Engine, to control the vibration patterns and optimize the engine perfectly to fit those needs. The other tool, Haptique, that the researcher recommends that designers use in pair with HapticFinder tool is also only built for iPhone, and it is used to explore the nine different system haptics and see how they feel in your hand. Further development should be made for Android so that all operating systems are equally covered. In creating this tool, developers and designers who are either new to iOS or haptics, in general, can find this helpful tool when working on their next mobile application.

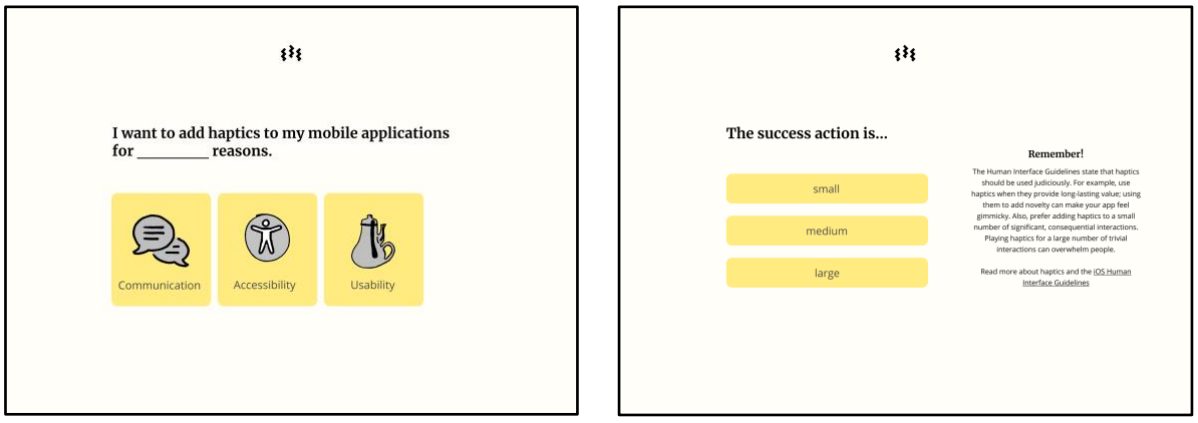


Figure 10: Screens from HapticFinder

HapticFinder aims to provide designers with an iOS system haptic based on their use case. Since Apple provides eight system haptics, there is opportunity for enhancements to current interactions. HapticFinder consists of solely statements so that the designer reads the statements from their point of view so that they are able to confirm

An example walkthrough of HapticFinder:

Scenario: A UX designer at ASOS wants to explore haptics and haptic feedback to improve their mobile application experience. They want to add a haptic to their iOS application when a buyer completes a purchase.

1. I want to add haptics to my mobile applications for **Communication** reasons.

In this circumstance, the designer would select communication as adding a haptic will increase the communication between the user and the application.

2. I am trying to convey to the user… **something went right or wrong**.

The haptic being added is used to communicate that the purchase has been completed. Therefore, something went right.

3. I want the user… **to know an action was successful**.

The completed purchase interaction means the action was successful, and the user's package is on the way.

4. The success action is… **large.** (Remember! The Human Interface Guidelines state that haptics should be used judiciously. For example, use haptics when they provide long-lasting value; using them to add novelty can make your app feel gimmicky. Also, prefer adding haptics to a small number of significant, consequential interactions. Playing haptics for a large number of trivial interactions can overwhelm people.)

The success action of complete a purchase is large, possibly the largest action that can be completed in an app. Since it is not common for users to make multiple purchases throughout one session of the app, then it is okay to add a haptic for a large success action.

5. This action needs to be paired with visual feedback.
   I have **visual feedback** in my mobile application. (Remember! Use haptics in ways that complement other feedback in your app. When your app's visual, auditory, and tactile feedback are in harmony — as they are in the physical world — the user experience is more coherent and can seem more natural.)

When completing a purchase, there is visual feedback involved as you receive your order number and delivery time. The haptic will be used to aid the visual confirmation feedback.

HapticFinder then provides the designer with the result, which is the iOS success system haptic.

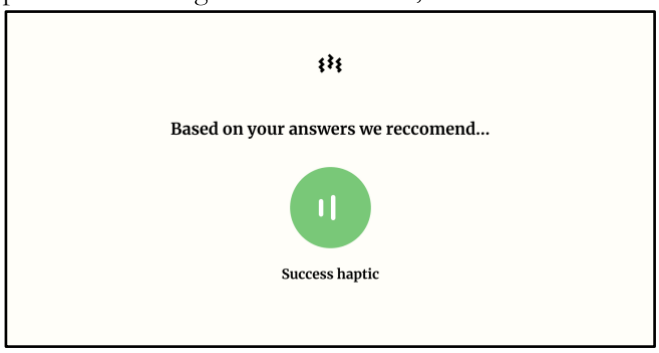


Figure 11: The resulted haptic

HapticFinder results in providing a haptic that is specified for the action. In the scenario, HapticFinder provided the designer with the success haptic from the eight system haptics.

4.3 Discussion

4.3.1 Interview

In answering the question, 'How are haptics and haptic feedback currently incorporated in the design process?' there is little to concluded about this topic. In the case of the expert interviewed, they already have previous knowledge about the subject, which could affect how haptics is implemented in the design

process compared to a designer with no knowledge in the field. Because the researcher limited themselves to one expert who had previous knowledge, there should be nothing to conclude. The expert interviewed also saw the implementation process as a problem and decided to make an application themselves to improve the process. Having previous knowledge about haptics makes it more likely that they bring it up in the future. However, the expert designer did say that the developers are mostly the ones to bring it up because they know about the latest technology. This might be true in other use cases and would be a future point of investigation.

A wider angle should be taken to gain insights into a representative sample of companies and their haptic implementation process when answering this research question. This being because company structures vary and could have different implementation processes. In addition, every company will not have an expert on haptics, making it less likely for certain companies to implement haptics in their mobile applications.

From the expert interview and background research, it could be concluded that 'Designers who have background in haptics are more likely to implement or find a reason to implement it into their mobile application'. The researcher is using deductive reasoning in saying the statement that 'Those who have a background in haptics are more likely to use haptics and have an implementation process and implement them in their mobile application'. The base of the reasoning comes from the expert interview conducted where the designer had previous knowledge of haptics and therefore would find ways to use haptics in their mobile application, even though the designer worked at a commodity marketplace company. That being that the expert stated specifically that the developers are usually bring it up in the handoff process. The point being that if there is no previous knowledge of haptics by the designer that the developer would be the one to bring up the topic.

This statement can be loosely tied to the Baader-Meinhof Phenomenon which states that when you learn something new, you begin to see it everywhere. Another take in relation with this study is that: If you know about something, you are more likely to use it. As having previous knowledge of haptics and an interest in haptics could make it more likely that it would be implemented in their design process and implemented in their mobile applications. As a designer, when creating and planning out your screens and flows, if you are aware of haptics and have knowledge about it then it makes it more likely that there will be implementation. Some designers have special superpowers which is influential in how they approach design. So, when answering the research question 'How are haptics and haptic feedback currently incorporated in the design process?', it can be concluded that if the designer knows more about haptics then it will be incorporated into the design process.

For answering this research question, a different approach should have been taken. Initially, the researcher only wanted to interview experts in haptics, or those who have implemented haptics in a mobile application. Which was difficult to find people as they found that it is hard to find people who have specifically implemented haptics in a mobile application. There are so many applications out there in the Google Play store and Apple's app store and a slim amount use haptics, so it was not a strong approach. When going about answering this research question, it would have been interesting to speak with designers about the topic of mobile phone haptics in general and where they see the opportunities like Mülller (2020) did. The topic could have explored more of opportunities of haptic in mobile phones or speak about device haptics in general and where they see the strengths and weakness of the devices. The device specific topic when talking about mobile application, is an interesting debate and how designers deal with the different operating systems. Another investigation that the researcher should have undertaken was the interviewing of designer who have implemented haptics on Android phones or spoken with Android developers directly. As stated by the expert designer, the developers are often the ones to bring up the topic of haptics so it would be valuable to speak with Android developers and to

investigate how common they implement haptic feedback. Or if it is on their mind at all when writing code.

With the data being only from one source it was influenced by sampling bias. Sampling bias is any factor that yields a nonrepresentative sample of the population being studied (Leedy & Omrod, 2015). When choosing to only interview experts and the people that they were in connection with the researcher, the population became biased as there is no way these opinions could apply or be generalized to the whole population. The researcher should have taken a more wide approach and collected a more representative sample. When it comes to designing with haptic feedback and how it is implemented in mobile phones, scientific literature is lacking. This could be in part by the design processes when working for larger companies, startups and consultancies are becoming messy and pressed for time. In design school, the basic processes are taught such as double diamond, design thinking, and user-centered design which are not one size fits all type solutions. But as the expert designer pointed out, companies such as consultancies are pressed for time and money and do not have time to spend on each design phase.

As stated in the Results, Müller's (2020) paper was used to gain more insight into designers' feelings and approach with haptics. The paper that was used as a reference was a mater thesis and did not have strong scientific support. In addition, the paper is written on haptic feedback in physical products therefore the discussions could vary. Though the results found were similar to the semi structured interview conducted as designers who know about the topic are excited to talk about it and find use cases for it.

4.3.2 Evaluation Method

From the literature review (section 4.2.1), it was clear that there were no visual models for designers evaluating haptic experiences in mobile applications. In the table, there are various types of evaluations such as a checklist, guidelines, scoring systems, etc. To avoid text-heavy guidelines such as Apple's (n.d.) and Material Design (n.d.), the researcher chose to combine a checklist and a flowchart to form the new evaluation guidelines. Apple (n.d.) and Material Design (n.d.) are created by two large companies that provide their developers and designers with guidelines but no testing plans to consider. Khan et al. (2011) proposed a scoring system to evaluate the usability of a haptic system. The term haptic system is very broad. It would be too complex to perform the usability of a mobile application as some of the evaluation is inapplicable because they refer to the system itself. Müller (2020) introduces a checklist that considers haptic feedback before the designer enters the prototyping phase. The checklist was broken down and more complex; as for physical products, there is more focus on creating the product around the haptic engine, whereas, in mobile phones, haptic engines are already in place. These guidelines do not apply to mobile phones, but the new evaluation method was created for mobile phones only.

The evaluation method was created solely by the researcher. To add validity to the evaluation method, it should be checked or created in tandem with an expert in the field. This would have allowed for confirmation of concepts, instead, the researcher confirmed with fellow designers. In addition, the evaluation method is purely subjective. In the 'Examine' section, the designer could quickly act blind and check all the boxes even though they do not apply. When creating a tool, there are always these things to keep in mind. The result of the evaluations is not measurable, and there is finalized score, such as Khan et al. (2011). Combining a checklist and a flow chart, the researcher aimed to make it easy for designers to examine and evaluate rapidly. The guidelines do not consider the device itself, but the designer should be aware of the limitations of the haptic engines of the different devices they are designing for.

4.3.3 HapticFinder

The expert designer also stated that the most challenging part of the haptic implementation process is finding which haptic to use and how to talk about it. Having the designer and developer exchange emails or slack messages back and forth wastes time that can be used for other things. This is where

HapticFinder comes into play. Even though haptics is experienced through touch, designers should be aware of the different use cases and opportunities for haptics. As being a beginner with haptics, it is challenging to choose where to begin. When taking the quiz, designers should already have a use case or opportunity where they would like to add haptics. If they are looking for guidelines about haptics, they should turn to Apple's (n.d.) Human Interface Guidelines. As Apple manufactures its devices and controls the operating system, it is best to follow Apple's guidelines on their own devices. HapticFinder should be used in tandem with Haptique, which allows designers to experience the eight system haptics. As in other use cases, HapticFinder would provide users with different haptics to choose from as there is no specific haptic for each use case. Haptics is heavily based on feeling, which is why it provides multiple options. That way, the designer can use Haptique and select the perfect haptic that feels the best with the interaction.

5 Conclusion

This study aimed to investigate haptics and haptic feedback in mobile phones from the user's perspective and the designer's perspective. Haptics is still a new technology that many designers are often unfamiliar with, as they were not classically trained to design for touch. The field of haptics is only growing. As haptic engines become quicker, subtler, quieter, and more powerful, designers, developers, and researchers' focus should be turned to them. The field of prototyping and evaluating haptics is still underdeveloped, and the evaluation guidelines aim to improve that and improve user testing sessions and the preparation that comes with them. As for designers, the more known about haptics can help the implementation process and decrease the back and forth with developers.

Mobile phone users were introduced to haptics through the system occurrences but are now accommodated with haptics in mobile applications. As haptics only aim to improve the experience and enhance interactions. It is apparent that mobile phone users enjoy haptics, as all mobile phone users interviewed had positive things to say about haptic feedback, even the participants who have their haptics settings turned off. The participants who turned off haptic feedback had other reasons than bad design. It is clear that bad design in mobile applications does not play a role in mobile phone users turning off their haptic settings. There are many other factors to why mobile phone users turn off the haptic settings on their mobile phones. Depending on the device, haptic and haptic feedback are experienced differently. The literature and the comparison of Android and iOS haptic systems support that Apple has a more sophisticated haptic experience. The use of haptics in mobile applications is still slim and should be kept that way. With most mobile phone users' inability to describe a haptic experience, specifically in a mobile application, designers are doing a good job of not overusing or going overboard with haptics. There is still more work to do regarding mobile phone haptics. As the overall market of mobile phone haptic engines improve, the opportunities will be limitless.

5.1 Further Work

Further work regarding this topic should focus on the further development of the evaluation method and the topic of sensitivity. The evaluation method should be tested with designers in design teams of all different sizes to validate its accuracy further. Sensitivity concerning mobile phone haptics should be further investigated as it will become a more prominent topic when haptic engines become more subtle and haptics is implemented more in mobile phones.

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7 Appendices

Appendix 1: Information Letter and Consent Form- Mobile Phone User's

Appendix 2: Information Letter and Consent Form- Designers

Appendix 3: Interview Guide- Mobile Phone User's

Appendix 4: Interview Guide- Designers

A1 Information Letter- Mobile Phone User's

Are you interested in taking part in the research project

"New Ways to Provide Richer Haptic Feedback"?

This is an inquiry about participation in a research project where the main purpose is to gain insight into mobile phone user's experiences with haptic feedback on their mobile device. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project
The purpose of my project is to understand when developers and designers implement haptics in the design process and learn how they test haptics and haptic feedback. This project is a master thesis, and the personal data collected will not be used for other purposes.

Who is responsible for the research project?
NTNU is the institution responsible for the project.

Why are you being asked to participate?
The sample has been selected through my network and the network within NTNU. I have received your contact information from another person. You have been selected because you have a mobile phone and I am interested in hearing your thoughts relating to your mobile phone use.

What does participation involve for you?
If you chose to participate in this project, this will involve a 15-20 minute interview. The interview will include questions about haptics and haptic feedback on mobile phones. Your audio will be recorded through Dictaphone. The information being collecting relates to user's experiences with haptic feedback and whether or not they use it on their mobile phone. Additional information will be collected relating to how it makes them feel.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- The student collecting the data and their supervisor will have access to the personal data. For this project, the student is Anne Norenberg and the Supervisor is Giovanni Pignoni.
- No unauthorized persons will have access to the personal data. I will replace all of the contact information with a code so that it is anonymous who said what. The list of names with the key will be stored separately from the rest of the data and be store on NTNU one drive.

The participants job title will be recognizable if published.

What will happen to your personal data at the end of the research project?
The project is scheduled to end June 15th, 2021. The audio recordings will be destroyed at the end of the project, as well as the key with the access to the participants contact information.

Your rights
So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with NTNU, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:

- NTNU via Giovanni Pignoni. (Giovanni.Pignoni@ntnu.no)
- NTNU via Anne Norenberg. (anne.nore@stud.ntnu.no)
- Our Data Protection Officer: Thomas *Helgesen (thomas.helgesen@ntnu.no)*
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Giovanni Pignoni	Anne Norenberg
Project Leader	Student
(Researcher/supervisor)	

A2 Information Letter- Designers

Are you interested in taking part in the research project

"New Ways to Provide Richer Haptic Feedback"?

This is an inquiry about participation in a research project where the main purpose is to gain insight into designers and developers' implementation of haptics and haptic feedback. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project
The purpose of my project is to understand when developers and designers implement haptics in the design process and learn how they test haptics and haptic feedback. This project is a master thesis, and the personal data collected will not be used for other purposes.

Who is responsible for the research project?
NTNU is the institution responsible for the project.

Why are you being asked to participate?
The sample has been selected through my network and the network within NTNU. I have received your contact information from another person. You have been selected because you work on mobile applications and I am interested in hearing your experiences relation to implementing haptics and haptic feedback.

What does participation involve for you?
If you chose to participate in this project, this will involve a 15-25 minute interview. The interview will include questions relating to implementing haptics and haptic feedback as a developer or designer. Your audio will be recorded through Dictaphone. The information being collecting relates to user's experiences implementing haptic feedback and whether or not they them self uses it on their mobile phone. Additional information will be collected relating to how the participant thinks it effects the user's experience.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- The student collecting the data and their supervisor will have access to the personal data. For this project, the student is Anne Norenberg and the Supervisor is Giovanni Pignoni.
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The participants job title will be recognizable if published.

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Your rights
So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
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- NTNU via Giovanni Pignoni. (Giovanni.Pignoni@ntnu.no)
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- Our Data Protection Officer: Thomas *Helgesen (thomas.helgesen@ntnu.no)*
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Giovanni Pignoni	Anne Norenberg
Project Leader	Student
(Researcher/supervisor)	

A3 Interview Guide- Mobile Phone User's

Opening Questions:

1. What is your age?
2. What type of mobile phone do you have?
3. Are you familiar with haptics/haptic feedback?
    a. If no, I will explain haptics and haptic feedback.
4. Do you use haptics on your mobile phone?
    a. If no, ask questions #5 & #13. Omit #6.
    b. If yes, omit question #13 and Ask #6

Discussion:

5. Why do you not use haptics on your mobile phone?
6. Why do you use haptics on your mobile phone?
7. Can you describe your thought process when encountering haptic feedback?
8. How often do you experience haptics while using your mobile phone?
9. Can you describe your last experience/encounter with haptic feedback on your mobile phone and how it made you feel?
10. When do you experience haptic feedback the most on your mobile phone?
11. How does haptics/haptic feedback add to the experience when using your mobile phone?
12. How do you think the haptic experience on your mobile phone could be improved?

Closing Questions:

13. What would make you turn on haptic feedback in your mobile phone?

A4 Interview Guide- Designers

Opening Questions:

1. What is your job?
2. How long have you been working as a _____?
3. What types of applications do you work on, can you tell me about some of your recent projects?
4. What devices do you work with specifically?
5. What industry do you work in?

Discussion:

6. Do you know what haptics are? Have you ever implemented/designed haptics in one of your applications?
7. Can you describe the process of implementing haptics or haptic feedback into a mobile application? How it came about to implementation.

Follow ups:

- How were the specifics defined/by whom?
- Did you follow any particular guideline?
  - Do you consult Material Design or the Human Interface Guidelines when implementing haptics in your applications?
  - Can you talk about what was conveyed through haptics in one of the projects you have mentioned (i.e. what were they used for? "warning", "feedback on an user action" etc..)
- Did you encounter any specific challenge in this process?
- Do you know if the haptic functionalities were tested?
  - How do you/your team test haptics or haptic feedback?
- Is this a structured/defined process (implementing haptics on mobile)?

Closing Questions:

8. Do you think your/your team's implementation process of haptics in mobile phones could be improved?
9. What is your impression on haptics and their contribution to the user experience?
10. What is your personal opinion, do you use them/like them as a user?
11. Do you know that haptics can be disabled the users?
12. Why do you think they would want to do that?
13. Was this considered as part of the design process? Either to achieve a higher user acceptance or to make sure that the application is usable without haptics(redundancy)?

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