Tickle Trunk: a Toolkit for Communication and Brainstorming Between Hapticians and Non-Hapticians

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

While the first person singular, “I”, is used throughout this thesis, the contents are collaborative efforts with my supervisor, lab mates, and collaborators. These include:

- Dr. Oliver Schneider shared with me his valuable ideas and guidance throughout the project.

- Bibhushan Raj Joshi, a PhD candidate, was the primary researcher for the Feel-Play-Imagine (FPI) process, which is described in chapter 4. He led the organization and implementation of this project. He also implemented the Haptic Mini-Tour, the worksheet components and conducted the data collection and analysis for the workshop (chapter 5) and lab study (chapter 6). To the FPI process and studies, Ana’s main contribution was the design and implementation of the Tickle Trunk, which serves both as the implementation of the “Play” activity and as a standalone tool outside of the FPI process. Ana led development of the Tickle Trunk (chapter 3), provided assistance with planning and running the workshop (chapter 5) and lab study (chapter 6), with a focus on the operating the Tickle Trunk and facilitating discussion. Ana then developed the Tickle Trunk independent of the FPI process (chapter 7).

  Ana and Bibhushan worked on their respective projects (Tickle Trunk and FPI) as part of a larger project supporting restorative justice with haptic-enabled VR storytelling. Both actively contributed to regular team meetings, site visit planning (where the workshop was conducted), requirements gathering and relationship building with the wider team, which consists of Prof. Kristina Llewellyn, Prof. Jennifer Roberts-Smith, Prof. Jennifer Llewllyn, Prof. Michael Barnett-Cowan, Tony Smith, Tracy Dorrington-Skinner, and Gerald Morrison.

  Two peer-reviewed paper submissions are planned, one about FPI with Bibhushan as lead author (previously submitted) and one about the Tickle Trunk with Ana as lead author. Additional outputs, such as a retrospective about the wider haptic VR storytelling project and potential contribution to a museum exhibit, are also planned.

- Fiona Yang, an undergraduate research assistant, contributed to the aesthetics and design decisions of the Tickle Trunk. She also helped by taking pictures during the workshop and lab study. I focused on the hardware design and implementation of the toolkit.

- Faduma Ahmed, an undergraduate research assistant, supported me in the schematic, PCB design, and conceptualization of the new version of the Tickle Trunk.

Abstract

This thesis introduces the Tickle Trunk, a haptic communication toolkit designed to support communication and brainstorming for haptic and tangible interaction design. Haptic technology is becoming increasingly popular in various fields, including robotics, medicine, education, and virtual reality. However, designing haptic systems can be challenging due to the need for interdisciplinary communication and collaboration. Current solutions that serve a similar purpose are specific to haptic modalities, theme or use case, or support the prototyping stage of the design process.

The Tickle Trunk is designed to address this challenge by providing a playful and approachable way of communicating haptic feedback. The toolkit is multimodal, allowing non-hapticians to experience haptic feedback and develop a better understanding of haptic sensations. The Tickle Trunk is also extensible, allowing hapticians to add new modalities as widgets to the toolkit depending on their specific needs.

The effectiveness of the Tickle Trunk was evaluated in a workshop with VR storytellers and a lab study with designers. The results show that the toolkit is effective in facilitating communication and brainstorming between hapticians and non-hapticians. The toolkit was then redesigned to make it easier to add new components to the collection of widgets, reducing authoring time and complexity.

The Tickle Trunk is open-source and will be available to the community. Overall, this thesis demonstrates the potential of haptic communication toolkits in supporting interdisciplinary collaboration in haptic and tangible interaction design.

Acknowledgements

I would like to extend my heartfelt thanks to the many people who have supported me in the completion of this master's thesis.

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Chapter 1

Introduction

As the use of haptic technology becomes increasingly widespread, designers are presented with new opportunities to create immersive experiences and forge stronger connections with users. In recent years, a plethora of new haptic devices have been developed and applied in diverse fields such as robotics, medicine, education, safety training, accessibility, rehabilitation, and virtual reality[19, 28, 68, 40, 44].

When designing haptic systems, hapticians, the makers of haptic technology, typically form interdisciplinary teams comprising experts in software and hardware engineering, design and psychology, and domain specialists [63]. Effective communication among such teams is crucial for the successful design of haptic systems. However, this task can be challenging when working with non-haptic stakeholders, such as co-designers, clients, and external team members, who may lack first-hand experience with haptic technology [63]. To bridge this communication gap, hapticians must demonstrate the potential of haptics and cultivate a shared language with their non-haptic co-designers. Additionally, novice hapticians require assistance in making critical design decisions, such as conceptualizing the design [65].

To address these challenges, this thesis introduces the Tickle Trunk, a toolkit that facilitates communication and brainstorming for haptic and tangible interaction design. The Tickle Trunk allows hapticians to explore and illustrate haptic possibilities using different haptic modalities, making haptic communication rapid, playful, and approachable for non-haptic stakeholders. Hapticians can customize the toolkit to their unique needs by adding new modalities (such as heat, vibration, etc.) as widgets, leveraging the toolkit's extensibility to tailor their toolkit to their specific requirements.

While existing tools serve a similar purpose, they are often limited to specific modalities

[43], themes or use cases [70], or the prototyping stage of the design process [49]. In contrast the Tickle Trunk allows non-hapticians to experience an array of haptic sensations, a crucial step in designing haptic systems, expanding their vocabulary and understanding of haptic sensations. Also the toolkit can be customized to a specific theme or can retain a general design. As a result, non-hapticians can more effectively communicate design decisions and brainstorm haptic designs.

This thesis reports on the development and implementation of the Tickle Trunk in a workshop with three VR storytellers and a lab study with ten designers in the fields of gaming, storytelling, art, and user experience design. The toolkit was designed with specific requirements in mind, and the different haptic and tangible widgets' inputs and outputs represent important objects and sensations for the non-hapticians. Participants in both studies were able to use the toolkit to communicate desired requirements using examples, technical terminology, and details of haptics learned from their experience using the toolkit.

Based on feedback from these studies, the Tickle Trunk was redesigned to enhance its functionality and flexibility. The redesign focused on improving the toolkit's extensibility, making it easier to add new features and modules as needed. With just four simple instructions, hapticians can add a new widget, input, or output to their collection of haptic sensations. A study to evaluate the toolkit's extensibility and gather further requirements is planned for the summer of 2023.

The Tickle Trunk is open-source and will be available online to the HCI community, providing a valuable resource for those seeking to enhance their communication and brainstorming process for haptic interaction design.

Chapter 2

Related Work

Related work includes the relationship between emotional state and effective brainstorming, other approaches to involve diverse people in haptic design, communication and language surrounding haptics, and sketching in hardware and haptics.

2.1 Emotional state and Brainstorming

Recent studies have explored the intersection of play, emotional states and brainstorming sessions in the field of Human-Computer Interaction (HCI). Studies have investigated how playfulness and playful environments can impact the emotional state of individuals and subsequently influence their creative output in brainstorming sessions. This research aimed towards new engaging ways to brainstorm haven't been explored in a haptic design context yet.

One study by Herring et al. explored the role of playfulness in brainstorming sessions [31]. They found that playful brainstorming sessions led to higher levels of positive emotions and creative output compared to non-playful sessions. The study also showed that participants in the playful session reported feeling more comfortable expressing their ideas and more engaged in the brainstorming process. Similarly, Rehm et al. investigated the impact of playful interventions on the creative output of individuals in a design thinking workshop. The study found that introducing playful elements such as games and puzzles led to higher levels of creative output and positive emotions in the participants [59]. In another study, Chen et al. explored how playful interactions with a robot could impact the emotional state of participants in a brainstorming session. The study found that participants who interacted playfully with the robot reported higher levels of positive emotions and generated more original ideas in the brainstorming session [8]. Studies have shown that positive emotions, induced through different mediums like music or virtual reality environments, lead to higher levels of creative output [37, 1].

Overall, these studies suggest that playfulness can have a significant impact on the emotional state and subsequent creative output of individuals in brainstorming sessions. Designing playful environments and interventions may lead to higher levels of positive emotions, greater engagement, and more successful brainstorming sessions.

2.2 Haptic Vocabulary

Previous research has focused on creating a haptic vocabulary that is easy to interpret and learn, with the goal of communicating messages through touch [61, 47, 18, 6, 55]. Researchers have explored various methods of using haptic feedback to convey information, from small haptic signals known as haptic phonemes [18], to communicating brief information through haptic icons [47] to more complex tactile messages [6, 5, 13].

To support haptic design, some studies have involved communicating with potential users to extract design requirements [56], such as through metaphor-based design, which uses metaphors from one user group as an anchor to develop effects for a specific device [6]. Other studies have focused on creating accessible language for controlling haptic properties, such as the HapticTouch toolkit, which allows users to quickly prototype haptic tabletop applications[43]. The Haptic Instrument is another tool that facilitates collaboration and communication between designers by allowing two users to experience the same vibration during the design process [64]. Studies have shown that metaphors and vocalizations can be effective means of expressing haptic feedback, an example is Voodle, a prototyping system that translates vocalizations into motion, vibration, or light for social robots[49].

There are gaps in the literature surrounding the impact of haptic feedback in multimodal interfaces, where different types of haptic feedback are introduced to the users. These gaps in the literature highlight the importance of continuing research in the field of haptic design and exploring new ways of communicating haptic feedback to enhance user experiences.

2.3 Hardware Sketching

Hardware sketching is a design approach that involves the use of physical prototyping tools to quickly and iteratively explore and test ideas in the early stages of the design process.

This term coined by Holmquist [32], allows designers to quickly create and modify physical models and test them in real-world contexts, helping to identify potential design issues and refine the final product. Researchers have designed and implemented hardware prototyping tools to facilitate this process, examples for different scenarios are designing for VR, [27], physical user interfaces [26], education [58], and exploration of haptic interaction [53].

Some examples of hardware sketching toolkits include the Circuit Stickers [7], which enable users to create functioning circuits using adhesive stickers. Similarly, the MaKey MaKey toolkit enables users to create interactive circuits using everyday objects such as fruit and vegetables [2]. Ion et al, [34] developed PiezoRadar, a sensing technique that uses piezoelectric touch sensors to detect solid objects, allowing users to create touch-sensitive interfaces on non-traditional materials. The LittleBits [4] system is a set of magnetic electronic building blocks that allows users to easily create complex electronic systems without the need for soldering or breadboarding. Finally, the Snap Circuits [16] system is a set of electronic building blocks that snap together to create working circuits, allowing users to explore electronics through hands-on building and experimentation. Other commercially available options like Arduino, Adafruit, SparkFun, and Raspberry Pi have been successful in reducing costs and removing entry barriers for individuals seeking tools to quickly prototype hardware and electronics. These systems concentrate on inexpensive and modular tools to acquire data from sensors and manage actuators.

Despite the availability of various hardware prototyping tools, there are still gaps in the literature regarding how these tools can be made more accessible and user-friendly for non-expert users, particularly those with little to no experience in electronics or programming. The Tickle Trunk aims to address these gaps by providing a playful and intuitive interface that allows users to quickly and easily prototype hardware without needing specialized knowledge or skills. By doing so, it has the potential to democratize the design process and enable a wider range of individuals to participate in the creation of new and innovative hardware devices.

2.4 Haptic Sketching

The use of haptic sketching toolkits has gained attention in recent years for facilitating design exploration. Designing for haptic experiences can be challenging since exploring the space of design possibilities is a crucial yet difficult step in the process [48]. To facilitate design exploration, maker kits and browsing tools can be utilized.In the area of haptics, some researchers have developed hardware kits and guidelines for this purpose. An example of this is SimpleHaptics, created by Moussette et al., which leveraged emerging 3D fabrication and maker movements to allow for rapid sketching with haptic hardware [52]. Other projects such as WoodenHaptics [21] and Haply [14] have also provided customizable, open-source starting points for design exploration of force feedback for those new to haptics.

Most existing sketching toolkits are focused on a single haptic feedback, like force feedback [21, 14, 50, 73, 69], vibrotactile [12, 71], pressure feedback [72, 17], and tactile experiences [35].

However, there are some toolkits that combine different haptic feedback to design a multimodal haptic experience like PneuMod, a wearable haptic device that can present pressure and thermal cues to different parts of the body [72]. Another toolkit example is the Soma Bits, designed to support sketching in soma design processes, Windlin et al created simple technology pieces that enable one bit actuation like vibration, heat or shape-changing behaviors [70].

Overall, these studies and the development of haptic sketching toolkits suggest that haptic feedback can play a valuable role in the design process by facilitating rapid prototyping and enhancing creativity. Due to a lack of toolkits that can enable simple exploration and support communication of various haptic sensations the Tickle Trunk aims to fill this gap by providing a toolkit that can significantly improve communication and collaboration in haptic design. There is a need for an extensible and multimodal feedback toolkit, a tool for hapticians and non-hapticians alike. With the Tickle Trunk, haptic design can be made more accessible, playful, and effective, helping to create more engaging and immersive experiences for end-users.

Chapter 3

Tickle Trunk Version 1.0

The Tickle Trunk is a plug-and-play toolkit created to support communication and brainstorming during the design of haptic systems. The name is inspired by the Tickle Trunk used by Mr. Dressup, the beloved children's entertainer, who could pull out any costume or prop he needed from the trunk. In a similar way, the Tickle Trunk (Figure 3.1) provides an open-source toolkit for users to experiment with a variety of haptic modalities and physical interactions. It offers an array of haptic feedback that allow designers to explore and create haptic sensations, with the flexibility of adding devices or modalities. The Tickle Trunk addresses a gap in literature regarding the lack of playful and accessible haptic brainstorming toolkits for designers and makers. Additionally, it provides a unique platform for exploring the potential of haptic feedback and introducing this new medium to designers.

The toolkit was designed for haptic sketching, which enables the creation of haptic sensations through simple, intuitive interactions. It works by providing a variety of tangible objects or "widgets" that users can use to design and experiment with haptic feedback.

The Tickle Trunk uses different inputs such as pressure, shake, and turn that map to output effects such as heat, vibration, and force feedback. It allows users to operate the device through a plug-and-play system that helps hapticians and non-hapticians to come up with ideas, rapidly explore different sensations, and brainstorm haptic feedback.

The toolkit works with a collection of widgets, each of which encapsulates a specific interaction technique or modality. The Tickle Trunk is completely hardware based; no coding is required to mix and match the widgets to try out different combinations of modalities. Widgets are divided into two groups, inputs and outputs:

- Inputs (painted white) are sensors; they modulate output sensations through different actions like proximity, force sensing, clicking, touching, lighting something, shaking, twisting, sliding, etc.
- Outputs (painted black) are actuators; they are controlled through the input widgets to be able to feel different physical feedback like vibrations, force feedback, shape changing, temperature, wind, warmth, textures, etc.

Both input and output widgets were designed to enhance their discoverability to the non-hapticians. With perceived affordances in the design, for example color, shape or range of motion, to signal their appropriate usage.

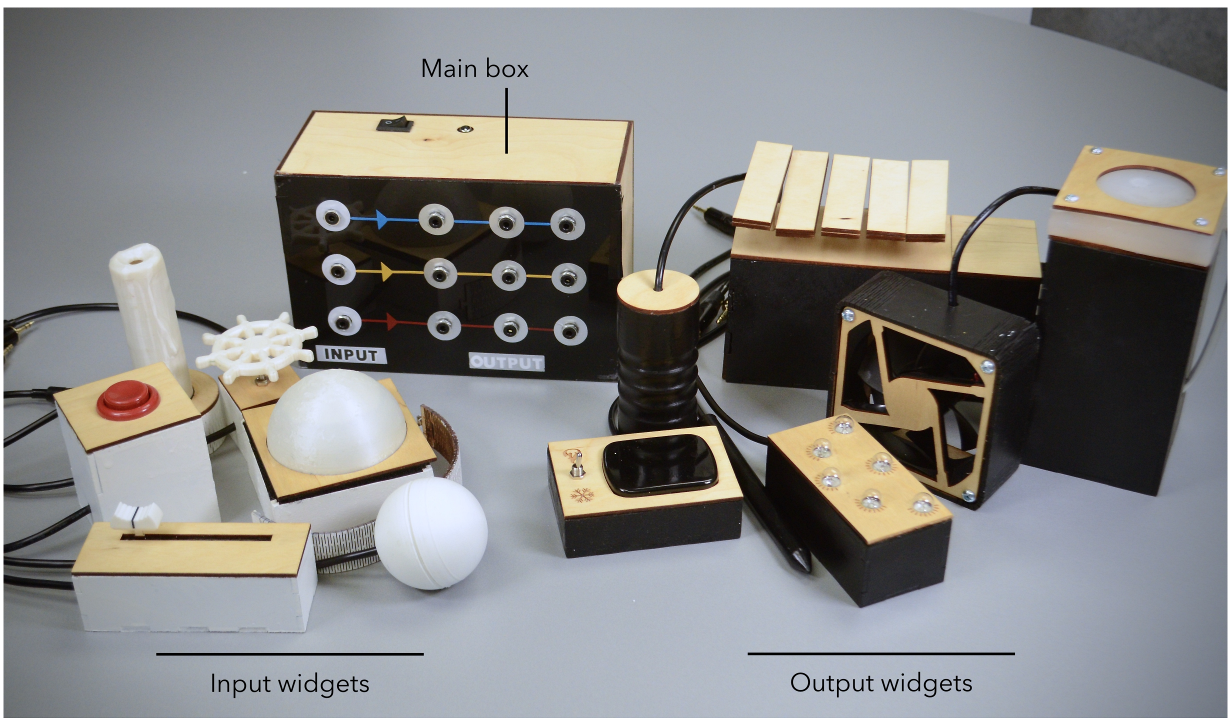

Figure 3.1: Tickle Trunk 1.0: a plug and play device to show different haptic modalities in forms of inputs and outputs. When someone manipulates an input widget, e.g., shaking the ball, the mapped output widget activates. A single input widget can be mapped to multiple output modalities, and can modulate the intensity of the output widget. For example, the gesture recognition input can activate the force feedback and shape change output widgets when connected in the same channel.

3.1 Implementation

The Tickle Trunk includes simple mappings between inputs and outputs through adjustable voltage regulators, where the output voltage level can be adjusted using an external feedback mechanism, such as variation from the input widgets. Each input can activate up to three outputs when connected in the same coloured channel. Once connected, by activating the input the connected outputs will be activated as well. Some input widgets can also modulate the output effects. For example, a button causes an output to activate (when pressed)/not activate (when not pressed), but the shaker, slider, and wheel can intensify the output effect by shaking in a higher frequency, moving the slider from one end to the other, or rotating the wheel in a clockwise angle. A small change in input corresponds to a small change in output and the output remains unchanged until the input is varied again. The general state of input and output widgets was considered as "always-OFF", until a trigger changes the state of input and output to "ON". The Tickle Trunk functions on a 5V power supply which is connected to the main box and all widgets are powered through it. The input widgets that contain sensor modules, need an extra 3V battery supply to power them up, which is included inside the widget case. The output widgets are regulated by the change of state (ON/OFF) or the modulation of the input widget. Meaning that at if a single output widget is connected inline with a state changing input widget, when turned full ON the output widget will receive 5V, and if OFF 0V. However, if the output widget is connected to a modular input widget then the output voltage range would be any value between 5V to 0V.

The main box uses a circuit design that includes voltage regulators to map inputs to outputs. The LM317 is an adjustable positive linear voltage regulator which was used to regulate the output voltage of output widget depending on a signal received by the input widget. Each channel functions with their own voltage regulator and each output is independent from the other in the same channel. The circuit design for the Tickle Trunk can be found on Figure 3.2.

A plug-and-play system was designed to encourage storytellers to learn and explore haptic sensations in an easy and playful way. There are three channels (i.e., a mapping from input to outputs) ; for each channel, a single input maps to up to three outputs (all of which respond simultaneously to the input). We chose this design so that users can experiment different combinations of more than one output at the time, but limited the design to three channels and three outputs per channel to balance flexibility and simplicity. The visual and material design of the Tickle Trunk was chosen to be accessible and not intimidating by labelling each channel with different colored arrows to show which input maps to the outputs. Widgets were painted different colors (black and white) for better

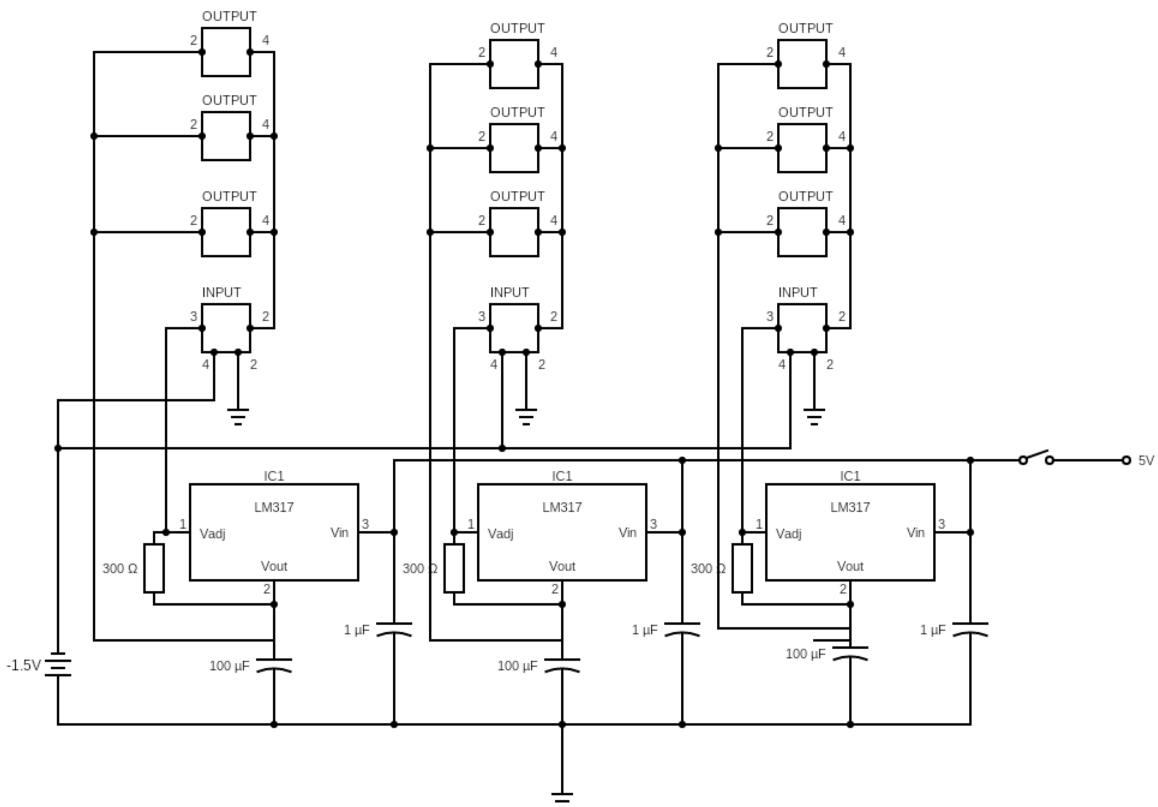

Figure 3.2: Circuit design for the first Tickle Trunk version. The circuit shows a 5V supply and three channels of input and output mappings with their respective voltage regulator.

visual discrimination between them, with corresponding colours on the main board.

3.2 Design Decisions

This section includes the discussion of the various input and output widgets, as well as how play influences the design of the toolkit and the aesthetic code of the Tickle Trunk.

3.2.1 Widgets I/O

The haptic sensations chosen for the widgets, both input and output, were based on rendering tactile feedback to the user through vibration, touch, pressure, temperature, force feedback, tangibles and texture [41]. The tactile feedback available for exploration through the first version of the Tickle Trunk were targeted to introduce the basics of haptic rendering and recurring sensations in the stories we were designing for, for example thermal feedback is present in the stories, as well as wind. The overall design of the widgets targeted both specific objects and general shapes as can be seen in Figure 3.3. This was to show flexibility, the widgets can be shaped to be any object (e.g. candle), but also keep some with an open design (e.g. sphere) so that the storytellers could imagine other uses due to its ambiguous shape.

Since the Tickle Trunk was first designed to be used in a storytelling project, the first iterations of the widgets included more object-oriented designs that would fit in the stories of the co-designers. However, as this toolkit can be used in many scenarios the choice between the shape and format of the widget would be entirely up to the haptician or the non-haptician. The sensor or actuator that is within the widget can be adapted to be enclosed in any sort of case. For the creation of the widgets the boxes or cases were 3D printed pieces or laser cut designs depending on the desired shape for the storytellers.

Haptic feedback can be created through a wide range of technologies [63], however for the purpose of this toolkit the sensations were based on rendering basic tactile feedback to users. Even though haptic technology has advanced and developed new devices that render more realistic experiences, they will not be include in the toolkit since the end goal is to introduce basic haptic feedback and be able to brainstorm ideas.

3.2.2 Play

User experience research has always been focused on making user interaction more enjoyable and pleasant, focusing on positive emotions like fun, joy and pride [29]. Playful user experiences allow users to build something new using existing elements and develop skills through exploratory behavior [20]. Playful activities may involve imagination, experimentation, exploration and social interaction [23].

Much thought and effort was put into making the Tickle Trunk a fun and enjoyable device, it has a vibrant and playful design, complete with colorful materials and interactive features such as buttons, knobs, and switches, inviting users to engage in a fun and enjoyable prototyping experience. We wanted to inspire confidence and autonomy to the

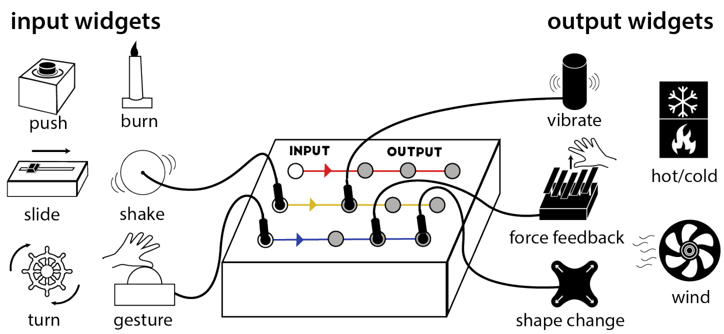

Figure 3.3: The input and output widgets available in the Tickle Trunk. The input widgets, from top to bottom, include a push button, flame sensor, haptic slider, shake sensor, potentiometer and proximity sensor. These input widgets allow the user to create different haptic sensations through the output widgets such as vibration, temperature, force feedback, wind and pressure. Each widget can be combined with different input and output modalities to create unique haptic sensations and feedback, enabling hapticians to explore and prototype different haptic designs.

users in order to be able to explore, combine, experiment, and feel various haptic feedback, and to retain a sense of enjoyment whilst doing so. In addition to providing a fun and enjoyable experience, the Tickle Trunk also serves practical purposes such as brainstorming and communication. By allowing users to explore and experiment with various haptic feedback, the device can encourage creativity and imagination, making it an effective tool for idea generation and problem-solving.

The use of colours, simple shapes, intuitive interactions (plug-and-play), and customization of the system enables users to communicate ideas and test them out on the spot. One of the requirement while designing the toolkit was to design it in such a way that inspired simplicity, inviting the user to try it out without taking into account their level of familiarity with the technical aspects of the device itself.

The use of the Tickle Trunk was designed to be a social activity as can be observed in Figure 3.4, two or more people should play together with the toolkit in order to explore, explain and understand haptic sensations, with the goal of leading to effective communication and brainstorming.

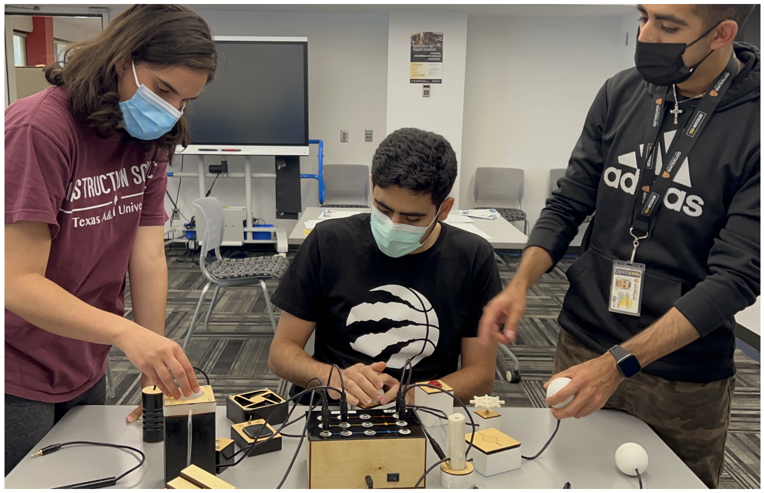

Figure 3.4: The Tickle Trunk being used by author and collaborators.

3.2.3 Aesthetic code

Based on the design goals and decisions stated above, focused on delivering a simple and playful interaction, the Tickle Trunk followed aesthetic principles to guide the design and accomplish these goals. Hekkert's four general principles of aesthetic pleasure were followed [30], (1) maximum effect for minimum means, (2) unity in variety, (3) most advanced, yet acceptable, and (4) optimal match, the Tickle Trunk was designed to express a simple, playful and approachable feel while maintaining an aesthetic and pleasurable design.

The first principle, **maximum effect for minimum means**, refers to the principle of sensory economy, which states that we tend to prefer stimuli that require less effort from our senses. Investing the least amount of resources for understanding, learning or exploring something new is pleasing to us, a relatively simple design that reveals important and necessary information is the optimal solution. The three different coloured arrows connecting the inputs to their possible outputs creates a simple yet effective way of communicating the ease of use of the device. Avoiding ambiguity and over crowding the design, clear labels and different colours announce functionality and important connections.

The second principle would be **unity in variety**, which refers to benefits of perceiving connections and making relationships; to understand what belongs together and what not, and being able to detect order in chaos or unity in variety. The Tickle Trunk includes a collection of different input and output widgets, they come in a variety of shapes and sizes, but there is a clear easy way to differentiate them by colour. Colour coding the widgets, white for inputs and black for outputs, gives the user an easy way of making quick connections to understand the device and how it works. On the main box as well, the inputs column is labelled in the same colour as the corresponding widgets that connect there, same for the outputs.

The third principle the concept of a design being the **most advanced, yet acceptable** option, a term coined as MAYA by the famous American designer Raymond Loewy in 1951. This theory refers to preferring the most typical examples of a category, the ones that are familiar and we have been exposed to repeatedly. This is an adaptive trait since it will lead to safe choices instead of risking the unknown. However, people are also attracted to the new and unfamiliar things, possibly related to the fact that novelty facilitates learning. These two concepts may seem incompatible and as a result of wanting the joint effects of typicality and novelty, designers aim for increasing novelty while preserving typicality as we tend to prefer products with an optimal combination of both. The design of the Tickle Trunk was inspired to attract people of all ages and backgrounds, hence the simple design of plug-and-play interactions could be familiar to all, as it relates to everyday objects, while introducing a new concept of haptic sensations.

The fourth and final principal is **optimal match**. It refers to the relationship that exists between aesthetic experience and the experience of meaning. Congruence between the sensory impression of a design and the appropriate function it provides. In the case of the Tickle Trunk the function is to inspire playfulness, exploration, experiment, enjoyment, so it is important to make all the sensory messages congruent with the intended experience. This is why the design is colourful, simple, allowing quick interactions with carefully labelled modules.

In this section, we explored the design choices taken to choose the haptic feedback for the input and output widgets, as well as their overall design case. Based on prior work as well as best practices in design the Tickle Trunk was designed to be easily accessible and playful to introduce haptics. In the next section, we will dive deeper into the use cases of the Tickle Trunk and how they relate to the design process of haptic systems.

Chapter 4

Feel-Play-Imagine (FPI) Process[1]

The Tickle Trunk as a toolkit can be used on its own to support communication and brainstorming between hapticians and non-hapticians. However, it can also be used collectively with other devices or processes with the same objective. The Tickle Trunk was originally designed for a project aiming to support communication in an ongoing co-design project with VR storytellers. As part of a team of hapticians, we created a process for initial communication and requirements gathering for our collaborators.

During our initial online meetings, we found our co-designers did not have an embodied sense of what haptics are or how they might be used, so it was difficult to brainstorm ideas. Prior research into haptic experience design tells us that this is the case generally; people unfamiliar with haptics "don't really know what you can do with haptics" [63].

To accomplish this we developed the Feel-Play-Imagine (FPI) process. The goal of this process is to help people understand what haptic experiences might feel like and express what they might want to have when designing their own experiences.

However, one important aspect of our co-design process was to give our storytellers control over the experiences they want to create. To solve this problem, we decided we needed to accomplish three things during our first in-person meeting. 1) We wanted to showcase polished haptic experiences to allow people to understand where and how haptics will fit in VR (and similar) applications. The polished haptic experiences typically incorporate only a specific device, but show it in depth in a final experience. 2) The second goal is to give a breadth of what different types of sensations could be used in haptics.

[1]The material in this chapter has been co-authored; for more information please refer to the Statement of Contributions

We wanted to illustrate the possibilities, from vibration to change in temperature to force feedback to shape change and more. Our goal was to encourage people to experiment with various modalities, play with them, and quickly test them in different formats. For example, participants could combine different modalities or try them on different parts of their body. Finally, we 3) wanted to allow storytellers to visualize how haptics can fit in their existing stories, when and how they wanted to apply it as well. Here haptics could be related to environment, actions or illustration of object/people's behaviour. As suggested by MacLean et al. [48] and Seifi et al. [65], we had to find ways to guide non-hapticians in their design decision process. By incorporating the three steps of Feel, Play and Imagine we support communication and requirement gathering for the co-design of haptic experiences. For our the implementation of this process we designed a Haptic Mini-Tour for Feel, The Tickle Trunk for Play and a custom designed Worksheet for Imagine, as can be seen in Figure 4.1. For the purpose of this thesis the Feel and Imagine step will be shorty introduced just to get an overview of the process.

Feel: Haptic Mini-Tour We support feeling haptics in context using a Haptic Mini-Tour. The Haptic Mini-Tour is a collection of commercial haptic devices which allows users to experience different types of high fidelity haptic feedback. It consists of devices employing different types of haptic feedback to allow users to understand the possibilities of haptic technology and become familiar with it. Any available set of high fidelity haptic devices that showcase different types of haptics could be used for the Mini-Tour. The devices used for the workshop and lab study were Haply, Tanvas, Feelcraft and 3D Systems as these devices were readily available to us in our lab.

Play: Tickle Trunk We support playing with haptic modalities by using the Tickle Trunk which has been explained in the previous section. The open-source, custom-built tangible toolkit allows users to experiment with tangible, haptic, and physical interactions by using a wide range of modalities. It also allows participants to manipulate the device using a plug-and-play system to help storytellers and designers to come with ideas, rapidly explore different sensations, and prototype how haptics could be used in the stories.

Imagine: Worksheet Haptics is not always about replication of how people perceive touch in the real world but can also be about how creativity and imagination could be infused with touch sensation [36]. In FPI, after supporting feeling of haptics in context and playing with potential modalities, a facilitator needs to elicit the potential design decisions from participants, enabling them to imagine what haptics will be for their use case. This is the last step of the FPI process used to collect useful requirements from the users which is utilized to create prototypes in the next step of the design iteration. In our implementation, we support the Imagine step with a custom-developed worksheet to help non-hapticians understand and make design decisions. We created the FPI Storytelling Worksheet, an open source documentation and brainstorming work package. The FPI Storytelling Worksheet consists of a pamphlet and a set of questions. The pamphlet serves as a reference for participants; it includes a list of haptic terminologies and devices from the Haptic Mini-Tour as well as the input-output modalities from the Tickle Trunk. The pamphlet was created to help non-hapticians recall the haptic feedback and devices they experienced during the previous steps. The question set is divided into three sections: story description, object-description, and storyboard. The story description sheet consists of a structured set of questions related to the people, the environment, and the actions and outcomes of a story which help storytellers to decide **"where"** haptics can be implemented.

The Tickle Trunk as a part of the FPI process was used in two case studies, a workshop with our co-designers and a lab study with artists and creators.

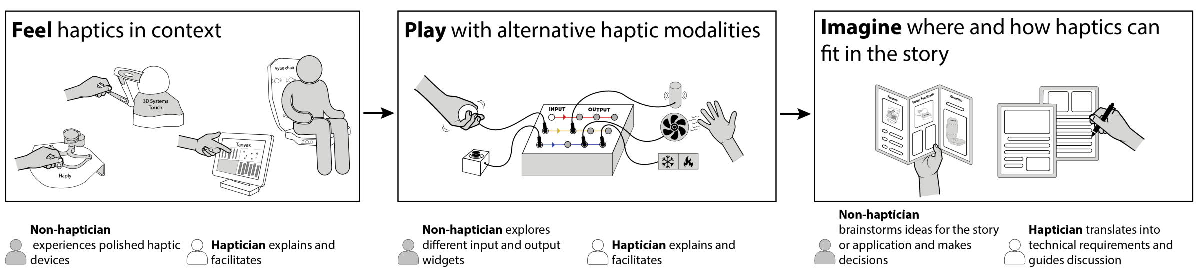

Figure 4.1: The FPI process. For **feel**, we gave a Mini-Tour of 4 haptic devices to show haptics in context. For **play**, we used the Tickle Trunk to showcase different haptic modalities. For **imagine**, we designed a worksheet for users to brainstorm where to use haptics in their stories.

Chapter 5

Case Study: Workshop with VR Storytellers[1]

In order to evaluate the effectiveness of the Tickle Trunk toolkit, a case study was conducted, involving the use of the Tickle Trunk in a real-world design context. By presenting the findings of this study, we aim to provide readers with insights into how the Tickle Trunk can be used to support haptic design and foster creativity.

The FPI process was developed in the context of a larger research project. However, due to the nature of this project the FPI process did not include the third and final final in the form of the worksheet. Instead the team imagined where haptics could be used through sharing circles and other brainstorming activities to gather requirements and communicate possible haptic sensations in their stories. In this project, we are working with storytellers who want to try including haptic VR feedback to tell stories guided by social justice so that voices of marginalized communities can be heard by a broader audience. The stories in this project addresses sensitive subject like the historical harms of institutionalized racism [67].

These stories are planned to be shown as a museum exhibit and included in grade 11 history courses where a wide range of audiences are involved. Our collaborating storytellers are interested in taking advantage of haptic technology to expand their storytelling capabilities to attract more people, enrich the stories themselves, and potentially make the experience more accessible.

[1]The material in this chapter has been co-authored; for more information please refer to the Statement of Contributions

This project consists of an interdisciplinary team with various backgrounds like Communication Studies, Human Computer Interaction, Social Development, Engineering, Law, Psychology and community storytellers, most of whom were new to haptics. While the storytellers had already partnered with other team members to create a VR experience, haptic technology was not used. To help the team understand the concept and possible sensations of haptics, we needed to provide embodied experiences of the wide range of possibilities in haptics and to help them communicate their ideas to us, so that we could implement prototypes and derive towards a final haptic experience.

We used the Tickle Trunk alongside other devices and requirement gathering tools in the FPI process to clearly communicate with our storytelling team and collaborators to support the discussion about how to include haptics in a new design.

5.1 Online meetings

Due to the COVID-19 pandemic, the project started as a remote collaboration. The team working on this project met several times online to discuss the project's beginnings. In the original project plan, a site visit would enable team members to meet, establish connections, understand the project mission, and for the haptics team to introduce haptics to the rest of the team. Due to the circumstances the meetings turned to online, and the haptics team struggled to teach and the storytellers and other collaborators struggled to understand and grasp the meaning of haptics and how it could be incorporated into the stories. Visual presentations and demos were given by the haptics team, but real understanding of the technologies were not truly grasped by the whole team. As circumstances started to ameliorate with the pandemic, our first in person meeting and workshop was planned. This experience further highlights the necessity of the FPI process to bridge understanding between stakeholders and establish a common vocabulary concerning haptics.

5.2 Haptic Workshop

The main objective of the Haptic Workshop was to gather important requirements from our collaborators to create haptic system/device that can be used in a new version of the stories involving haptic technology. The workshop included 5 collaborators from the co-design project, 4 members from haptics team, and 2 other participants with a background in restorative justice. In the workshop session we followed the FPI process to introduce the audience to haptics (Figure 5.1). We structure the session with a relational approach [45] to allow active collaboration and participation in the activity and help in brainstorming ideas and gathering requirements of how to include haptics in the stories. Because the team had already met to discuss possible stories, and because the team had established relationships and experts in VR design, the Worksheet was not needed in the Imagine stage since most of the questions emerged organically from the discussion.

The discussion touched on topics related to the benefits and objectives of using haptics, how to use haptics in stories, and important details to consider while incorporating haptics in stories of marginalized groups, especially when telling stories about institutionalized racism. The discussion was recorded, transcribed and analyzed, as well as the personal notes from the haptics team, leading to the extraction of the main takeaways from the workshop described in the next section. Not all takeaways from the workshop have been included in this thesis, some were selected to portray the main insights regarding the Tickle Trunk.

Figure 5.1: Workshop participant using the Tickle Trunk input and output widgets.

5.3 Main takeaways

5.3.1 Learning haptics can be playful.

The feedback and reaction from the participants showed the ease of learning and excitement of using the toolkit. By allowing participants to easily explore different haptic sensations using games and a plug-and-play device, they had the freedom to learn about haptics in a fun way. Some of the words used to describe the Haptic Mini-Tour and Tickle Trunk were: *"therapeutic", "intuitive", "playful", "curiousness", "learn through play", "unexpected", "evocative", "approachable"*, *"feels like you are in the picture"*, *"enjoyed witnessing the rain"*, and *"engaging".* Participants found the Haptic Mini-Tour and Tickle Trunk to be engaging, approachable, and unexpectedly evocative, describing the experience as both therapeutic and intuitive while enjoying learning about haptics through play.

5.3.2 Haptics can be a collective, social experience.

During the interaction with the Tickle Trunk, people in the background were excited about others' reactions, and encouraged them to try different effects. Everyone enjoyed the different widgets and effects and wanted others to try them as well: *"feel the bubble!"*, *"light the candle!" "did you feel the rain?"* In the workshop, one of the participants asked the others: *"What if you light up the candle and you feel cold?"* At this suggestion, everyone was really surprised and curious about how it was going to make them feel, so most of the participants tried the light input and cold output setup. This experience was discussed later in the discussion which highlighted the importance of sharing similar experiences that we could collectively refer to.

5.3.3 In-person haptic experiences was essential to "get" haptics.

At the time of the workshop, we had been working with our collaborators for over a year, but for most team members it was only in online meetings; the Haptic Workshop was our first in-person meeting. In our online meetings, we tried to explain about haptic technology, its terminologies and its potential usefulness in storytelling, however it was not fully grasped by our collaborators until the in-person workshop was completed. Our collaborators were able to use the haptics terminology, expression words and devices to explain their requirements: *"Add vibrations, or wind or even textures, if that is even possible, that would be things I'd like to see in the stories"* and *"this stuff is high tech, you're immersing yourself, you get the feel of riding on the horse, the fall and the explosion, and all that, it creates a new body experience, the combination of visual, plus the actual perception of events. And I think it is amazing myself."* The discussion after learning and feeling haptics started the brainstorming phase with high emotions: *"opening up new possibilities and ideas, that is where I am right now. I'm in this euphoric possibility space."* This response from our collaborators further highlights the necessity of feeling haptics, of being able to interact with the sensations to understand the capabilities and start brainstorming about the possibilities. Collaborators were able to better understand haptic technology and express their requirements after experiencing it in person, leading to a brainstorming phase with high emotions.

In conclusion, this case study with our co-designers demonstrated the effectiveness of the Tickle Trunk as a toolkit for haptic sketching, brainstorming and communication. The co-designers were able to explore and create various haptic sensations using the toolkit, and the flexibility of the Tickle Trunk allowed them to experiment with different modalities and devices. The feedback received from the co-designers allowed for further improvements to be made to the Tickle Trunk, like making it more accessible to include new sensations and design new widgets. The insights gained from the study contributed to a better understanding of the design process for haptic systems.

Chapter 6

Lab Study: Evaluation with Storytellers and Designers[1]

In this lab study, we evaluated the effectiveness of the Tickle Trunk toolkit in facilitating communication and ideation of haptic sensations. Participants were able to explore various haptic sensations and provide feedback on the effectiveness of the toolkit. This study allowed us to gather valuable insights on the use of the Tickle Trunk in a controlled environment. Furthermore, the feedback received from participants will inform future improvements and iterations of the Tickle Trunk.

In this section, we present findings from our lab study, a qualitative analysis using semi-structured interviews and questionnaires with ten non-hapticians with backgrounds in Storytelling, Art, Gaming, and User Experience Design (UX). The main purpose of the study is to evaluate the usefulness of the FPI process and understand more about how haptics communication works. This study was intended to complement the findings from our workshop. The implementation of the FPI process for the lab study included the three steps: the Haptic Mini-Tour for Feel, The Tickle Trunk for Play and the custom designed Worksheet for Imagine.

[1] The material in this chapter has been co-authored; for more information please refer to the Statement of Contributions

6.1 Method

We conducted an in-person study in a large lab space. We physically setup three stations: the Haptic Mini-Tour, the Tickle Trunk, and the worksheet, each on a different table in sequence. Participants were given instructions at least one day prior to the study, which provided information about the study and requested that they come to the study session prepared with their own short story that they would like to incorporate haptics into. Participants were encouraged to use their original stories, children stories, or stories from their personal experience. On the day of the study, the pre-session started by participants being greeted by the haptician who then provided brief introduction to the study and the steps that were going to be followed in the whole study. Participants then read and complete consent form and demographics questionnaires. As shown in Figure 6.1, the participants went through the three steps of the FPI process, starting the from the Feel step where the haptician facilitated the demonstration of the Haptic Mini-Tour. Afterwards, participants moved to the Tickle Trunk, where more liberty was given to participants to play with the input and output widgets to understand about the basic modalities of haptics. Participants were then brought to the Imagine station to use the worksheet; participants were given silent space to write their story with haptics. This station included multiple sheets from the worksheet and the pamphlet. Finally, we conducted a short semi-structured interview and administered the questionnaires. To understand the challenges of adding haptic feedback to stories, a 10-20 minute semi-structured interview was conducted. We then administered a usability questionnaire, which measures the subjective usability of a tool or service using four dimensions of usability (usefulness, ease of use, ease of learning and satisfaction) [46], and the Creativity Support Index (CSI) questionnaire, which is used to measure the ability of the tool to support users engagement in creative works [9].

The study took approximately 90 minutes and the participants were given a $20 remuneration in appreciation of their time given to the study. Photographs, audio and video recording were taken for the whole study with the permission of the participants to later analyze the feedback and interaction of participants with the devices.

6.2 Participants

We recruited ten participants (self reported genders: 1 female, 8 male, 1 non-binary) with age between 21-34. Participants were recruited using our professional networks, word of mouth, and by reaching out to theatres and art institutions. Participants were adults with background in gaming, design, UX, and visual arts.

Figure 6.1: Participants using different supporting tools from the FPI process. A and B show participants in the Feel step, C shows a participant in the Play step interacting with The Tickle Trunk and D shows a participant writing on a worksheet in the Imagine step.

Here we have described each participant in terms of their highest qualification along with their professional and educational experience.

- **P1** (over 10 years of experience in art, designing and storytelling, Undergrad) held experience in making experimental alternative controller games in collaboration with hardware hackers.
- **P2** (5 years of experience in storytelling, Masters) has experience in narrative designer and games studies.
- **P3** (7 years of experience in designing and storytelling, Doctorate) held experience in designing games and gameful systems for educational purposes.
- **P4** (7 years of experience in designing, art and storytelling, Doctorate) is a writer, designer and artist with primary interest in comic books.
- **P5** (5 years of experience in designing, Undergrad) is a UX designer with experience in mobile and industrial design.
- **P6** (3 years of experience in designing, art and storytelling, Doctorate) held experience in designing and video game storytelling as part of dissertation work.
- **P7** (4 years of experience in designing and storytelling, Masters) is a UX designer with experience in VR and games.
- **P8** (3 years of experience in art, Undergrad) held experience in digital arts and multimedia storytelling.

- **P9** (5 years of experience in designing, art, and Storytelling, Masters) held experience in theatre, music and writing.
- **P10** (5 years of experience in storytelling, Masters) is a mechatronics engineer with music and theatre experience.

6.3 Resulting Themes from the Lab Study

The interview session and feedback given by the participants was transcribed and analyzed using thematic analysis [60, 54]. While eight themes were created based on the analysis of the study session, I have chosen to focus on three themes related to the Tickle Trunk.

6.3.1 Experiencing haptics helped to generate ideas

There was active interaction from each of the participants while using the devices and curiousness of the how the devices would act in different situation. Hands-on interaction with the toolkit helped in the brainstorming and learning experience. All participants were able to use the devices and experience the feedback generated from the Tickle Trunk. Participants expressed the usefulness of the toolkit: *"falling of a boat could holding something like ball (from Tickle Trunk) and its tipping"* (P2),*"I definitely focused more on the devices other there (pointing to the Haptic Mini-Tour)"* (P8) and *"Main thing I used was chair to give subtle vibration and aggressive vibration to show changes in the surrounding of the character"* (P6). (P2) and (P5) mentioned that they did not know things outside of vibration like texture, shape change, temperature were considered haptics. Advantage of being able to touch and feel the haptic devices to brainstorm ideas was also mentioned by the participants : *"Demos were great for sparking creativity."* (P10), *"I like to feel and see the tool first and come up with the idea"* (P1) and *"Definitely having hand on stuff was engaging and interesting"* (P4). The active interaction and hands-on experience with the Tickle Trunk helped participants to brainstorm and learn while providing a useful and engaging tool for haptic feedback exploration.

6.3.2 Need a balance of abstract and real word examples in Haptic Mini-tour and Tickle-Trunk

To demonstrate different types of feedback and toolkits in haptics, a combination of real-world and abstract objects was used for interaction. As there were different genres of stories used by the participants (fantasy, sci-fi, real experience, children's story, embellished real story), participants wanted abstract objects to help in their imagination and real world objects to practically see how haptics can emulate the real world scenarios. *"abstract things gives you room for imagination."* (P1), *"vaguely described scenes in the stories have lot of room for haptics to carry that moment"* (P1), *"combination of real world and abstract object is the most powerful because its something you are familiar with and something that is foreign"* (P9) and *"real world objects like candle would be great to drive the narrative."* (P10). Using a combination of real-world and abstract objects in haptic interactions allowed participants to use their imagination while also seeing how haptics can emulate real-world scenarios.

6.3.3 Using multiple types of feedback could make the story more natural

As the Tickle Trunk provided individual output feedback and the Haptic Mini-Tour was mostly focused on devices with one specific feedback, participants wanted a combination of different haptic sensations at once. During the study, (P1) found it difficult to try 2-3 output feedback from the Tickle Trunk at once and expressed the frustration of being able to grab only one output at a time. Participants expressed their desire for multimodal interactions, stated that a *"combination of fan with warm temperature to get a feeling of warmth in the air with vibration of the bike could be handy"* (P6). Some participants wanted to not only feel different sensations, but to have them combined to enhance the feeling, saying *"I wish I could feel multiple haptic sensation at the same time (pointing to the Tickle Trunk)."* (P3), and stating they *"want to combine output to feel its effect (pointing to Tickle Trunk) like vibration, heat and motion"* (P1) and as well said a *"mixture of sensation at the same time like vibration, warmth and texture could be helpful"* (P5). This shows participants desired to use multiple sensation in the story to make it feel more alive and provide a similar feeling of using a real world object. Although the Tickle Trunk provides the opportunity of interacting with different individual modalities, participants would like to go a step further and be able to combine those effects in a single form. Participants desired a combination of different haptic sensations at once, showing the importance of multimodal interactions and the desire to combine effects to enhance the feeling of a story and provide a similar feeling to using real-world objects.

6.4 Results from Questionnaires

The participants were able to creatively use haptics in their stories using the concept of haptics provided using the Tickle Trunk. There were 10 different stories with different genre like fantasy, sci-fi, real experience, children story and embellished real story. The participants evaluated the usefulness of the different devices from the Mini-Tour used (Haply, Haptic Gaming Chair, 3D Systems Touch and Tanvas), the Tickle Trunk and the Worksheet. As shown in Figure 6.2 every participant found the worksheet helpful while only some of the participants found the widgets from Tickle Trunk and devices from the Haptic Mini-Tour useful while adding haptics in their stories. The results from the usability questionnaire Figure 6.3 and Figure 6.4 clearly show the effectiveness of the toolkit and process to help participants to create and communicate haptics in their stories. The high values from the CSI scale show the success of the process in creating creative work. The steps and order of FPI process have shown to be of help in the ease of learning about haptics which is explained in Subsection 8.1. The other factors from the USE metric also show the efficacy of the Tickle Trunk, Haptic Mini-Tour and worksheet in brainstorming ideas for haptics in stories.

The results suggest that participants found the FPI process and toolkit to be highly usable and effective in achieving its intended goals. The high ratings on all factors indicate that the implementation of FPI was well received by the participants and that the FPI tools were easy to use and useful in their work. This positive feedback can help guide future development and refinement of the FPI process and toolkit to further improve its usability and effectiveness.

The lab study with the storytellers and designers demonstrated the potential of the Tickle Trunk as a tool for haptic prototyping and ideation. Participants were able to easily experiment with different haptic sensations and modalities using the various input and output widgets. The study also revealed some limitations and areas for improvement, such as the need for customization and a wider range of haptic sensations. Overall, these chapters presented two case studies that showcased the Tickle Trunk's potential for supporting haptic design and ideation, while also providing insights into its strengths and weaknesses. By sharing these experiences and findings, we hope to inspire other designers and researchers to explore the possibilities of haptic prototyping and to contribute to the ongoing development of haptic design tools.

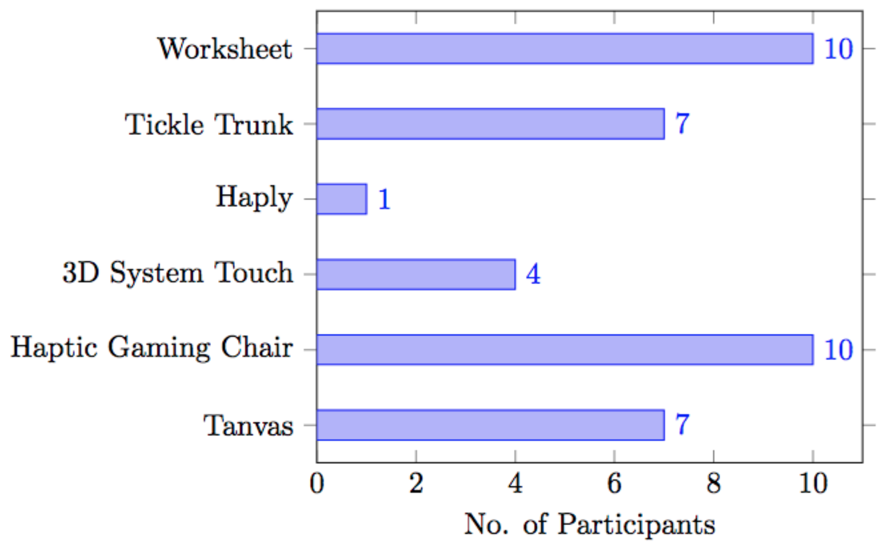

Figure 6.2: The graph shows the usefulness of the toolkits for participants in the FPI process

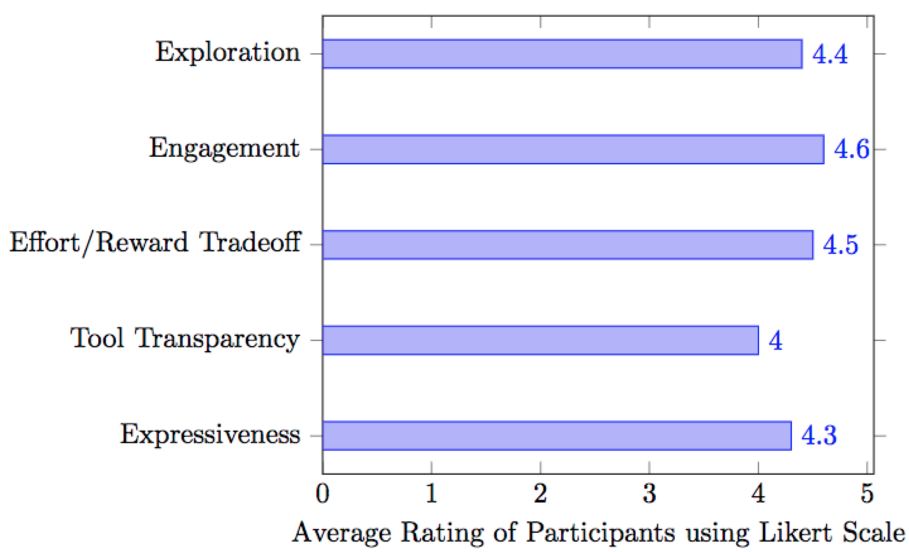

Figure 6.3: CSI Index for the FPI process. Participants rated our implementation of FPI highly on all factors.

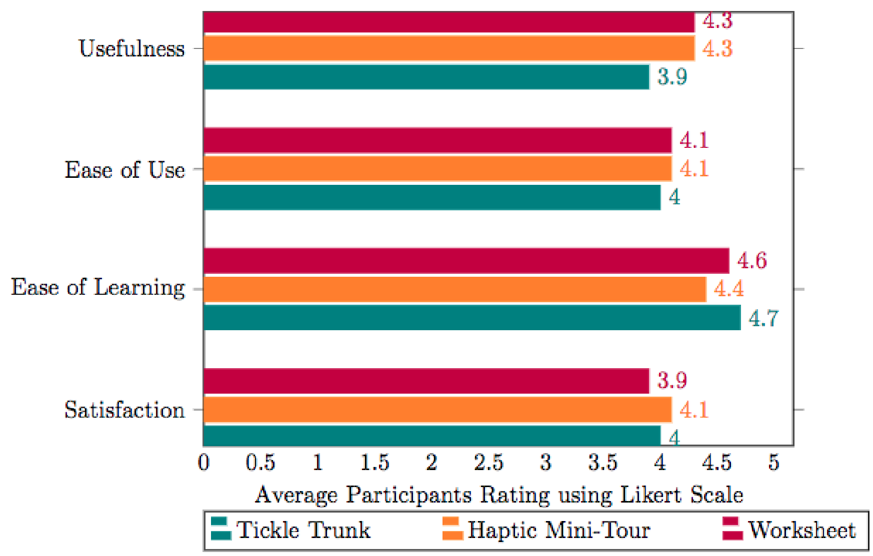

Figure 6.4: USE Usability Metrics for FPI toolkits. Participants rated FPI tools highly on all factors.

Chapter 7

Tickle Trunk 2.0: Do-It-Yourself version

In this section, we present a second version of the design of the Tickle Trunk, aiming to improve specific aspects of this toolkit like making it open source, easy to customize, and extensible as needed. The section will cover design decisions, the building of a collection of widgets, and a planned evaluation for these new improvements.

7.1 New Design Requirements

The development of toolkits to assist in the sketching process has a lengthy history in the field of HCI. Several requirements have been identified, with Ledo et al. summarizing the objectives of HCI toolkits, such as the need for generative design that allow designers to create new interactive artifacts, easy access to complex algorithms, rapid prototyping, and creative exploration of the design space. Toolkits should enable designers to discover new properties or design possibilities, thereby extending their design knowledge [42]. For haptic experience design, supporting communication and learning of haptic sensations and how to articulate them is crucial [63].

At present, there is a lack of toolkits that enable designers to freely explore and generate their own unique haptic experiences by combining different forms of haptic actuation. Although there are some available toolkits, like Soma Bits [70], they often have a narrow focus on specific sensations or are tailored towards specific projects, without providing the flexibility for users to design their own toolkit to facilitate communication, brainstorming, and sketching. This gap is what the Tickle Trunk aims to fill, and for the second version of this toolkit we focused on three goals to add value to our toolkit by reducing authoring time, empowering new audiences, and enabling replication and creative exploration for our users.

7.1.1 Reducing Authoring Time and Complexity (DIY)

The first goal is reducing the authoring time and complexity of using and building the Tickle Trunk. We decided to focus on the ease and simplicity of building the toolkit and adding new components to it.

It is important for the Tickle Trunk to be built by almost anyone. As a physical authoring tool the Tickle Trunk should be able to support different styles, designs, widgets and ways to customize your toolkit. To achieve this we reduced the steps towards designing, building and customizing the toolkit. By designing custom printed circuit boards (PCB) and making them available to the public.

The are two types of PCBs for the Tickle Trunk, the main board and the input widget boards as can be shown in Figure 7.1 and Figure 7.2. The main board includes the input and output grids where the widgets can be connected, as well as the connection to power and a switch to power on or off the device. When assembling the main board the number of input channels as well as the outputs can be decided by connecting the female AUX terminals to the board. This way any user can customize the main box depending on their needs. The standard board includes three input channels with three outputs per channel.

The main box PCB includes transistors to map inputs to outputs. I used the BS270, an N-Channel MOSFET, to switch on and regulate the voltage flow from the input widget to the output widgets. Each channel functions with their own transistor and each output is independent from the other in the same channel. The circuit design for the Tickle Trunk V2.0 can be found on Figure 7.1.

The Tickle Trunk features two distinct types of input widget boards to support different types of sensors. The first board is designed to accommodate resistive-based sensors, while the second board is meant for use with sensor modules. Both circuits include a 3V battery to power the sensors and provide a signal to the main box to map to the output widgets. The circuit diagram for the resistive based sensors can be seen on part A of Figure 7.2, it consists of a voltage divider that connects to the two terminals of the sensor. For the sensor module circuit it is a simple connection between power, ground and signal output, as can be seen in part B of Figure 7.2. The circuit design aims to accommodate as many low voltage sensors as possible to encourage diversity and customization in input widget creation.

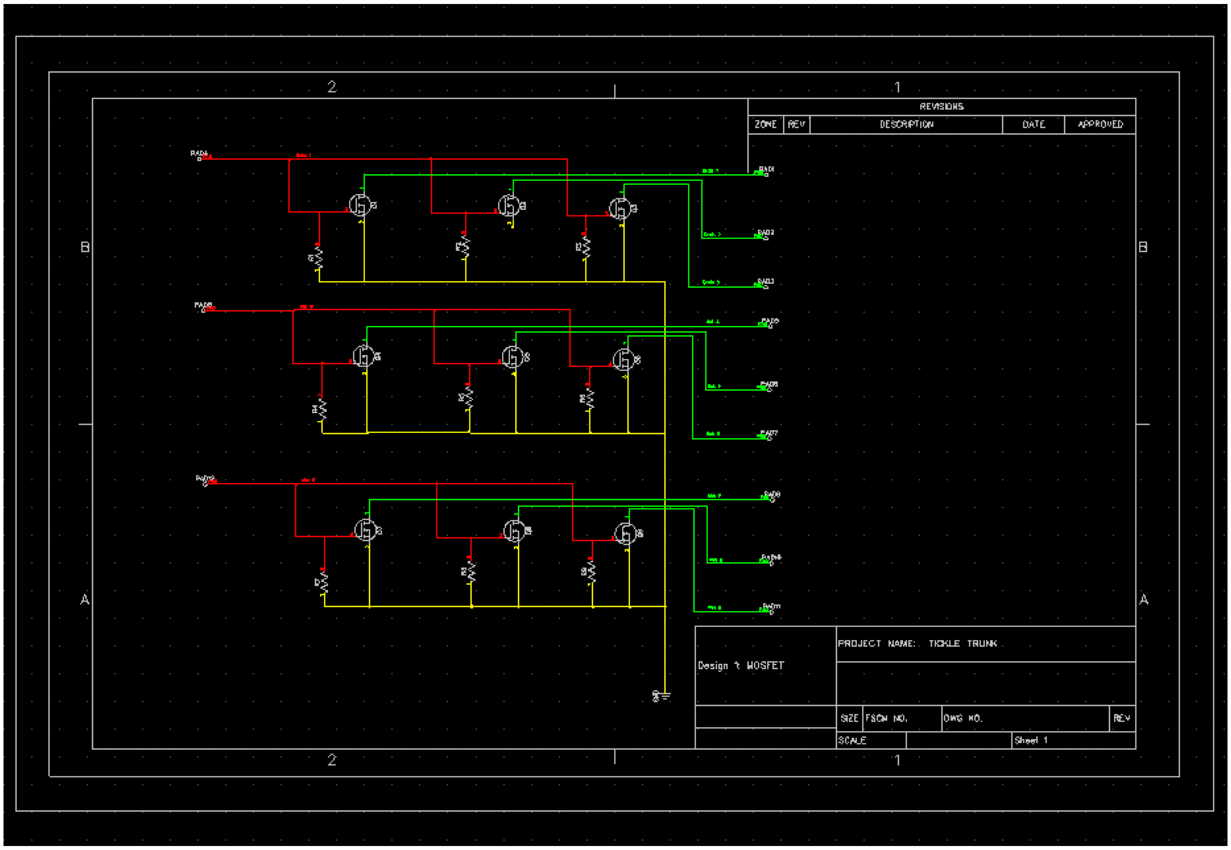

Figure 7.1: Main board PCB circuit design for the Tickle Trunk 2.0

7.1.2 Empowering New Audiences (Open Source)

The second goal was to make the toolkit accessible in order to reduce effort of understanding and using the Tickle Trunk, this enables new audiences to experiment with haptic design. This goal inspired the design of the Tickle Trunk since the first version, by making the design simple, intuitive and playful users were invited to experiment with the toolkit. However, for the second version of the toolkit we focused on simplifying the building and connecting of the toolkit, and making all plans, files and instructions open source for any

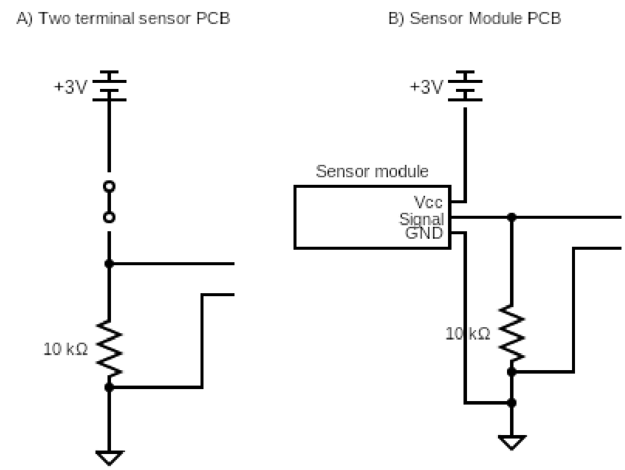

Figure 7.2: The Tickle Trunk features two distinct types of input widget boards to support different types of sensors. The first board is designed to accommodate resistive-based sensors, while the second board is meant for use with sensor modules.

designer, artist, or anyone interested in haptics to easily design and make their own Tickle Trunk.

As mentioned in the above section, three PCBs were designed to reduce authoring time and invite customization. These resources as well as the design files for the main box and some existing widgets will be made available upon request to the public through an online website.

7.1.3 Building a Collection of Haptic Widgets

The third goal involved enabling replication and creative exploration with the Tickle Trunk. This was addressed by increasing the ease of customizing and extending the toolkit. One of the main advantages of the second version of the Tickle Trunk is its extensibility. With this new ability to easily add new components to one's collection of widgets depending on one's specific needs for a project or situation. Widgets represent different haptic sensations, so by building a growing collection of widgets, users are invited to explore new inputs and outputs and create a complete new suite of sensations.

By following four simple instructions the user can add a new widget, input or output, to their growing collection.

1. Choose a new widget, input or output (sensor or actuator), to add to the collection.
2. Design the case for the new widget. this can be a specific shape like a candle or it can also be a simple shape like a sphere or box. Build the case using digital technologies like a 3D printer or a laser cutter.
3. If you chose to add a sensor, connect the sensor to the custom made PCB specific for that type of sensor. Solder the sensor to the PCB and then to the wire with the AUX port. If it is an actuator just solder the terminals to the wire with the AUX port.
4. Insert your sensor or actuator inside the case you designed for it and try out your new widget.

Once the haptician has a collection of widgets they can choose to use only the relevant ones for the specific need of the project.

7.2 Planned Evaluation

Two study cases have already been performed to evaluate how the Tickle Trunk 1.0 supports communication, however, we want to perform two more user studies to examine the benefits and challenges of using this new version of the toolkit. Using the data collected, we will ensure the usability of the toolkit before making the second version available to researchers and haptic designers. The two use cases discussed previously helped to evaluate the usability of the Tickle Trunk 1.0, involving the lab members as hapticians and our co-design collaborators, artists, and creators as the non-hapticians. However, there are other aspects of this toolkit that we found important to evaluate with the new version, 1) is this toolkit necessary for other haptic researchers? By gathering requirements and understanding their current methods for communication and the opportunities for improvement by using the Tickle Trunk 2.0. 2) is the toolkit easy to extend? For extensibility, a study will be performed to evaluate the ease of use of this toolkit when building a new widget, input or output, to add to the collection. Participants will be asked to interact with the toolkit and extend it by designing and connecting a new component.

7.2.1 Requirements gathering study

For the requirements gathering study participants with a background of haptics will be recruited to present insights of their current approach to communicating and brainstorming with non-hapticians. Participants will be given a brief introduction of the Tickle Trunk during the study and briefed verbally about how the study will be conducted. There will be a unstructured interview where participants will be asked to talk about their background, how they communicate between hapticians and non-hapticians, their brainstorming and prototyping process. Then after explaining the toolkit we will ask them to say if they had the toolkit, what type of haptic feedback would they like having, what would they use the toolkit for, and would they think it would be useful for communication and brainstorming. A Qualtrics end survey will then be performed after the unstructured interview. This survey acquire participants' demographics, their familiarity with systems that employ haptic feedback, and questions related to how participants plan to use the toolkit for communication.

7.2.2 Extensibility study

For the extensibility study participants with a background of haptics, hardware design or interaction design will be recruited to present insights on the ease of extending the Tickle Trunk by adding a new component to the collection of widgets. Participants will be given a brief introduction of the toolkit used during the study and briefed verbally about how the study will be conducted. Participants will then be given some requirements and asked to design their own component of haptic feedback to the toolkit collection. Following close instructions, they will connect the sensor or actuator to a PCB and case these electronics in a 3D printed design or box give by the one conducting the study. Participants will then interact with the toolkit, using their new component and the existing collection of components. Finally, participants will take part in a short interview about their experience using it, followed by them answering the end survey. This survey acquire participants' demographics, their familiarity with systems that employ haptic feedback, and questions related to how participants found the difficulty of adding a new component to the toolkit. Finally the participants will answer the usability and user experience questions and provide comments and feedback on their overall experience.

The information related to the process and procedure of gathering the requirements and using the toolkit will be carefully looked into during the study. These studies have been approved by the ethics board, however they are outside the scope of this thesis due to timing.

Chapter 8

Discussion

The use of the Tickle Trunk to explore, introduce and brainstorm different haptic effects was studied as part of a process in two case scenarios: 1) in a VR story with topics such as institutional racism and, 2) a lab study with different genre of stories (such as fantasy, sci-fi, real experience, children story and embellished real story), helped us to understand how communication happens when working with haptics, and what are the things that needs to be considered during a session between a haptician and non-haptician. As seen in the literature review there is a lack of toolkits that can enable simple exploration and support communication of various haptic sensations, and the two case scenarios show how the Tickle Trunk could be able to fill this gap by providing a toolkit that can significantly improve communication and collaboration in haptic design.

8.1 People need to experience haptics to understand it

The physical context and interaction with the haptic devices plays an important role in understanding the concept of haptics [10]. The learning experience using these devices helps to practically understand how the device works and feeling of using the device, which was useful for storytellers during the imagination process. The participants were able to describe the feedback they wanted the audience to feel using the concepts learned. Besides that, participants enjoyed getting hands-on exposure with the Tickle Trunk and experimenting with different settings and (P1) mentioned that the availability of the toolkit was a "good conversation starter". The workshop with our co-design team was more comprehensive using examples, technical terminologies and details from their experience of the toolkit. For example, we designed a candle to show real-life like object could be incorporated into the widgets, and including important sensations like wind and temperature which come up as important aspects in their stories. Many examples from the toolkit were used to express their desired requirement of haptic for their story. Using actual physical interactions in the discussion helped to create meaningful and in-depth conversation.

8.2 The Tickle Trunk supported communication between hapticians and non-hapticians

In both the workshop and lab study, as part of the FPI process, the Tickle Trunk elicited useful requirements from our participants and supported discussion. Every participant was able to come with design requirements and details of haptic feedback they wanted for in their story (Subsection 8.1). In the workshop, participants referred to elements from both the Tickle Trunk to make their points in the resulting discussion; they noted practical outcomes like accessibility, commented on the embodied sensation of the feedback, such as "immersing yourself...it creates a new body experience" (workshop), and came to conclusions about how to deploy haptics, e.g., to not enhance realism, but to showcase resilience and strength. Participants in the lab study similarly made references to the Tickle Trunk when expressing what they liked and didn't like, arrived at decisions about combinations of haptic modalities and their relationship to the plot of their stories, and finally demonstrated their design intentions through a variety of gestures and other means. The process received positive feedback, high rating, and participants in the lab study specifically commented on the usefulness of the questions to help guide the experience.

8.3 More examples are always handy

Demonstration with simple examples and application of haptics can help non-hapticians to understand its possibilities and build foundational concepts of haptics (Subsection 6.3.2). Using the Tickle Trunk in both the workshop and lab study a demo of the toolkit was given to the non-hapticians and any queries related with its application and its working mechanism were answered. Some of the challenges faced by the participants were due to not knowing the working mechanism of the tangible haptic toolkit included in the FPI:

"devices did not simulate grabbing so I did not know how it will work" (P5), *"something in arm and legs to change the balance to get the feeling that you couldn't move that much"* (P2) and *"would have been better to sense things that you are not actively touching"* (P1). For this, participants wanted an embodied experience of haptic feedback.

The findings of this research project have the potential to pave the way for further exploration of playful design in haptic interfaces. Future work could involve the development of more sophisticated and versatile versions of the Tickle Trunk, with additional features that cater to specific user needs. Furthermore, user studies could be conducted to investigate the effectiveness of playful design in enhancing accessibility for diverse user groups, including those with physical or cognitive impairments. These studies could provide valuable insights into the role of user engagement and motivation in shaping the user experience of designing haptics, and inform the design of more inclusive and effective interfaces in the future.

Chapter 9

Conclusion

The Tickle Trunk toolkit developed in this thesis provides an innovative and effective solution for improving communication and brainstorming between hapticians and non-hapticians. The toolkit offers a wide range of haptic feedback options that facilitate communication and collaboration, regardless of the user's level of experience with haptics technology. The findings of this research indicate that the Tickle Trunk can support the quality and efficiency of communication and brainstorming sessions, enabling hapticians and non-hapticians to work together more effectively towards common design goals. Future work could focus on potential applications of this toolkit ranging from use in the field of haptics research to its application in a variety of industries and sectors, such as education, interactive technologies, and entertainment. Overall, this research contributes to the growing body of knowledge on the potential to improve hapticians and non-hapticians' communication and collaboration.

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