Tickle Trunk: A Toolkit for Playful Exploration and Brainstorming with Diverse Physical Interactions

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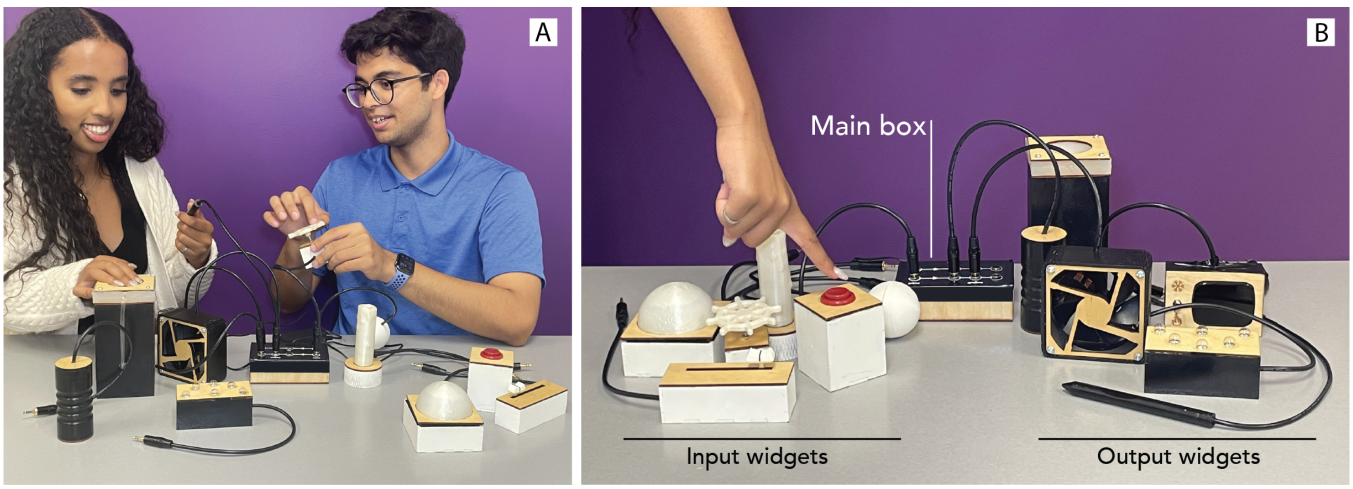

Figure 1: The Tickle Trunk enables exploration for a wide range of physical interactive modalities. (A) By connecting different "widgets", designers and storytellers can explore different haptic and tangible modalities and experiences. (B) A selection of input and output widgets. This toolkit is open source and hardware-based, with total cost less than CAD$75.

ABSTRACT

As haptics and tangible interaction are increasingly adopted, designers face challenges when coming to a shared understanding of capabilities and materiality with collaborators. Existing tools either impose or limit the available technologies, reducing the ability for non-technical team members to make decisions. We present the Tickle Trunk: an open-source, hardware-only toolkit for rapid, playful exploration of diverse physical modalities. The toolkit consists of plug-and-play widgets that can be combined in seconds without programming. We report on the design of the Tickle Trunk within a larger co-design project, and on a 14-person user study that found the toolkit to be highly usable, supportive of creative exploration, and easily extensible by designers, with participants adding new components in less than four minutes. By prioritizing speed of iteration, a broad multimodal palette, and open extensibility, the Tickle Trunk facilitates early-stage mutual-learning and ideation to democratize the design of haptic and tangible interactions for any team.

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CCS CONCEPTS

• **Human-centered computing → Haptic devices**.

KEYWORDS

haptics, brainstorming, open-source, hardware sketching

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1 INTRODUCTION

Haptics — technology that connects to perceived senses of touch [55] — and more broadly, physical and embodied interaction, is becoming a widely used way of enriching experiences with technology. Haptics is appearing in applications such as education, gaming, safety training, medicine, and virtual reality [20, 34, 38, 59]. While our design knowledge in these fields is growing [55, 56], our understanding of collaboration and co-design is still limited. We do know that, when designing haptic experiences, hapticians (makers of haptics) make use of different disciplines, including software, hardware, psychology and design knowledge, and need to effectively showcase the capabilities of haptics and establish a common language with those unfamiliar with it [55].

Unfortunately, establishing a shared understanding takes significant iteration, which is not always possible. The initial exploratory phase of haptic design relies on haptic sketching [48]: the rapid creation of low-fidelity tangible sensations to quickly test and communicate ideas. Not all teams have time to rapidly and repeatedly brainstorm with hardware. For example, teams face challenges sharing access to hardware, especially when working remotely [56], and in community-based research, there is significant "hidden" work needed to overcome institutional barriers and build relationships and trust [35], dramatically extending design timelines and reducing the ability to rapidly iterate. We encountered this problem firsthand. The Digital Oral Histories for Reconciliation (DOHR) project [17] developed a virtual reality (VR) experience that shares oral histories of former residents of a segregated care home. When looking to add haptic feedback, we needed to communicate the expressive capabilities of the technology to storytellers and domain experts, while navigating a distributed team and without imposing upon community-based members' limited time.

Existing toolkits and design tools can facilitate rapid prototyping, but impose limitations on the chosen technologies, e.g., vibrotactile feedback [1, 45] or stretch, twist, and vibration wearables [70]. If the technology is known from the outset of a project, then a design tool can be selected or created to support rapid iteration and co-design with design experts (e.g., [37]). However, the relational context of the DOHR project necessitated a commitment to centering first voice of the former residents, and thus followed the principle of subsidiarity (decisions made by those most affected by them) [39]. Technology could not be chosen without the involvement of our collaborators; we needed a way for our mixed-expertise, community partners to make creative decision of what modalities or technologies to use.

We present the Tickle Trunk[1], a toolkit aimed to facilitate rapid communication and ideation about hardware modalities for mixed-expertise, distributed, or community-based teams. By being a hardware-only plug-and-play system that requires no programming, Tickle Trunk prioritizes the speed of iteration over technical complexity, making haptic exploration rapid, playful, and approachable for all interested parties. Unlike other simple plug-and-play systems with limited options, the Tickle Trunk provides a broad, multimodal haptic palette from the outset and is designed to be openly extended and customized with new modalities using low-cost, open-source PCBs as new projects or contexts emerge. This lets the designer prepare a Trunk with an array of possible technologies ahead of time to make the most of in-person sessions for ideation and shared learning.

We previously reported on the Tickle Trunk as it supported our "Feel-Play-Imagine" (FPI) method for structuring shared learning and ideation for haptics [29]. In that context, it helped contribute to a *"euphoric possibility space"*, helped our team establish a shared vocabulary, and was further evaluated for introduction of haptic and tangible modalities to VR storytellers. In this paper, we provide a more thorough description of the design and implementation of the Tickle Trunk and evaluate its extensibility and effectiveness as a standalone tool for designers.

We first cover the related work of haptic and tangible design toolkits and their use in early design, then describe the Tickle Trunk, its features, and design decisions. The Tickle Trunk is open-source and available online at https://tickletrunk.tech, provided as a resource for those seeking to enhance their co-design and ideation processes for haptic and tangible interaction design.

2 RELATED WORK

Our work builds on previous work in embodied interaction and ideation, physical brainstorming, hardware sketching, and toolkits that support haptic and tangible interaction design. Rather than arguing that haptics lacks prior methods or vocabulary, we situate the Tickle Trunk within this broader literature as a tool for early-stage exploration: a way for designers and mixed-expertise teams to quickly try out and discuss possible haptic and tangible interactions before moving into more fully developed prototypes.

2.1 Theoretical Foundations: Embodied Interaction and Ideation

Our work is grounded in theories of embodied interaction, which emphasize that meaning-making and interaction are fundamentally shaped by bodily experience rather than abstract cognition alone [12]. Within this perspective, tangible interaction couples digital information with physical artifacts, allowing designers to reason about interaction through material engagement and bodily action [26]. By thinking through doing, tangible artifacts enable exploration of interaction concepts in situ rather than through symbolic or verbal representation alone. These ideas are especially

[1]The name comes from the Tickle Trunk used by acclaimed children's entertainer, Mr. Dressup, who could reach into the trunk to grab whatever costume or prop he needed at that moment. In a similar fashion, our Tickle Trunk enables designers and engineers to produce ad hoc experiential prototypes when needed during exploration and brainstorming activities.

relevant for haptics, where many important qualities of an interaction, such as intensity, texture, force, and affect, are difficult to fully communicate through words alone [31, 55]. While tangible and embodied interaction research often focuses on the broader design space of physical action and material engagement, haptics is concerned more specifically with mediated touch and force sensations [55]. In this work, the Tickle Trunk operates at the intersection of these spaces: it supports tangible interaction as a general mode of exploration while placing particular emphasis on haptic modalities.

In both cases, designing embodied and tangible interactions requires ideation methods that similarly engage the body. Haptic sensations are experiential, situated, and difficult to articulate through language alone, making them poorly served by purely verbal or screen-based design practices. Embodied ideation addresses this challenge by supporting the generation and refinement of ideas through physical action, sensing, and felt experience [24, 64]. In the context of haptic design, physical artifacts created during embodied ideation externalize felt experience, enabling designers to reflect on and explore what an interaction should feel like. The Tickle Trunk builds on this foundation by supporting embodied ideation through tangible, experiential artifacts that enable rapid exploration of haptic interactions.

2.2 Designing with Novices and Mixed-Expertise Teams

A growing body of work has examined how people with limited experience in haptics learn to design with touch. Seifi et al. show that novice hapticians often struggle with selecting tools, connecting sensations to design goals, and navigating the technical complexity of the field, pointing to the need for better resources that support learning and practice [56]. Other work on digital touch education similarly suggests that novice designers benefit from hands-on materials and structured ways of engaging with touch so they can better imagine, discuss, and prototype tactile experiences [28]. Community efforts such as Haptic Playground reflect this broader push to make haptic design more accessible to a wider range of people, not only experts [30].

Our work is also informed by the idea of boundary objects: artifacts that help different groups work together without requiring them to share the same expertise or vocabulary [60]. This is especially useful in haptic design because early-stage conversations often involve people with different forms of knowledge, such as engineers, designers, artists, domain experts, or community collaborators. In these settings, the challenge is not only building a prototype, but building a shared understanding of what the technology could do. The Tickle Trunk is meant to support that kind of shared exploration.

2.3 Physical Brainstorming and Hardware Sketching for Early Ideation

Brainstorming is a common ideation practice aimed at generating a wide range of ideas before evaluation. Prior work shows that incorporating physical artifacts into brainstorming supports ideation by grounding abstract concepts in material interaction, enabling designers to reason through direct engagement rather than verbal description alone [6, 32]. This is particularly important for haptic design, where touch-based sensations are subjective, non-visual, and difficult to communicate without embodied experience.

Research in HCI further demonstrates that playful, hands-on brainstorming environments increase engagement and creative output [21, 52]. However, existing approaches often rely on static props or abstract discussion, offering limited support for rapidly creating and exploring experiential haptic artifacts during early-stage ideation.

Hardware prototyping platforms such as Arduino, Raspberry Pi, and AdaFruit lower barriers to building interactive systems through modular sensing and actuation [3, 5, 15]. While powerful, these platforms typically require software development and electronics expertise, making them less suitable for fast-paced brainstorming. Further research systems have been developed to support this process, including tools for VR interaction like ActuBoard, [19], physical user interfaces ("Phidgets") [18], and education [51]. In contrast, hardware sketching prioritizes speed and experimentation over completeness [22]. Toolkits such as Circuit Stickers, MaKey MaKey, PiezoRadar, and LittleBits support this approach by making basic electronics accessible [2, 4, 7, 25], but are often limited to a narrow set of outputs like lights, motors, or sound.

Together, this work highlights a gap in early-stage design tools: few support rapid, playful exploration across a broad range of haptic and tangible modalities. The Tickle Trunk is designed to address this gap by enabling fast, embodied brainstorming with a deliberately multimodal, hardware-only toolkit.

2.4 Tangible and Haptic Toolkits for Exploration

In order to facilitate haptic and tangible design exploration, the use of software tools and toolkits has gained attention in recent years. In both cases, exploring the space of design possibilities is an important, yet challenging step in the process of designing for physical experiences [40]. In order to facilitate the exploration of design, maker kits and browsing tools can be used. In the field of haptic feedback, a number of researchers have developed hardware kits and guidelines for this purpose. Simple Haptics and haptic sketching, created by Moussette et al., takes advantage of the emerging 3D fabrication and maker movement to enable rapid sketching with haptic hardware [47]. Other projects, such as WoodenHaptics [16], Hapkit [41], and Haply [11], have also provided customizable, open-source starting points for those new to haptics to explore force feedback design.

Other prior tools have also supported the prototyping and communication of haptic interactions in different contexts. The Hapticon Editor supported the creation of haptic icons for communication research [14], while Swindells et al. discussed the broader role of prototyping tools in haptic behaviour design [61]. HITPROTO supported rapid prototyping of haptic interactions for data visualization [49].

Most existing haptic sketching toolkits focus on a single haptic modality, such as force feedback [11, 16, 42, 62, 68, 69], vibrotactile [10, 50, 54, 66], pressure feedback [9, 13, 58, 67], skin deformation [44], textures [23, 36], tabletop pucks [63], and tactile experiences

[27, 45, 57]. However, some toolkits combine different haptic feedbacks to design multimodal haptic experiences. PneuMod is a wearable haptic device that presents pressure and temperature cues to different body parts [67]. CoTacs is a software tool and hardware platform for group brainstorming of vibration and skin stretch [43]. Soma Bits are designed to support sketching in the Soma design process, with the ability to combine modules for vibration, heat, or shape-changing behavior [65].

Both the Tickle Trunk and Soma Bits share the general goal of exploring touch interactions, but meet different needs in the design process. Soma Bits aim to articulate joint somatic understanding and direction, and feature software control for more expressive capabilities but longer design iterations. The Tickle Trunk aims for extremely rapid exploration and brainstorming of a wider range of haptic and tactile experiences for both novices and experts, with a focus on understanding the materiality of technology and possible technology choices. In implementation, Soma Bits are are structured as more independent, programmable, self-sufficient modules, while the Tickle Trunk is a single hub with many quick, cheap, extensible hardware-only widgets that can be rapidly swapped out and connected. Thus, a gap remains for a tool that combines a broad, multimodal palette with the speed and accessibility of a hardware-only approach for brainstorming, a niche the Tickle Trunk is designed to fill.

3 TICKLE TRUNK

3.1 Design Rationale: A Tool for Mixed-Expertise Brainstorming

The Tickle Trunk was born from the challenge of co-designing haptic experiences with a team of collaborators with diverse expertise, including storytellers, artists, and engineers, a context necessitated by our involvement extending the Digital Oral Histories for Reconciliation (DOHR) project [17, 39] to potentially support haptic technology [29]. Our primary objective was to create a tool that could serve as a 'boundary object' [60] to bridge the gap between technical and non-technical stakeholders, establishing a shared, embodied language for haptics [12]. This objective, together with insights from prior work [29] and early exploratory design iterations, informed three core design goals: (1) instant usability, (2) approachability, and (3) expressive diversity. These goals were derived from the need to support fast-paced, collaborative ideation while lowering technical barriers and enabling rich exploration of haptic interactions. To support rapid brainstorming, the toolkit was designed to be *instantly usable* as a plug-and-play, hardware-only system. Users can quickly connect and swap input and output widgets without writing code or configuring software, minimizing disruption during ideation.

To ensure *approachability* for users with varying levels of technical expertise, the system employs a clear, playful aesthetic inspired by familiar physical artifacts. Form and color were iteratively refined to enhance intuitiveness—sliders convey range through linear motion, and buttons invite pressing—allowing users to understand interactions through visual and tactile cues.

Finally, *expressive diversity* was prioritized to enable creative exploration. The toolkit supports a broad and extensible set of input and output widgets, offering a wide range of haptic and tangible modalities (Figure 2A), allowing users to experiment with and communicate diverse interaction ideas.

3.2 System Components and Use

The Tickle Trunk (Figure 1 B) is a plug-and-play toolkit created to support playful exploration and brainstorming during the design of haptic and tangible systems. It provides an open-source toolkit for users to experiment with a variety of tangible, physical, and haptic modalities for both input and output. It offers an array of haptic feedback that allow designers to explore and create haptic sensations, with the flexibility of adding new modalities.

The toolkit was designed for haptic sketching [46], 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's widgets provide different tactile or haptic sensations. The plug-and-play system helps users explore and brainstorm various types of haptic and tangible interaction.

3.3 Hardware-based Design

We designed the Tickle Trunk to be a pure hardware device; no software or programming is needed for set up or use. While this intentionally limited flexibility, it reduced complexity and cost of the kit and enforced interaction with widgets to be on the order of seconds. The low cost and complexity enabled a large number of widgets to be supported. Removing the temptation of creating more elaborate prototypes meant that user focus would be on trying modalities. The result is a toolkit that enables rapid exploration of modalities, which complement existing tools (e.g., Arduino platforms, Soma Bits [65]) which handle more complex prototypes at the cost of time and material.

This ever-growing collection of widgets, which can be seen in Figure 2, can be separated into two groups: inputs, which are sensors or switches, and outputs, which are actuators. These widgets can be mixed and matched to explore different combinations of modalities. Both input and output widgets were designed to enhance their discoverability to the users, for example, using color, shape, or range of motion to signal their appropriate usage.

Input widgets: These widgets can turn ON/OFF or modulate the signal the output widgets will receive. Each input widget offers a unique way to activate the output widgets connected in the same channel. These widgets can be activated by several interactions.

Output widgets: These widgets are controlled by the input widgets and will be activated to display several types of haptic feedback. Each output widget offers a unique sensation. Our initial set of inputs and outputs can be found in Table 1.

Aesthetic code. The use of colors, simple shapes, intuitive interactions (plug-and-play), and customization of the system enables users to brainstorm ideas and test them out on the spot. One of the key design requirements for the Tickle Trunk was to create an experience that felt approachable, inspiring simplicity and encouraging users to engage with the toolkit regardless of their technical expertise. To achieve this, we drew inspiration from children's devices and systems designed for non-technical users. These devices often prioritize clear visual cues, playful aesthetics, and ease of use, which

Table 1: The initial set of input and output widgets for the Tickle Trunk toolkit. Each widget is designed to explore a different interaction or haptic modality.

Widget Type	Name	Interaction / Sensation
Input	Push Button	A binary ON/OFF switch activated by a simple press.
	Shake Sensor	A spring-type vibration switch activated by shaking.
	Slider	A sliding potentiometer for continuous intensity control.
	Flame Sensor	An IR (infrared) sensor that detects heat sources as a non-contact switch.
	Proximity Sensor	A linear Hall sensor activated by moving a magnetic object nearby.
	Turning Dial	A potentiometer for continuous rotational control.
Output	Fan	Blows a stream of air with variable speed.
	Vibration Handle	Provides strong vibrations via a 12-volt DC motor.
	Vibration Pen	Provides localized vibrations via a 3-volt DC motor.
	Shape Changer	A pump inflates a silicone bubble, creating pressure and texture.
	Thermal Feedback	A Peltier module that can produce heating or cooling sensations.
	Lights	Incandescent bulbs that provide both light and radiant warmth.
	Force Feedback	A servo motor that provides physical resistance or movement.

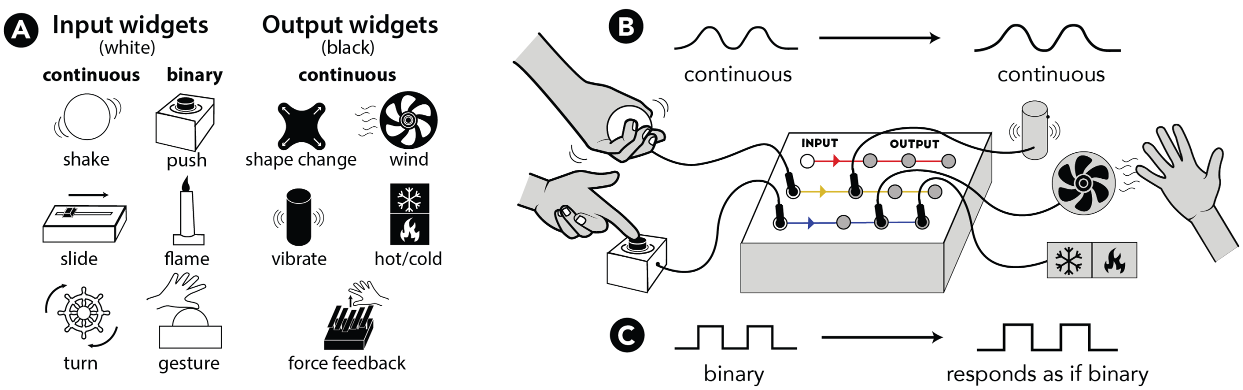

Figure 2: (A) shows the initial input and output widgets built for our first version of the Tickle Trunk. The input widgets, from top to bottom, include a shake sensor, push button, slider, flame sensor, potentiometer and proximity sensor. These input widgets allow the user to create different haptic sensations through the output widgets such as shape change, wind, vibrations, thermal feedback, lights, and force feedback. (B) and (C) show the process of interacting with the Tickle Trunk and how the internal mappings of inputs and outputs work. We can see the two types of signals the inputs can provide, continuous or binary, when connected the outputs will receive this signal and activate in a continuous or binary way, respectively. (B) shows a continuous waveform by the shake sensor, causing a continuous activation of the vibration motor. (C) shows a binary waveform by the push button, causing an binary activation of the fan and temperature pad.

influenced the toolkit's visual look and feel. Color helped signal function: input modules are white to suggest user interaction, while output modules are black to indicate a responsive role. This contrast makes the system easier to understand at a glance. Consistent color coding supports quick recognition, especially for non-technical users. This cohesive design language made the Tickle Trunk feel intuitive, accessible, and playful for all users. The versatility of the toolkit allows for its application in various situations, providing flexibility for both expert and non-expert stakeholders to determine the shape and format of any new widgets. Additionally, the sensors or actuators housed within these widgets can be customized to fit any type of enclosure. In the production of these widgets, we utilized 3D printing and laser cutting to create the boxes or cases, further enhancing the adaptability and accessibility of the toolkit.

Haptic and tangible interaction can be created through a wide range of technologies [55], however for the purpose of this toolkit, our initial set of sensations were based on rendering basic tactile feedback to users through vibration, touch, pressure, temperature, force feedback, tangibles and texture. Our specific widgets were structured as a mix of elements that were abstract (e.g., vibration) or metaphorically relevant to our context (e.g., flame to mimic lighting a candle). In other contexts, a designer could vary the included widgets to provide a suitable set of elements to experience, and use it in either a structured or ad-hoc way.

3.4 Technical Implementation

To enable a hardware-only design that can support arbitrary sensors and actuators, we focused on creating a flexible system for mapping input to output. The Tickle Trunk achieves this by using transistors to route signals from input widgets (sensors) to the activation of output widgets (actuators). Specifically, the BC337 transistor is used to amplify and control the signals from the input widgets, allowing them to drive and activate the output widgets. Since the signal remains analog, there is no latency introduced by digital conversion or processing, ensuring real-time responsiveness (Figure 2).

The design allows for multiple channels, with each channel mapping a single input widget to up to three output widgets. This makes the system highly adaptable, enabling complex interactions without overcomplicating the circuitry.

We categorized the input widgets into two types: binary and continuous. Binary widgets, such as push buttons or toggle switches, function as simple on/off devices. Continuous widgets, like potentiometers (sliders or turning dials) or analog sensors such as accelerometers, provide a variable voltage signal corresponding to user input. All inputs are ultimately translated into a standardized analog voltage signal—typically ranging from 0V to 5V—which is used to drive the output widgets.

Within each widget, we ensure voltage compatibility either by selecting components with the appropriate range or by using voltage dividers and resistors to match expected input/output behavior. Binary inputs produce two discrete voltage levels (e.g., 0V and 5V), while continuous inputs vary smoothly across the range.

In terms of circuit design, we prioritized ease of integration into existing projects by ensuring compatibility with commonly used off-the-shelf sensors and actuators. To achieve this, we defined input widgets to operate on a digital voltage range (0V-5V), while output widgets support either digital or analog signals. This makes the Tickle Trunk compatible with a wide range of sensors and actuators commonly used in electronic prototyping, such as those available in the Arduino Sensor Kit. This flexibility allows the toolkit to be easily incorporated into various prototyping environments and encourages experimentation with different sensor-actuator combinations.

The toolkit comes together with the help of two PCBs, one inside the main box and the other for the output widgets. These custom made PCBs are open-source[2], and were designed to make our system easily reproducible.

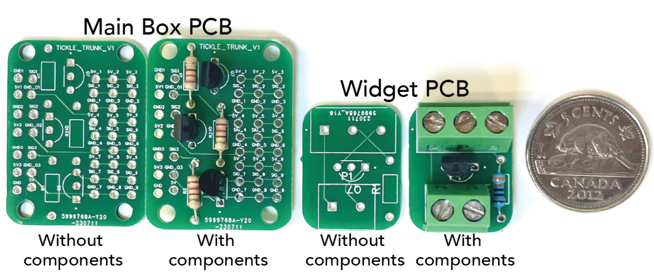

Figure 3: Tickle Trunk's Printed Circuit Board (PCB). The first two show the "Main Board" circuit, and second two show the "Widget" circuit. Both versions of the board show first the board without components and then with components for each version of the PCBs.

[2]Plans and guide available at https://tickletrunk.tech

Main Box PCB (CAD$1 without components, CAD$3 with components). The main box PCB, shown on the left of Figure 3, connects through simple mappings the input and output channels. The NPN amplifier transistor from ON Semi-conductor (BC 337) regulates the flow of current to the output widgets depending on the input signal. The circuit between input and output is closed by the user, when connecting input and output widgets in their corresponding place and the input is triggered.

Widget PCB (CAD$1 without components, CAD$5 with components). The output widget PCB, shown on the right of Figure 3 and in Figure 4, is a bridge between the actuator and the main box. The actuators chosen for the output widget need this PCB to be able to turn on when activated. This PCB requires a BC 337 transistor, a resistor that matches the sensor or actuator power requirements, and two mounting screw terminals to connect the actuator to the wired jack. Direct soldering can be used in place of screw terminals for more robust widgets.

All designs including schematics, PCB designs and laser cutting are provided as open source designs in our GitHub repository for reproduction[2].

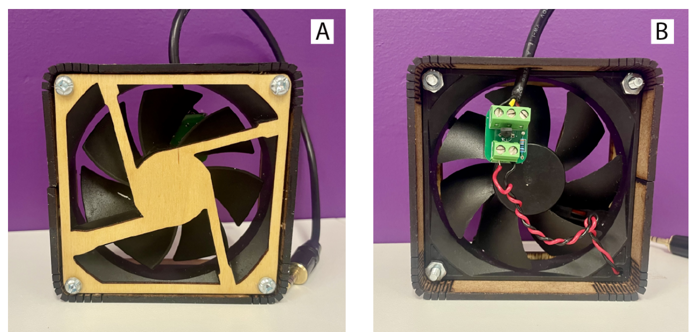

Figure 4: An output widget showing the front side in A and on B the back side of the widget with the PCB connected.

4 METHODOLOGY

To evaluate our toolkit we focused on two key aspects, functionality and extensibility. We needed to test if the Tickle Trunk could serve to rapidly explore and brainstorm with diverse physical interactions between mixed-expertise teams. However, the second goal was to evaluate if the Tickle Trunk could also be extended and remain a flexible tool for the owners of the toolkit (hapticians).

4.1 Prior Evaluation as part of the Feel-Play-Imagine Process

Having developed the Tickle Trunk for use ourselves when engaging with the DOHR project, we previously evaluated the Tickle Trunk in our developed design method documented in the Feel-Play-Imagine (FPI) process [29], where the Tickle Trunk primarily supported the Play step (exploring diverse modalities). We conducted two evaluations of the FPI method, including the Tickle Trunk, where we found it was effective in supporting our mutual learning and ideation needs with a mixed-expertise team involving community story tellers, diverse domain experts, and HCI and haptics researchers.

(1) We conducted a one-day workshop focused on HCI and haptics team members understanding the DOHR project [17] and the DOHR project team understanding the technology options for haptic, tangible, and embodied interaction using the FPI process. Notably, due to the time constraints of our community partners as well as health and travel restrictions, we only had the one day to meet in person, meaning slower iteration strategies (like sketching interactive prototypes [46, 65]) were not feasible and would preclude certain technology decisions.
(2) The FPI process, including the Tickle Trunk, was then evaluated with 10 storytellers who followed the process to brainstorm stories [29].

These evaluations processes were storyteller-led but facilitated by designer-hapticians on the research team. FPI features the Tickle Trunk complemented by more polished demos. We found that physical interaction was essential to understand the modality (*"ooh, I get what you mean by strong vibration"*), brainstorming invited curiosity (*"what happens if I hold more than two feedback in one hand?"*), and supported a discussion on how and why haptic feedback may or may not provide value, especially emotionally [29].

This evaluation provided us with confidence that the Tickle Trunk could support rapid ideation and shared learning between hapticians, domain experts, and storytellers. It further provided details about how to use it in those contexts. However, we were not yet sure about how it could deliver on its design promise to be scalable tools for designers and hapticians.

4.2 Evaluating designer use and extensibility

To understand the Tickle Trunk as a more standalone tool that could be extended to include new widgets and support ideation outside of the FPI process, we conducted a follow-up lab study with 14 participants to answer our remaining research questions based on the toolkit's initial goals of being instantly usable, approachable and expressively diverse.

We recruited 14 participants, which is consistent with prior formative HCI evaluations of design tools and interactive systems. Our goal was not statistical generalization, but to capture recurring interaction patterns and reach thematic saturation in qualitative insights. During analysis, we observed convergence in participant behaviours (e.g., number of ideas generated, multimodal exploration strategies) and recurring themes across interviews, suggesting sufficient coverage of the design space for this stage of evaluation.

RQ1: How do designers perceive the learnability of a plug-and-play hardware-only toolkit for haptic exploration?
RQ2: In what ways does such a toolkit encourage and enable the exploration and brainstorming of various tangible and haptic experiences?
RQ3: How readily can designers extend the toolkit with new sensors or actuators to meet evolving creative needs?

We conceptualize learnability as the ease with which participants can understand and begin using the toolkit, exploration as the breadth and diversity of interactions and ideas generated during use, and extensibility as the ability to successfully add new components to the system. To operationalize these research questions, we map each construct to specific measures collected during the study. Learnability (RQ1) is assessed through self-reported ease-of-use and ease-of-learning ratings, as well as observed ability to use the toolkit without assistance. Exploration and brainstorming (RQ2) are assessed through the Creativity Support Index (CSI) [8], the number and diversity of ideas generated, and the variety of widgets and channels used. Extensibility (RQ3) is assessed through task completion time, number of errors, and participant-reported ease of extending the toolkit.

4.3 Study Design and Procedure

The study was carried out in a laboratory setting in which the Tickle Trunk was set up. This controlled setup allowed us to ensure consistent first-time exposure to the toolkit and to systematically observe learnability, exploration behaviours, and extensibility across participants under comparable conditions. To ensure our evaluation reflected our target audience, we recruited a mix of participants with and without deep expertise in hardware and haptic design. This helped us evaluate how the Tickle Trunk could serve as a tool for haptics and tangibles experts, and for designers with less expertise in hardware.

To measure engagement, we log all interactions that occurred during the study, from which we derive higher-level metrics of time spent in each step and the actions of the participants. The study took approximately 60 minutes and participants were given $20 CAD in appreciation of their time. Photographs, audio, and video recordings were taken throughout the study with the permission of the participants to later analyze their feedback and interaction with the devices. The study protocol was approved by our institution's Research Ethics Board.

4.4 Participants

We recruited 14 participants (self-reported gender: 6 female, 8 male; ages 21–34). Participants were recruited using our professional networks and word of mouth. Participants' education levels were doctorate (3), master's (5), and undergraduate (6), and had experience in one of the following fields: hardware design (5), haptic design (4), or interaction design (5). Most participants (10) did not interact with low-level electronics often, although the rest (4) stated they used them often.

4.5 Tasks and Materials

Usability Test (Figure 5). The first part of the study consisted of introducing the toolkit to the participant, inviting them to explore and interact with each widget, making themselves familiar with the different interactions the toolkit provides and the basic functioning.

After this, the participants were given a small challenge to solve using the toolkit. Participants were given three options of scenarios to choose from; these scenarios were predefined and included test cases where the user was asked to design haptic or tactile tools or experiences for a specific purpose, for example, designing tools for medical and surgical applications or improving a virtual training and simulation for firefighters. For a complete list of scenarios used, see the supplementary material. The scenarios were designed to be comparable in scope and complexity, each prompting participants to design a haptic or tangible interaction for a defined context while allowing creative flexibility. This ensured that participants engaged in a similar level of design activity, enabling comparison of interaction behaviours across participants.

Participants were asked to design a haptic, tactile, or embodied interaction based on a use case scenario of their choosing. They could come up with multiple ideas, either individual interactions or a combination, for a more complete experience. They were encouraged to use as many input/output widgets for their solution.

Participants were instructed to come up with ideas and test them at the same time with the toolkit, they were encouraged to speak out loud their brainstorming process to gather insights on how they solved the challenge. Finally, they completed the CSI and usability questionnaires.

Figure 5: Usability Test: the first section of the study was a demo of how the Tickle Trunk works. Participants were then encouraged to try out all widgets. The participants were given a case prompt which informed the brainstorming session to evaluate if the toolkit helped to inspire exploration and ideation of physical interactions.

Extensibility Test (Figure 6). The second part of the lab study focused on giving participants the task of creating their own addition to the toolkit by building a new input or output widget to add to the collection. The participants first had to choose between building an input widget or an output widget. Once decided, five options were shown for different sensors or actuators, depending on the widget they decided to create. The options for input widgets were joystick, sound sensor, touch sensor, reed switch, and rotary encoder; the options for output widgets were pump, fan, laser, small vibration motor, and multicolored LED. The participants were equipped with a screwdriver to complete their task. The participants were then directed to a website with a set of instructions. The participants followed the simple steps to learn how to connect the new widget and then tested it with the rest of the toolkit.

4.6 Data Collection

Each test ended with a questionnaire related to the usability and extensibility of the toolkit. Five-point Likert-like questions were asked about ease of using the toolkit:

- **Ease of use:** How easy was it to use the haptic toolkit for the assigned task?
- **Ease of learning:** How easy was it to learn how to use the haptic toolkit with the instructions provided?
- **Realism of brainstormed ideas:** How realistic/practical is your brainstormed solution? If you were to show your solution to someone, do you think they would accept it?
- **Level of enjoyment:** How enjoyable was the process of using the haptic toolkit for the assigned task?
- **Overall user experience:** How would you rate your overall experience using the toolkit?
- **Level of user-friendliness:** Did you find that extending the toolkit is user-friendly and intuitive?
- **Level of control:** Did the toolkit provide enough control and customization options while creating a new component?
- **Ease of extending the toolkit:** How easy was it to learn how to extend the haptic toolkit with the instructions provided?

After this questionnaire, we conducted the CSI and and an informal semi-structured interview.

4.7 Data Analysis - Quantitative

Data collected from questionnaires, activity logs, and interviews were analyzed using complementary quantitative and qualitative methods to address the research questions. Quantitative analysis captured trends in learnability, exploration, and extensibility, while qualitative analysis provided deeper insight into participant experiences and interaction processes.

To strengthen validity, we triangulated self-reported measures with behavioural data from activity logs, including time on task, number of ideas generated, and widget usage patterns. Quantitative data from the questionnaires, CSI, and activity logs were analyzed using descriptive statistics. Questionnaire responses were collected on five-point Likert scales and summarized to assess learnability (RQ1), exploration and creative support (RQ2), and extensibility (RQ3).

Creativity Support Index (CSI). To assess if the toolkit supports creativity we used five factors of the CSI metrics: *Exploration, Engagement, Expressiveness, Tool Transparency, and Effort/Reward Tradeoff.* Since the participant worked alone in this study, and we wanted to focus mainly on the usability of the toolkit, the *Collaboration* factor was removed. The CSI consists of two modules: the first contains agreement statements answered on a scale of "Highly Disagree" (1) to "Highly Agree" (20) for each factor; this factor score represents the level of agreement of these statements. The second module involves a paired-factor comparison test with 10 comparisons. This factor counts ranges from 0 to 4; the higher the factor counts, the more important the factor. Multiplying the factor score by the factor count gives the weighted factor score, showing the factors that were more important in carrying out the given task.

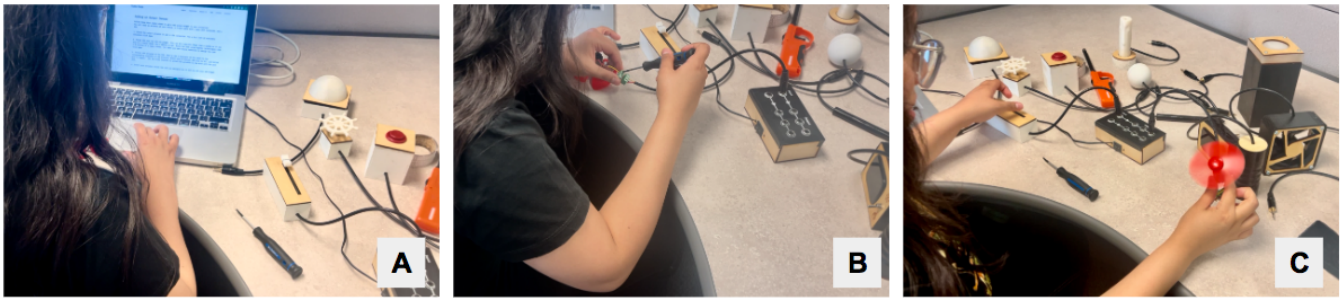

Figure 6: Extensibility Test: the second section of the study asked participants to extend the toolkit by adding a new input or output widget to the collection. (A) A participant reads instructions after choosing to add a new output widget. (B) The participant connects the actuator to the cable using screw terminals. (C) The participant tests their new output widget.

Participant Activity Logs. To better understand the participants' activities, we analyzed the video recorded sessions. The measurements for the usability section were: time spent in each test, number of separate ideas participants came up with, number of widgets participants used for brainstorming, number of Tickle Trunk channels participants used during the brainstorming task, number of participants who used a combination of widgets while brainstorming and the number of those who used a single input and output widget connection. The measurements for the extensibility section were: time spent to add a new widget to the toolkit, number of errors the participants made while connecting the new widget (e.g., connecting a wire to the wrong terminal), and number of participants who chose to create a new input and output widget.

4.8 Data Analysis - Qualitative

Qualitative data from the think-aloud protocol and semi-structured exit interviews were transcribed and analyzed using thematic analysis [53]. Analysis proceeded through multiple rounds of coding, beginning with open coding to identify initial concepts and then iterative refinement into higher-level themes. The primary coder met regularly with two additional authors to review and discuss the evolving codes and themes to ensure consistency and depth of interpretation. Discrepancies were resolved through discussion.

Data Preparation. All qualitative data were transcribed prior to analysis. Video recordings were reviewed to extract structured activity logs. Questionnaire and CSI responses were cleaned and organized for analysis. All data were anonymized prior to processing.

5 RESULTS

We report results from our general questionnaire, the CSI, observed behaviours from the task, and thematic analysis of the study. Together, these measures allow us to address RQ1 through usability ratings and observed interaction, RQ2 through CSI scores and heavioural exploration metrics, and RQ3 through extensibility task performance and participant feedback.

5.1 Quantitative Findings

Usability Questionnaire Ratings. Figure 7 presents the distribution of responses from 14 participants across usability dimensions using a five-point Likert scale. Overall, ratings skew strongly positive, with most participants reporting high enjoyment, usability, and overall UX. The majority also agreed that the toolkit is easy to learn, use, and extend, indicating strong acceptance across all evaluated aspects.

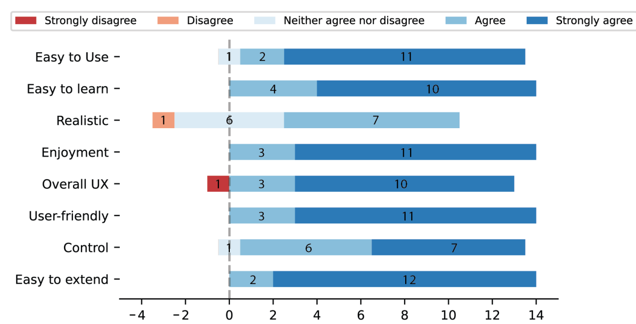

Figure 7: Analysis of usability questionnaire results. Participants evaluated different aspects of the Tickle Trunk using a five-point Likert-like scale (from strongly disagree to strongly agree). Each horizontal stacked bar represents one usability aspect, with segments showing the distribution of responses across categories. The x-axis indicates the number of participant responses per category. Overall, results show high levels of acceptance across all aspects.

Creativity Support Index (CSI). Results for each factor in the user study are presented in Table 2. The Tickle Trunk achieved a total CSI score of 88.85, approximating a "B+" grade as per Cherry et al.'s grading system [8], where scores above 90 are an "A" (excellent support for creativity) and below 50 an "F" (limited support for creativity).

Participant Activity Logs. One researcher logged and timed all observed actions during both sections of the study as shown in Table 3. Participants came up with an average of 4.6 ideas during a 15 minute brainstorming session, they used an average of 8 widgets to explain all their ideas, and 85% (12) of participants used multiple outputs, making their ideas multimodal. The choice between using

Table 2: CSI Results from user study (N=14). The Tickle Trunk received an 88.85 out of a 100, a B+ grade, with the 95% confidence interval also overlapping the 90+ range for "excellent support for creative work" (SD = Standard Deviation).

Scale	Avg Factor Counts (SD, 95% CI)	Avg Factor Score (SD)	Avg Weighted Factor Score (SD)
Exploration	17.14 (2.79, 15.68-18.60)	2.50 (1.02)	42.86 (9.85)
Engagement	18.35 (1.59, 17.52-19.18)	2.64 (0.84)	48.52 (7.04)
Effort/Reward Tradeoff	18.00 (1.92, 16.99-19.01)	1.07 (1.21)	19.29 (10.84)
Tool Transparency	17.14 (4.03, 15.03-19.25)	1.79 (1.53)	30.61 (13.89)
Expressiveness	18.21 (1.96, 17.18-19.24)	2.00 (1.30)	36.43 (11.84)

CSI Score (out of 100) 88.85 (11.30, 95% CI: 82.93-94.77)

one or two channels at the time was balanced, with 57% of participants using one channel at a time. While extending the toolkit, participants took an average of 3.6 minutes to choose which new sensor (6) or actuator (8) to add, go through the instructions on the website, connect the sensor to the cable provided, and try out their new widget with the rest of the toolkit. There were almost no observed errors made through this process.

Table 3: Participant activities during the study. All metrics are calculated through Mean (M) and Standard Deviation (SD), except number of channels, multimodal and I/O widgets, represented as a count of the number of participants who chose each option.

Test	Metric	Value
Usability	Time (min.)	M = 15.14 (SD 2.68)
	# Ideas	M = 4.64 (SD 2.17)
	# Widgets	M = 8.43 (SD 2.87)
	# Channels	One channel (n = 8)
		Two channels (n = 6)
	Multimodal	Multiple (n = 12)
		Single (n = 2)
Extensibility	Time (min)	M = 3.64 (SD 1.55)
	# Errors	M = 0 (SD 0.65)
	I/O Widgets	Output (n = 8)
		Input (n = 6)

5.2 Qualitative Findings from Thematic Analysis

Our thematic analysis of the think-aloud and interview data revealed three key themes that characterize the experience of using the Tickle Trunk. These themes ended up addressing our research questions regarding the usability (RQ1) and its support for creative brainstorming (RQ2).

5.2.1 A Trade-off Between Simplicity and Control. Participants found the Tickle Trunk was easy to use: *"I've never done this so easily"* (P7). They noted how simple it was to learn and start using the Tickle Trunk. Participants commented on the aesthetic choices, *"the toolkit was easy to follow, colors make it clear, white vs black"* (P1); the lack of technical know-how needed *"it's nice we don't see what's inside the widget, we don't need to understand the science of it"* (P14); and lack of required coding experience, *"I've used motors and sensors with Arduino...I had to code so it was harder"* (P10).

While the Tickle Trunk was described as *"user-friendly"* (P10), *"intuitive"* (P7), and *"rough and reliable"* (P14), our efforts of making this toolkit simple and easy to use did come with a price as participants noted that they *" would like more options"* (P7). Participants commented on the *"lack of control"* (P4) and *"flexibility"* (P11) the toolkit provided, and compared it to other solutions they had used before, *"another toolkit I have used was a bit more flexible, but was more complicated to learn"* (P2).

However, when participants were asked to create their own new widget, they found this process simple and straightforward, *"it's not a big deal, you just need to get the sensor, connect it and it's good to go"* (P2). Even if participants felt limited by the initial set of widgets or control of the toolkit, the fact that the Tickle Trunk is extendable makes it adaptable to new requirements down the line. One participant commented that *"if I were to constantly do projects with the it I might feel limited"*; however after thinking more about it they said *"I can always just make more"* (P13).

5.2.2 A Tool for Playful Validation and Embodied Discussion. Participants noted that the Tickle Trunk supported the design process: *"I can achieve my complex designs"* (P8), *"I would use it in my research to design interactions"* (P3). All participants were able to achieve brainstorming ideas for their prompts (Table 4). Participants came up with ideas that encompassed from trying small interactions like *"using the flame sensor to activate the temperature box"* (P8) to imagining very realistic combinations like a museum exhibition of a ship where *"based on the direction in which you steer your ship, let's say, you feel the cool wind from different directions"* (P9).

The Tickle Trunk was particularly useful to validate ideas during brainstorming, particularly because of its playful nature. Participants had the chance to try their ideas on the fly and quickly validate whether the interaction was valuable or not: *"you can get to that point very quickly were you can say yes I'll go with this design or not"* (P2). Initially, participants would try out all the widgets and started the brainstorming. After, they would come back to feel the widgets again to spark their imagination. When feeling the sensation again ideas would continue to flow and converge: *"if you play around with it enough you'll find a combination that's valuable"* (P9). P11 also highlighted this playful aspect, noting, *"the more I played*

Table 4: Participants were given the task to brainstorm ideas based on a case scenario of their choosing. Three ideas were selected to showcase the result and list the widgets used during the brainstorm.

Scenario	Brainstormed Idea	Widgets Used (I/O)
Firefighter training	When firefighters arrive at a scene they activate the water hose, a huge force and water comes out. But due to the fire, there is heat in the atmosphere, they feel it in what they're wearing, on their clothes. I think I could imagine. When they're using the hose, the forced back happens with the high pressure (P6).	Turning dial (I) Vibration handle (O) Temperature box (O) Fan (O)
Nature exploration	If we combine the shake sensor and the vibration we can image we are fishing. When you hang out your fishing rod and then sit at the bonfire and wait for some fish to bite and then get some kind of signal through vibration, that as a fish has bitten it. (P2).	Shake sensor (I) Vibration pen (O) Temperature box (O)
Medical and surgical applications	Want to mimic the experience of feeling someone breathing, how lungs inflate and feeling the touch of the tissue. Adding temperature, when breathing in, I feel that my hand gets colder, and by breathing out, I feel it gets warmer. It blows in and out (P1).	Slider (I) Fan (O) Temperature box (O)

around with the toolkit, the more I got a clear sense of what I wanted to achieve."

Overall, the Tickle Trunk made participants curious, *"I wanted to explore ... to feel it ... I wanted to see what they do"* (P13), and gave participants *"a wider perception of haptic possibilities"* (P14). This process was described as *"fun"* (P11), *"entertaining"* (P5), and *"playful"* (P6).

5.2.3 The Power and Challenge of Multimodal Exploration. The Tickle Trunk system was highly praised for its ability to support a broad range of modalities, significantly enhancing the user experience. Participants highlighted the versatility and novelty of the system, with one noting, *"So many possibilities, you can create almost any interaction"* (P3). This sentiment was echoed by another participant who observed, *"You have all these different types of modalities, you have temperature, wind, vibration, and that is really unusual"* (P2). The inclusion of multiple output types was seen as a major advantage, as another participant stated, *"It's good that we have multiple outputs, different types, this boosts the overall experience"* (P1).

The combination of these modalities not only diversified the interactions but also improved the realism of the experiences. One participant explained, *"Experiences are a combination of different senses and this increased the realistic effect"* (P6). Another participant emphasized the immersive nature of the system, sharing, *"When I wanna test haptic experience, I usually close my eyes to somehow neglect the effect of visual feedback. When it comes in, I could really think of breathing in and out about the scenario that I made. This [Tickle Trunk] could really resemble it"* (P1). Although using multiple widgets enabled more complex ideas, some participants found it challenging to grasp more than one widget at a time: *"it is not easy to sense all because of the size"* (P1). Similarly, P11 faced obstacles when attempting to feel multiple outputs, especially when handling both input and output simultaneously: *"I wanted to feel more, but I only have two hands, so it's tricky to feel everything"*.

Unsurprisingly then, some participants found value in focusing on single input, single output, as it *"helped [them] focus on one solution/haptic sensation at a time"* (P12). Handling one widget at a time was found *"helpful for maintaining focus"* (P7), and P13 *"appreciated the simplicity of the single approach"*.

Overall, the multiple modalities aspect of Tickle-Trunk allowed for *"novel ideas, apart from vibration"* (P12), making it a versatile and engaging tool for creating immersive interactions.

6 DISCUSSION

The Tickle Trunk toolkit has shown potential in both in brainstorm diverse physical interactions with mixed-expertise temas as well as simplifying and enhancing the process of designing haptic and tangible interactions for experts . Here, we will discuss the implications of our findings, offering prescriptive insight into the usability and flexibility of the Tickle Trunk. We will also address the limitations identified by participants and propose improvements to further refine the toolkit.

6.1 A Tool for Rapid Haptic Sketching

Our findings show that the Tickle Trunk served as an effective tool for rapid exploration and evaluation of early design ideas, a practice known as haptic sketching [48]. Quantitatively, this was evident in the high CSI score of 88.85 and participants brainstormed an average of 4.6 ideas in just 15 minutes. Our thematic analysis reveals the reason for the success: participants described the process as "playful" (P6) and "fun" (P11), emphasizing the toolkit's value in allowing them to "quickly validate" ideas on the fly (P2) rather than getting bogged down in technical setup. This aligns with the principles of hardware sketching and experience prototype, where low-fidelity tools shift focus to core design questions [6, 22].

It is worth noting the mixed results for the "Realism of brainstormed ideas" in our questionnaire (Figure 7). In the context of this study, "realism" was not meant to assess technical feasibility, but rather the experiential plausibility of the sketched interaction. We were interested in whether participants felt they could create a compelling enough sketch to communicate their idea to a team member. The split in the results likely reflects this ambiguity; some participants may have interpreted the question as being about technical viability, for which a simple hardware toolkit is ill-suited. In contrast, others may have focused on the experiential aspect. This finding highlights a challenge for all early-stage ideation tools: balancing the generation of creative, 'out-of-the-box' ideas with the grounding of those ideas in a plausible user experience.

The approachability of the toolkit was a key factor as one of our main goals (G2) . The hardware-only design, which does not require coding, significantly reduced the barrier to entry. The ease of use was not only reflected in the high scores in the questionnaires for "easy to use" and "easy to learn" (Figure 7), but was also demonstrated in the extensibility task. There, participants could integrate a new component in less than four minutes with virtually no errors (Table 3), a process that a participant described as "not a big deal" (P2).

However, simplicity comes with a price. The trade-off between simplicity and control was a central theme in our findings and is visible in our data. The qualitative comments of the participants about the "lack of control" (P4) and the desire for "more options" (P7) are subtly corroborated by the questionnaire results, where the rating for the "level of control", while positive, was lower than other usability metrics (Figure 7). Importantly, the participants themselves reorganized this trade-off, noting that another, more flexible tool they had used was "more complicated to learn" (P2).

This positions the Tickle Trunk firmly as a tool for the initial, divergent stages of the design process. Using the Tickle Trunk is the equivalent of making quick sketches while brainstorming; as ideas develop, designers will naturally require the higher fidelity and control offered by more advanced hardware [42] or programmable toolkits like Phidgets [18] or Soma Bits [65] for medium-fidelity prototyping. However, we have since made use of the Tickle Trunk for introduction or very rapid prototyping sessions for broad modalities, e.g., for workshops about democratizing haptic technologies [30].

6.2 A Boundary Object for Inclusive Haptic Design

A core challenge in haptic design is establishing a common language for teams of mixed expertise. This was the primary challenge that inspired this work, where initiatives like the DOHR project required storytellers, restorative justice scholars, and engineers to find common ground on sensitive historical topics [39]. Our findings further extend our previous work [29] to suggest that the Tickle Trunk on its own can addresses this need by enabling the creation of tangible artifacts that function as boundary objects [60]. The ability of the participants to explore a wide variety of modalities, in addition to vibration (P12), and to quickly connect new widgets in minutes meant that the entire team could engage in a shared physical dialogue. Simple physical widgets become shared artifacts that the engineer, designer, and storyteller can all understand from their own perspective, grounding their conversation in a collective, embodied experience. This process supports what Hummels and van Dijk call embodied sense-making [24], where a team builds understanding through shared physical action. By facilitating the rapid creation of tangible boundary objects, the toolkit helps democratize the design process, enabling individuals without specialized technical skills to actively participate in haptic ideation [33].

6.3 Implications for Designing Haptic Brainstorming Tools

Based on our findings, we propose three key implications for the design of future toolkits intended for early-stage haptic exploration. First, prioritize the speed of iteration above all else. Our study confirms that for brainstorming, the ability to rapidly test and discard ideas without technical interruption is paramount. The success of the Tickle Trunk's hardware-only approach suggests that designers of similar tools should aggressively minimize setup time, removing barriers like coding or complex software configuration that can stifle creative flow. Second, provide a broad, not just deep, haptic palette as discussed in our goal to make the toolkit expressively diverse. Participants consistently praised the ability to explore modalities "apart from vibration" (P12), which expanded their "perception of haptic possibilities" (P14). This suggests that to build a team's shared haptic vocabulary, it is more valuable for a brainstorming toolkit to offer a wide variety of simple sensations than to provide deep, complex control over a single modality. Finally, design for open extensibility from the start. Our findings show that participants not only valued the diverse set of widgets but also easily extended the toolkit themselves. Since no single toolkit can contain every possible sensation, a successful brainstorming tool should be built on an open and simple architecture that empowers teams to add new, custom components to suit the specific needs of their project.

7 LIMITATIONS AND FUTURE WORK

Although our study further demonstrated the Tickle Trunk's potential, we recognize several limitations in the current prototype and our evaluation, which point toward areas for future work.

7.1 Limitations of the Toolkit

A key limitation is the toolkit's deliberate simplicity. While the hardware-only design makes it accessible and easy to use for rapid brainstorming, it restricts the complexity of interactions that can be explored. As we discussed, it is a tool for early-stage sketching and is not intended to support medium- or high-fidelity prototyping, which requires more advanced control, e.g., through software.

Furthermore, the physical form factor of the current prototype presents challenges. As noted by a participant, the widgets are somewhat bulky ("it is not easy to sense all because of the size" (P1)). This can make it difficult to manipulate multiple widgets at once and may hinder the exploration of more complex compositional interactions. Finally, our evaluation was based on a curated set of 14 initial widgets. While the toolkit is extensible, the specific nature of this starting set inevitably framed participants' brainstorming processes.

7.2 Limitations of the Study

Our evaluation was conducted as a lab-based study with individual participants. While this allowed us to assess usability and individual creativity, it did not allow us to observe the toolkit's use "in the wild" on a real, long-term design project. In our own use of the toolkit in our longer-term design project, we found it was valuable for an initial meeting, but less useful as we developed medium-fidelity prototypes. While our mixed-expertise team members were not able to meet frequently, our initial meeting established enough of a shared vocabulary and trust that the larger team was able to delegate finer design decisions to the HCI and haptics team members.

Furthermore, while the Tickle Trunk was designed with the goal of supporting mutual learning and collaborative brainstorming, the present study did not evaluate its use within a group setting. This was a deliberate methodological choice; we wanted to complement our previous investigation into a group setting [29] to examine the tool as a standalone ideation tool, with a focus on learnability, usability, and extensibility. A single-person study helped us target those questions.

Finally, there are some limitations in our study sample. For example, participants were generally younger (under age 35), as we focused on diversity in disciplinary background.

7.3 Future Work and Opportunities

Looking ahead, we see several directions for this work. The most immediate solution is to address physical limitations through miniaturization, creating more compact and easily graspable widgets. We also plan to expand the open-source library of widgets, exploring a "kitchen sink" approach with many general options, as well as developing tailored widget sets for specific domains.

This points to a broader opportunity to customize the Tickle Trunk for non-experts beyond engineering and design. For example, a toolkit could be created for artists exploring expressive materials, for therapists designing sensory interventions for clients, or for educators teaching complex scientific or engineering concepts in a hands-on way. Our ongoing work with the DOHR project shows the potential impact of extending haptic and tangible interaction to a community-driven research context where we could not rely on frequent, in-person meetings and iteration. In this case, we have started to learn how to design haptic and tangible interaction feedback in a way suitable for engaging with difficult knowledge. By continuing to focus on a low-barrier, high-impact platform, we hope to support an ever-growing range of creative and exploratory applications; we are actively developing new kits for our future co-design projects and hope to report on their use in the future.

8 CONCLUSION

The Tickle Trunk is a hardware-only toolkit for exploring a wide range of haptic and tangible interactions. We found the Tickle Trunk showcased potential as a playful and easy-to-use toolkit for exploration and brainstorming for physical interactions. The participants enjoyed its wide range of tangible and tactile options, intuitive interface, and user-friendly nature, which allows a quick understanding of functionalities and the generation of creative ideas. Tickle Trunk's adaptability and ease of extension also left participants eager to explore future possibilities. Overall, this study demonstrates that Tickle Trunk holds promise as a tool to inspire any user to explore and create new physical interactions. Designing haptic experiences is a challenge for mixed-expertise teams that lack a shared embodied language. This paper introduced and evaluated Tickle Trunk, a hardware-only toolkit aimed at lowering this barrier by supporting rapid and playful haptic sketching. Our user study was designed to answer three key research questions, and our findings demonstrated that the toolkit (RQ1) is easy to learn and use, and participants find it intuitive and simple. We found that it effectively (RQ2) supports creative brainstorming, with participants generating numerous ideas and using the physical widgets as boundary objects for discussion. Finally, we confirm that the toolkit is (RQ3) readily extensible and that users can successfully add new components in under four minutes. The primary contribution of this work is a validated open-source platform that prioritizes speed of iteration and a broad haptic palette for crucial early stages of design.

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