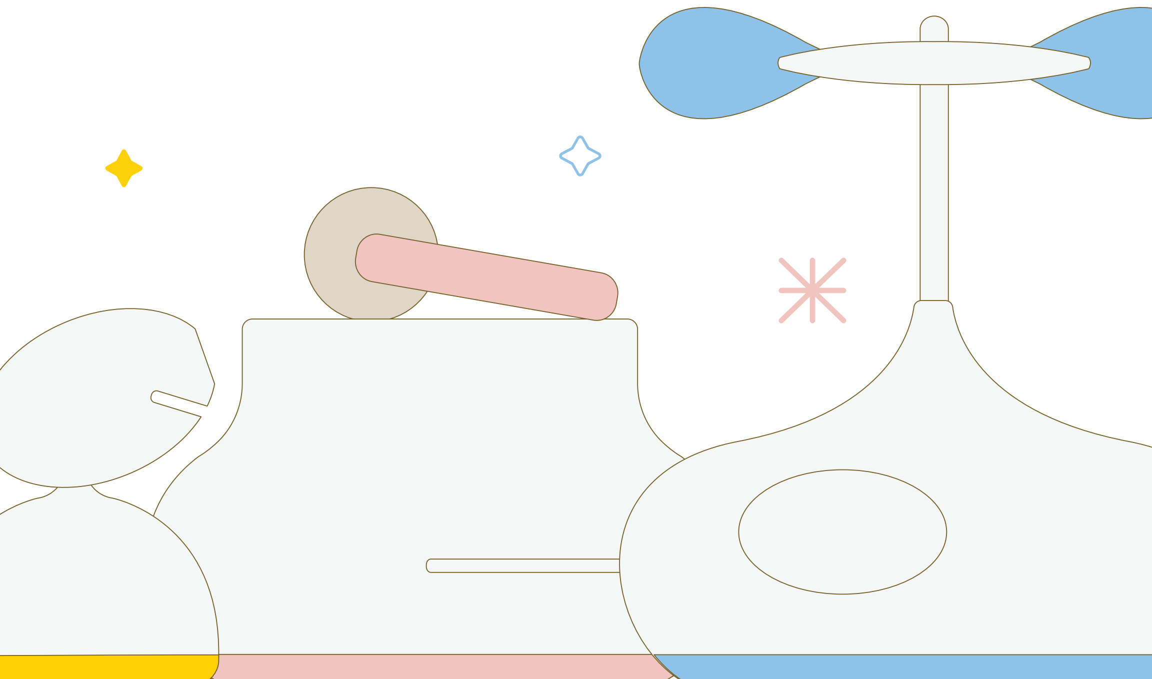
Poetic Technologies

Rethinking design paradigms around technology

Benal Johnson



Poetic Technologies
by
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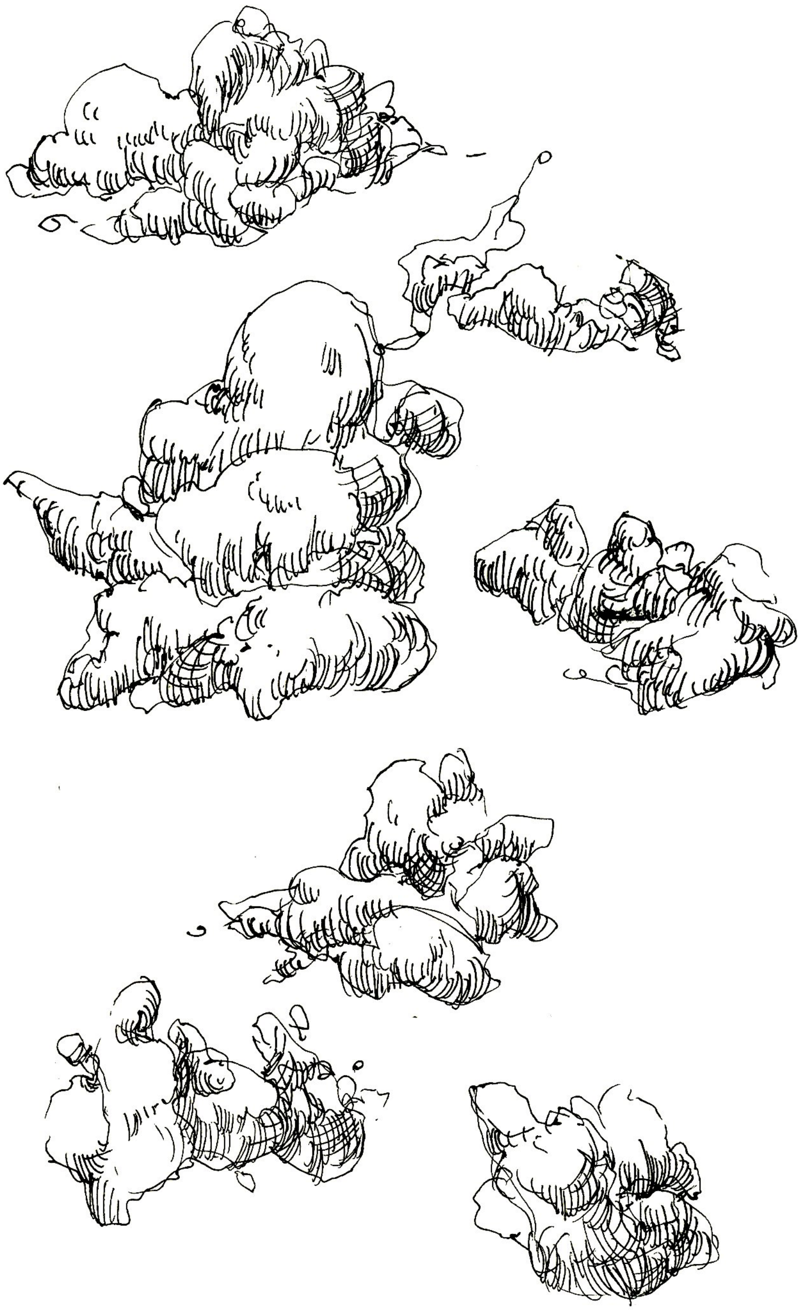

"The first encounter with any physical medium —— pencil dragging on paper, a lump of clay squeezed, a chunk of wood hefted in the hand —— starts us on a journey. Thoughts and feelings that come to mind are already entangled with the tacit, embodied knowledge we carry in our bodies, and in the material at hand."

Christopher Bardt

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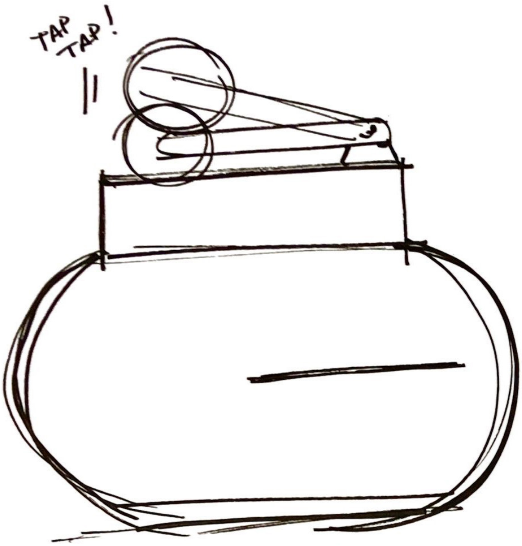
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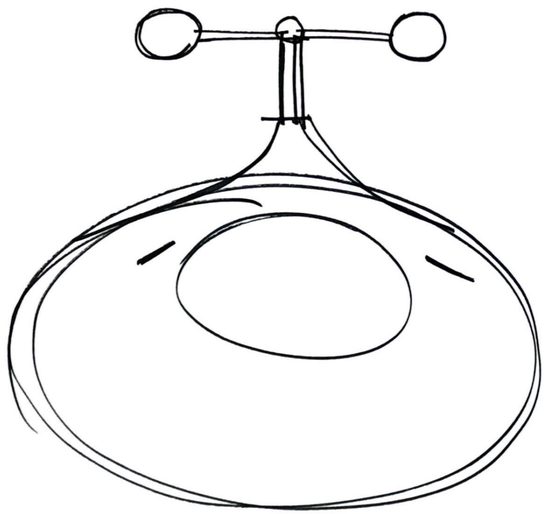
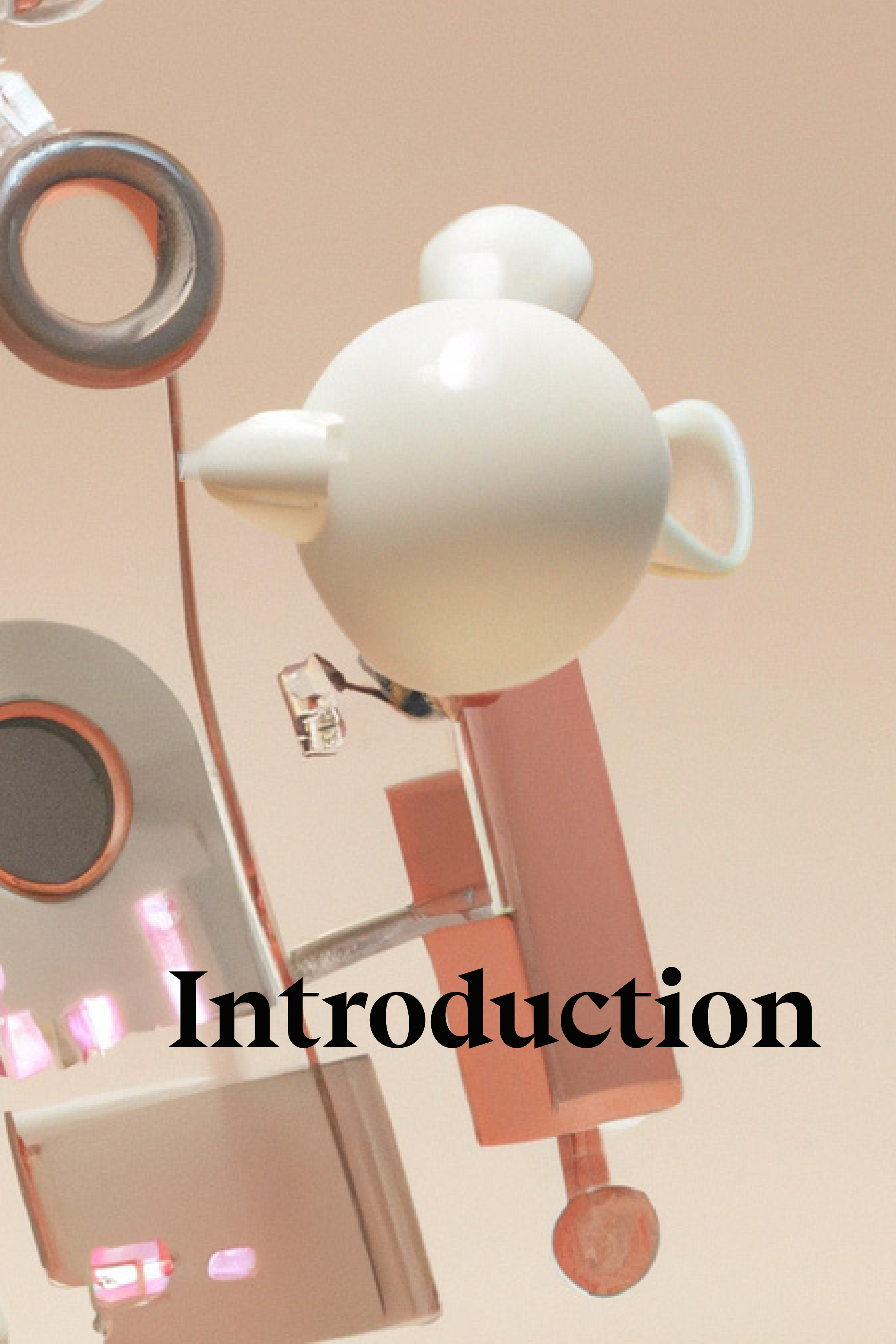



SWIVEL

Abstract

The variety of design decisions around interfaces, contextuality, and emotion in current smart home technology leaves a case for exploring how they could be designed differently. This thesis examines a new paradigm of interacting with technology in which devices are designed contextually, expressively, and with tangible and embodied methods of control. These themes are explored in a case study and speculative design in which three smart home devices are redesigned to express their personalities through form language, physical actuation, and embodied methods of control. Each device lives in a distinct context in the home - the bedroom, living room, and bathroom - and has a practical function that matches with each context.

Spray painting stage of the final 3D printed models.



Introduction

Introduction

The majority of consumer technology devices available on the market are designed with a technology-first mindset. For example, current home smart devices, such as Google Nest Hub and Amazon Alexa, utilize a combination of Graphical User Interfaces (GUIs) and Natural User Interfaces (NUIs) as their methods of interaction due to their novelty and not necessarily their usability. GUIs refer to screen-based interfaces while NUIs in the consumer product context typically refer to the use of multi-touch interaction, voice UI (VUI), and gesture based controls. NUIs and GUIs make assumptions about what is "natural" to users, claiming that these new methodologies and technologies are easy to adopt and learn when in actuality they introduce new complexities (Norman 6). Gesture-based controls are neither easy to learn nor natural, discarding any notion of cultural context in their interactions (Norman 7). Additionally, VUIs require a high cognitive load to interact with, especially with complex tasks (Miller 1). With regard to home smart devices, there is a distinct momentum away from tangible methods of interaction or physical interfaces on these devices, partly due to the claim that physical interfaces cannot handle the complexity of tasks that Internet-of-Things (IoT) devices are capable of (Scutt). Yet, work done by Donahue, Frens, Vianello, and Zuckerman show not only the ability of tangible user interfaces to adapt to the complexities of IoT commands, but also the preference and ease of use of physical interfaces over NUIs and GUIs (Donahue; Frens; Vianello; Zuckerman).

Beyond the issues of a technology-first approach, existing home IoT make compromises in several other areas of their design. One such area is its overall complexity; combining multiple tasks in a single device has consequences around its usability and ability to contextualize tasks. Placing a wide variety of context-agnostic actions into one device is most certainly an attempt to create a one-size-fits-all smart home product that captures the majority of the consumer market. This is an odd choice in light of the benefits of context-aware computing in anticipating user needs; if anything, creating a set of devices that are contextually relevant could improve usability with smart home devices (Laput 4000). Another design consideration that is

Google Home by Google.

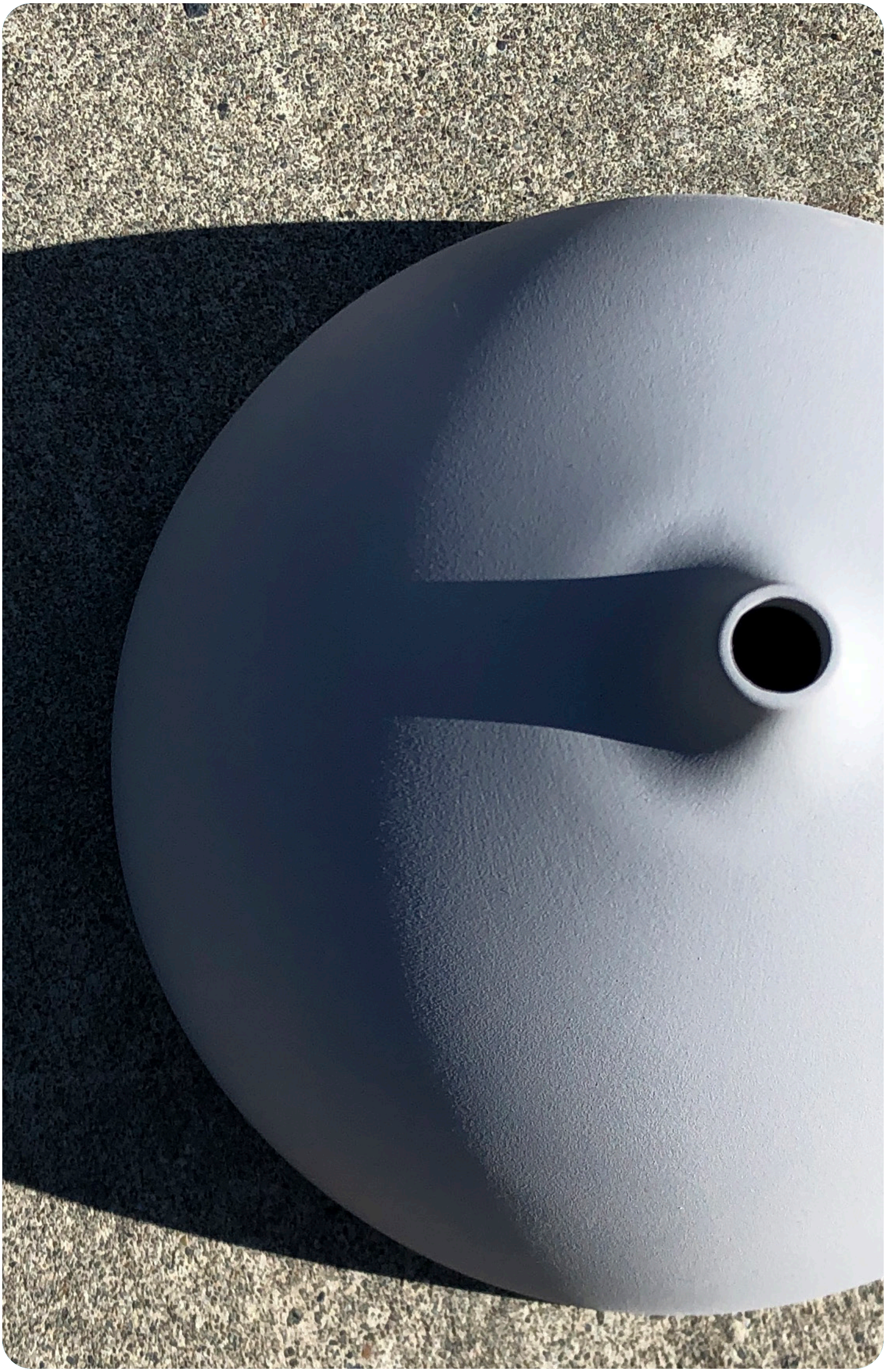
emphasized with IoT devices is its unobtrusive and simple branding (Woo). They are meant to be tools that live in the background of your daily life, put out of sight until needed. When we invite technology into a space as intimate as the home, why are they marked as just a tool and not a companion? There is potential to imbue these devices with a rich sense of expression and personality to build our relationships with these devices. Research done by Whittaker et. al. shows that imbuing robotic or smart devices with expression and personality promotes user acceptance and trust, yet this insight is not integrated on a consumer scale (Whittaker et. al., 1). Existing studies around personality in smart home devices focus on combining existing IoT devices with personality, rather than a full redesign of its physical appearance or movements (Menneken et. al., 123).

The variety of design decisions around interfaces, contextuality, and emotion in current smart home technology leaves a case for exploring how they could be designed differently. This thesis examines a new paradigm of interacting with technology in which devices are designed contextually, expressively, and with tangible and embodied methods of control. These themes are explored in a case study in which three smart home devices are redesigned to express

Introduction, *cont.*

their personalities through form language, physical actuation, and embodied methods of control. Each device lives in a distinct context in the home - the bedroom, living room, and bathroom - and has a practical function that matches with each context.

To execute this case study, a four phase approach was used. First, contextual inquiries were conducted with participants to uncover the routines in their daily lives to determine appropriate contexts in which to design an expressive IoT intervention. Second, low fidelity prototypes and interaction models were made in response to the needs uncovered in the preliminary interviews, ensuring they fit into appropriate contexts in the home. Third, a framework was created to match IoT devices with distinct personalities and practical actions within their given context in a person's routine. Finally, high-fidelity prototypes were fabricated using a variety of tools and filmed in a narrative format that brings both their interaction and sentimentality to life. With regard to the limits of this work, the short time frame to execute this is the biggest limiting factor. To balance the tradeoff of time and final quality of work, secondary research will not occur after the high fidelity prototypes are created in order to dedicate the most time for design and fabrication. In addition, there will be a limited set of expressions per device due to the scope and time to execute. The impact of this work will ideally challenge existing paradigms around what it means to interact with technology and to think about new possibilities of interactions beyond what is considered the norm.



Early prototype of final model

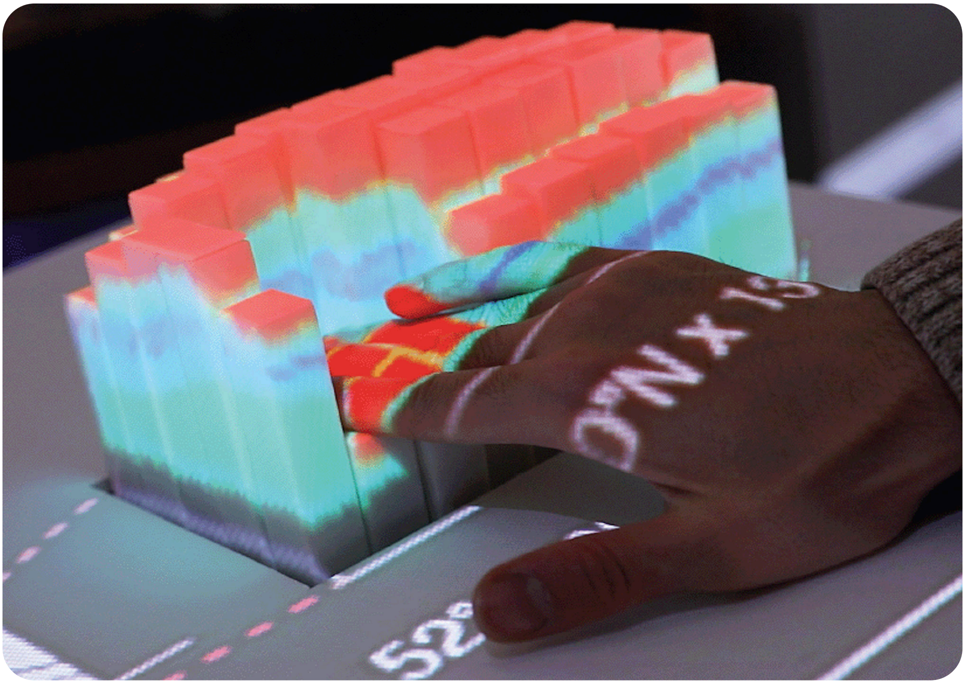
History & Prior Art

Defining the domain and historical context

History and Prior Art

Ubiquitous Computing and Natural User Interfaces in the Modern Age
Over the past few years, great strides have been made in incorporating aspects of Natural User Interfaces (NUIs) into Internet-of-Things (IoT)-enabled consumer products. NUIs seek to move beyond the basic interactivity of Graphical User Interfaces (GUIs) provide by incorporating more "natural" user inputs and outputs, focusing primarily on gesture-based interaction, but also incorporating things like voice, multi-touch, and tangible manipulation (Mortensen et al; Seow et al). Consumer products such as Google Nest Hub integrate specific hardware to enable gesture-based interaction on top of its existing Voice User Interface (VUI) and GUI, creating a product that is capable of several different modes of interaction (Wang et al). NUIs take their inspiration from the seminal work from software engineer and Xerox Parc CTO Mark Weiser in his paper, The Computer for the 21st Century. In this work, Weiser defines a new mode of technology interaction as "ubiquitous computing" (UbiComp), where technology is not locked behind an interface, but embedded in the fabric of our everyday lives and is both ever-present and invisible (Weiser 1). He further expands on this work in The Coming Age of Calm Technology in which he claims our relationship with technology and ubiquitous computing should be calm, claiming "both the center and the periphery of our attention, and in fact [move' back and forth between the two" (Weiser 3). Weiser's new mindset for interacting with technology pushed the boundaries of the Human-Computer Interaction (HCI) field, introducing new ways of considering how computing systems worked. A modern proxy for ubiquitous and calm computing is most certainly the emergence and continued development of IoT devices (Andrade et al).

Examining Tangible Methods of Data Manipulation
In tandem with the development of the UbiComp field came the creation of the new field of Tangible User Interfaces (TUI), which both criticized and augmented UbiComp ideals. TUI argued that interactions with technology should leverage the natural way in which humans physically live and interact with the world by taking advantage of "natural physical affordances to achieve a heightened legibility and seamlessness of interaction between people and



Example of Tangible User Interface from MIT Media Lab

information" (Ishii 1). TUIs aimed to couple digital and physical space through direct control and manipulation of "tangible bits" of data (Ishii 4); TUIs could take advantage of the interconnected nature of UbiComp, yet still remain easily manipulatable and visible to the user. One critical aspect of TUIs is the coupling of computational manipulation via physical manipulation; the direct linkages between the two mean that the leveraging of tangible affordances can teach us about a system's interactivity (Ibid). The sensory feedback that tangible user interfaces provide, such as haptics, detents, etc, allow us to have direct and timely information about a system of state without the need for visuals or sound. In a study conducted by Israel et. al. on the intuitiveness of TUIs, they point out that "the affordances of physical objects are often highly apparent and many physical manipulation skills are highly learned and automated by the user" (Israel et. al. 5). In short, TUIs allow for 1:1 couplings between physical and digital experiences, increasing the affordance and comprehension of an experience.

Critiques of Ubiquitous Computing and Natural User Interfaces

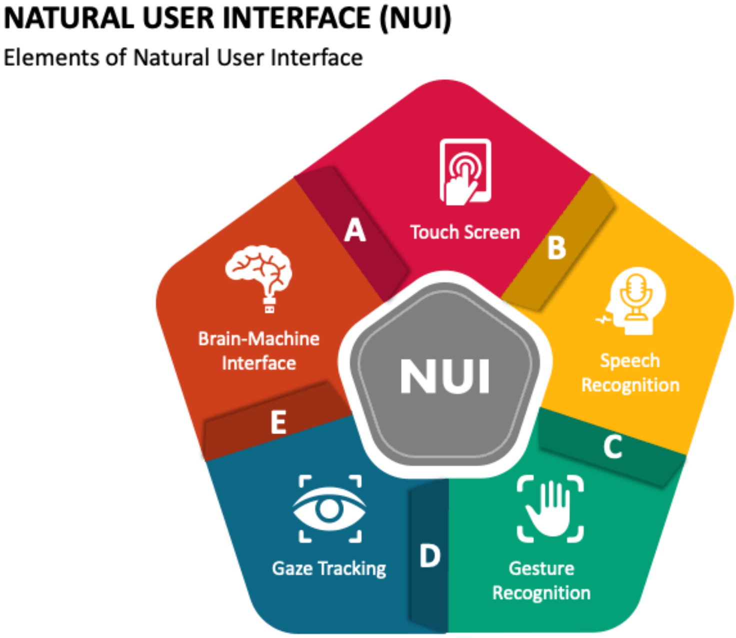
There are several other criticisms around the field of UbiComp and the use of NUIs. One piece of strong criticism of NUIs and ubiquitous computing

History, *cont.*

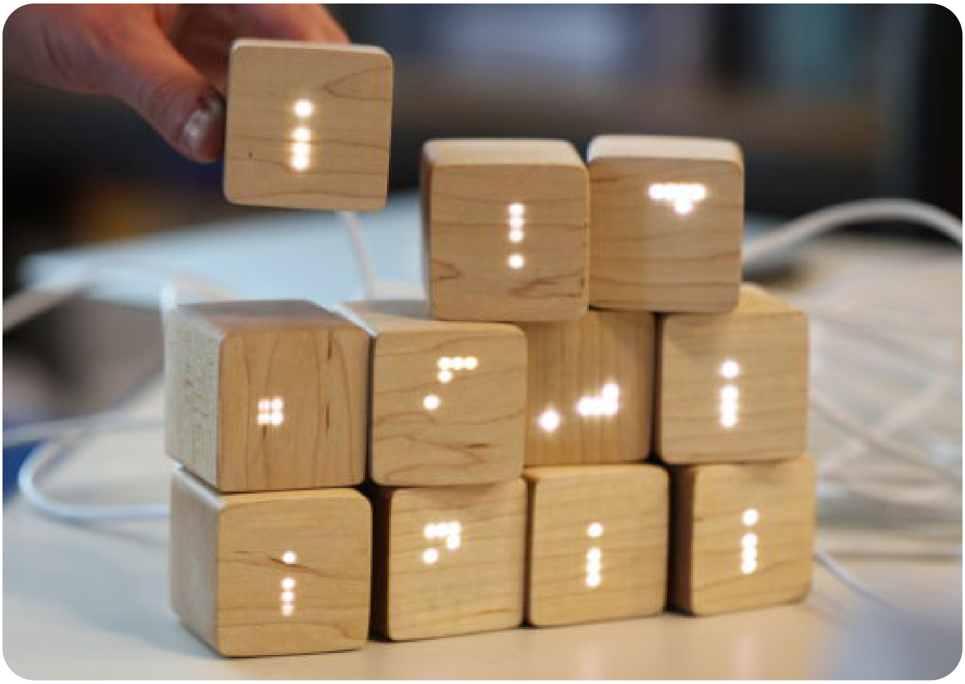
is the inherent lack of feedback from the system; they often rely heavily on the VUI and GUI to communicate any state changes, which can often be confusing to users (Esau et al). NUIs especially can be lacking in this regard as they are primarily gesture-based systems, so there is an ephemeral quality to them; it is hard to capture their "history" and it is also a challenge to give a user feedback (Norman 5). When systems are invisible and seamless, it makes it especially challenging to see the information being passed through the system (Inman and Ribes). In addition, the lack of any physical interaction leaves much to be desired with these invisible systems. In research done by Donahue et. al. on the overall efficiency of complex problem solving via touch or tangible user interfaces, they found that tangible user interfaces were far more efficient than problem solving via touch interfaces (Donahue et. al. 1). In a study from Zuckerman et. al., they found that users preferred a TUI to a GUI interface in a situation involving modeling and simulation primarily due to the "high levels of stimulation and enjoyment [from] physical interaction, rich feedback, and high levels of realism" (Zuckerman et al). NUIs that control devices and their states in the home disregard the value of a physical interface; they compromise physical interfaces within the home. Gestures and VUIs might be able to power on and off a device, but they do not physically flip switches and they even compromise the usability of these physical switches themselves. Physical interfaces use knobs, switches, and buttons not only to control devices, but also communicate the states of these objects - on/off, medium heat, etc. NUIs tend to override the benefits of physical interfaces by using stateless and programmable hardware over traditional hardware or providing feedback strictly through VUIs or GUIs. These drawbacks to NUIs limit the usability and comprehension of IoT and connected devices that use this technology.

Slow Technology as a Challenge

With the ever increasing prevalence of technology and the drive towards ubiquitous, seamless, and fast modalities of interaction with technology came the emergence of the field of slow technology. Slow technology affirms a relationship with technology that is reflective, emphasizing the quality of



Examples of Natural User Interfaces from Sketch Bubble.



Slow Game by Will Odom, an example of slow technology.

History, *cont.*

interaction over the efficiency of the interaction (Halnås and Redstrom). In research carried out by Grosse-Hering et al, they examine new principles for the creation of slow design-informed technologies that promote meaningful interaction, pointing out that wellbeing of people is the primary motivator of the slow design movement in general (Grosse-Hering et al). They point out interactions that promote “mindfulness and consciousness” tend to improve relationships with the product being interacted with and have a positive side effect of social interaction; users in this study valued slow technology informed interactions far more when they were executing them for a loved one or family member (Grosse-Hering et al). Existing interactions with home IoT devices tend to emphasize efficiency above all else, limiting opportunities for intentional and meaningful interaction with these smart devices. Slow technology also informed the concept of emotional durability (Chapman), a term coined to emphasize designing for relationship building between people and objects. Emotionally durable design encourages this relationship through creating objects that allow for emotional imprinting through features such as patina development, intentional wear, and manifesting historical use.

Technology and Personality

Another axis of relationship building between people and objects comes in the form of imbuing technology with personality or expression. In a study by Mennicken et. al. on the perception of personality in smart home devices, a set of existing IoT devices (Roomba, Phillips Hue Light, Xbox Kinect) are paired with certain actions (speaking, turning lights on) to imbue the home with a certain set of personalities (Mennicken et. al. 124). This study found that participants perceived certain actions, such as the home telling you “have a nice day” to be disingenuous and forced, but claimed energetic and positive personality traits in the home “make the home much more lively” (128). This study relied heavily on voice UI and lighting to communicate personality traits; they did not explore imbuing actual designed objects to communicate with users, which led to overall discomfort in participants’ experiences with this smart home (129). When it comes to incorporating physical devices with personality through movement and actuation, research

iRobot's Roomba via Wirecutter.

shows that people generally form stronger attachments and higher levels of trust with the objects and devices they interact with (Forlizzi et. al., Li et. al.; Whittaker et. al.). This is especially important with regard to robots designed for intimate and social space; in an ethnographic study by Forlizzi et. al. on social connections with home robotics , the authors noted that participants felt emotionally attached to their Roomba, going so far as to name it and assign a gender to it (Forlizzi et. al. 125). Forlizzi et. al. concluded that "when simple social attributes are part of the design of robotic products and systems, people may adopt them more readily and find them less stigmatizing" (125). When human movements and gestures are incorporated into robotics, people more readily understand their communication patterns (Hsieh 224).

Examples of New Paradigms for Interactions with Technology
There are several contemporary works from individuals, organizations, and researchers that touch on new modalities for interaction with technology, specifically investigating designing for expression, tangibility, and contextuality. Google's "Little Signals" experimental project (Fig 1) examines a new pattern of communicating information using the principles

History, *cont.*

of ambient and calm computing, imbuing a set of six unique IoT devices with subtle and physical notifications (Little Signals). Although these devices are physical, they do not incorporate any personality traits into each device; they are meant to be unobtrusive and in the background of the daily lives of users (Google). A similar experimental project that focuses primarily on the use case of checking the weather comes from Uniform Group's Weather Systems (Fig 2)(Uniform Group). A set of three devices communicate different information about the weather through physical actuation, whether it be mimicking the sound of rain, the strength of a breeze, or the physical temperature (Uniform Group). These devices express and visualize data using physical displays, yet are still in the same realm of "calm and unobtrusive" devices like that of Google's Little Signals (Uniform Group, Little Signals). Both of these projects do not incorporate expression and emotionality into their designs and emphasize technology as an unobtrusive tool.

A project that does examine the emotional aspect of physical interfaces comes from Hayeon Hwang's Expressive Tactile Controls project (Fig 3) (Hwang 223). Hwang experimented with imbuing several buttons with different personalities expressed through physical actuation such as "shy" or "impatient" to potentially improve human interactions with interfaces and technologies (223). The concepts put forth in this work have the potential to be explored further in a variety of case studies, as this work primarily focused on the creation of these interactions and not their integration into a product. A consumer product that incorporates many aspects of expression with technology is Cozmo (Fig 4), a toy robot with a curious and mischievous personality that teaches children how to code with Scratch (Digital Dream Labs - Cozmo). Cozmo utilizes a variety of sensors, machine learning models, and contextual actuation to communicate and express its personality (Pierce). Cozmo's manufacturer Anki Labs received critical acclaim and over $182 million in funding, showing the promise for "intelligent consumer products" in general (Azevedo and Rowley).

Fig. 1: Little Signals by Google.

Fig. 2: Weather Systems by Uniform Group.

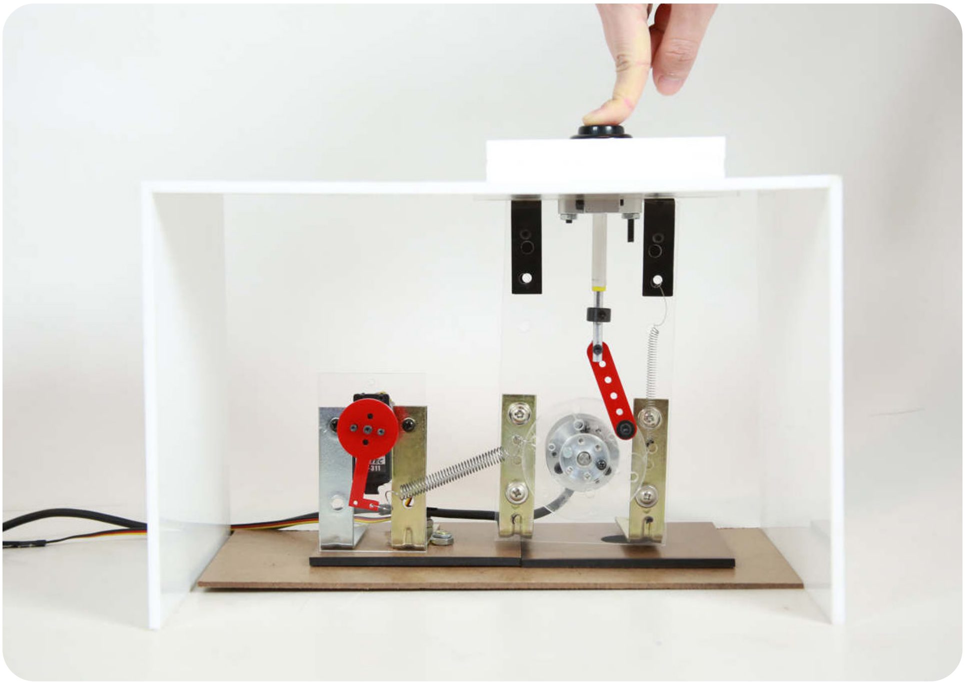


Fig. 3: Expressive Tactile Controls by Hayeon Hwang.

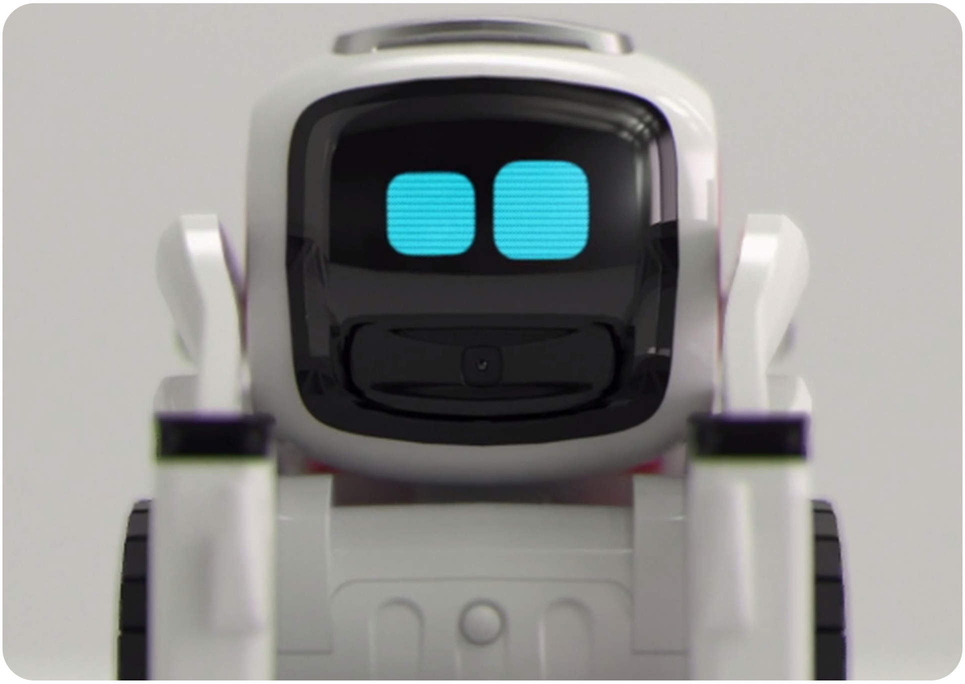


Fig. 4: Cozmo by Anki Labs.

History, *cont.*

Areas of Opportunity

Each of the projects and works of research mentioned look deeply into a few aspects of interactions across a range of technology from toys to smart devices. However, none of these projects combine expression, physical interaction, and actuation with smart home devices. There is a clear paradigm set forth by current projects in the smart home space in that they should be invisible and unobtrusive, focusing far less on adding personality or emotionality into the home (Little Signals, Uniform Group). The critical success of Cozmo, as well as the research demonstrating increased human trust and acceptance with devices and robots that express personality, leads me to believe that there is an opportunity to have more emotional and expressive interactions with certain home technologies.

Motivation

Why this? Why now?

Rewinding a tape with a pen by Allan Hazle. How can the whimsical nature of the technology of the past inform the future?

The resurgence of mechanical keyboards points to an increasing desire for tactility in our technology. Photo by CNBC.

Motivation

This project aims to challenge existing norms and future predictions around interactions with technology, arguing that we may leverage the interconnectivity and computing power of technology while combining it with human emotion, contextual appropriateness, and tangible interaction. At present, we primarily interact with technology in our day to day behind GUIs and NUIs through our smartphones, computers, and home smart devices. Smart devices especially are these monolithic hubs designed to be clean and ultramodern, utilizing only the most cutting edge technologies to enable their interactions. Yet, why do they have to be designed in this way with these specific interaction modalities? The importance of technological advancement is separate from its usability; many companies have confused the two, making the assumption that continued advancement in UI and GUI is the way forward. Why have contemporary smart home or IoT devices shed any elements of tangible interaction in favor of interactions behind a screen, a gesture, a voice UI? I believe that current paradigms of technology usage set forth by large tech companies have adopted an implementation strategy of "technology for technology's sake" mentality. This mentality does not consider the richness and ease of use of a physical interface, nor does it consider how humans interact and live in their daily environments. In addition, most home IoT devices are agnostic to their context; they condense the full breadth of their complexities into a single device that is meant to work appropriately in every context. The design of modern smart home devices do not take into account that people behave differently in each context and that their rhythms and needs change in every space. They also certainly don't take into account the value of human emotions in everyday interactions; we are emotional, social creatures who feel and experience things and I find it strange that most technology seems to ignore that.

With this thesis body of work, I intend to subvert the existing mentalities around home smart devices to paint an alternative picture of our interactions with technology around the home. What could it look like if our home smart devices were contextually appropriate, emotive devices that had rich physical interfaces? How would that change our dynamics and relationships with

Motivations, *cont*

technology? How could they offer an alternative reality in which people felt delighted by their interactions with their home devices, which supported them in their daily rhythms and routines instead of offering frustrated, singular interaction modalities? These are just some of the questions I hope to pose in this body of work. THis work draws upon themes of slow technology, tangible user interfaces, and even emotionally durable design; it most certainly is a thesis that fits into the world of HCI research and challenges the norms around emerging technologies. I want to offer an alternative thought process to existing dull and monotonous interactions with technology to offer a more humanist view on what these interactions could look like. I hope to accomplish this through the creation of an ensemble of devices that promote poetic and reflective interactions with technology across multiple emotional and physical touchpoints in the home. These devices will be hosted in an immersive exhibit that will invite viewers to physically touch, feel, and observe these pieces to understand what new paradigms of interaction with home technologies could be.

Methods

Methodology and Approach

Methods

In this body of work, a multi-phase and multi-modal approach was used to uncover related work, comprehend peoples' motivations, and fabricate the final deliverables.

Phase 1: Understand and Uncover
The first phase focused heavily on understanding the research and existing landscape that the project falls within, as well as uncovering the shortcomings and gaps that emerged from the research. In this phase, I to conducted a thorough literature review of HCI papers and other peer-reviewed articles that are adjacent to the fields relating to my thesis. I examined papers across ubiquitous computing, calm technology, and tangible user interfaces to discover the types of projects and work that had been done in this area. In addition, I reviewed related projects in these fields to not only see what had been done so far but also identify areas of opportunity in the existing work. All together, this phase solidified my understanding of the confluence of these different disciplines and topics to determine my project's contextual relevance.

Phase 2: Scoping and Thesis Refining
This phase took the learnings from phase 1 to scope down my thesis and identify its desired impact. I socialized my thesis with both peers and cluster advisors to understand different perspectives I may not have originally considered to flesh out the full breadth of this work. I reflected on and reframed my thesis as I continued researching related work that identified other areas of opportunity. By going broad, I then could make decisions that helped to narrow down my thesis to a more manageable and actionable scope that asks a specific set of questions.

Phase 3: Field Research + Interaction Prototyping
With the scope of the thesis further identified, I did field research to identify the exact location and context that the tangible deliverables can reside in. I performed a mix of contextual inquiry and empathy interviewing to identify participants' likes, dislikes, and challenges around technology in the home.

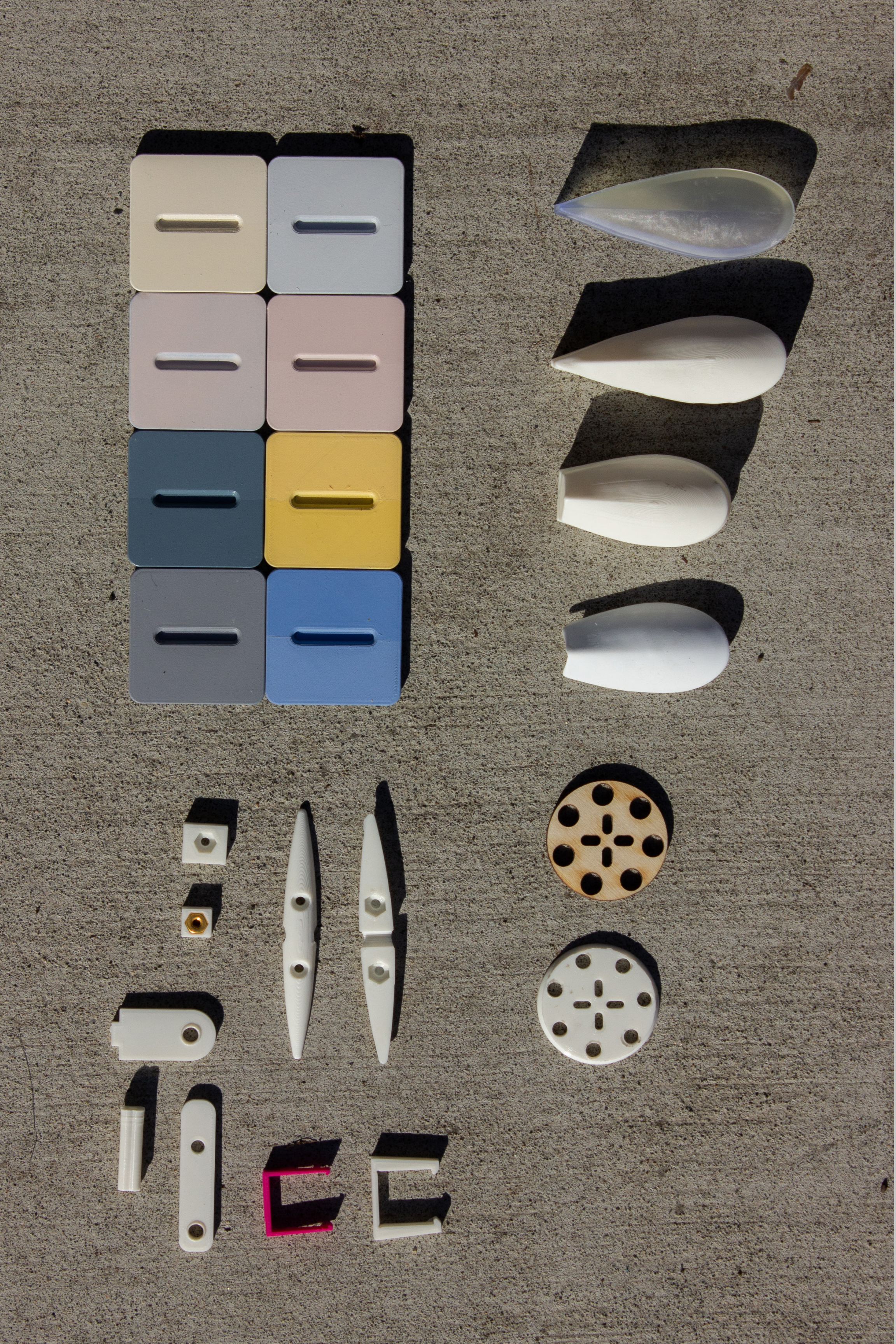
Contextual inquiry helped me to see the tacit and unsaid interactions that empathy interviews might not be able to uncover. Parallel to the field research, I created a variety of interaction prototypes that showcased a variety of ways that users might interact with smart home technology. This helped to identify novel ways of creating embodied interactions with technology.

Phase 4: Concept Finalization
With the insights from field researching and interaction prototyping, I finalized the concepts for the tangible deliverables in order to start designing and fabricating the pieces. Each tangible deliverable drew upon the field research done to set an appropriate context and have a distinct set of interactions.

Phase 5: Fabrication and Finalization
In this Final Phase I designed and made each piece using a variety of fabrication methods and techniques. I 3D modeled each tangible deliverable, fabricating them on a combination of SLA printing and 3D printing. I leveraged Arduino combined with a variety of sensors and motors to bring actuation to each piece. I also shot a narrative video that showed the interactions with each device in context to bring the story of their interactions to life.

Process

Fabrication and Iteration



Process

Literature Review

In the process of doing this work, I went through several initial iterations of theses before settling on my final idea. I started off by considering how calm technology and ubiquitous computing could be made more tangible, but realized that it wasn't really making a commentary on existing technology. I originally started down the path of changing relationships between people and their phones, but quickly realized my passions lied around IoT devices and smart home technology. I specifically wanted to highlight the importance of an embodied interaction with technology and the potential relationship that could form between people and their assistants. I wanted to point out the shortcomings in the design of existing smart home devices in that they do not emphasize any tangible interactions, and the interactions they do employ remain overly complicated and not human-centered. I started off with a thorough literature review of the fields touching my thesis, such as ubiquitous Computing, slow technology, IoT devices, and tangible user interfaces with IoT devices.

Further Scoping and Contextual Inquiry

Further discovery around related work and other peer-reviewed journals led me closer to the thesis that I wanted to explore: creating contextually appropriate IoT devices that had rich tangible interactions. I conducted a set of contextual inquiries and empathy interviews with peers to understand the different contextual rituals and routines people conducted in their day-to-day. Through this inquiry, I discovered an overarching theme of human rhythms - people might not have a set routine or ritual in their daily lives, but it followed a certain ebb and flow. I identified these rhythms as waking up, getting ready, leaving, coming home, and winding down. In a follow-up interview with the contextual inquiry participants, people classified their relationship with technology as one sided; they relied heavily on it to accomplish tasks and communicate with others, but didn't enjoy their reliance on it as a medium. Participants also mentioned that they enjoyed the experience of an embodied task, such as writing a to-do list on Post-it notes or paper, far more than its digital equivalent, such as typing a to-do list in a Notes app.

Process, *cont*

Subject Matter Expert Feedback

I presented my thesis and subsequent progress and contextual inquiry findings to my cluster advisor, Dr. Will Odom, an expert researcher on the field of tangible interfaces, slow technology, and home/domestic technology. He provided helpful feedback around the outcome of this work: namely, that I should consider what I wanted people to uncover about themselves and how they might reconsider their relationship with technology today based on engaging with my work. This made me focus more on the emotional angle of smart home devices – namely, the lack of any sort of expression in these devices. I realized that there was an opportunity to build relationships between people and the technology they keep in their homes, while also affording a tangible interaction.

Low Fidelity Prototyping & Second Feedback Cycle

From here, I started experimenting with a series of low-fidelity prototypes to explore different modes of interacting with technology. I made one controlled with wind, one that required the user to tilt it, and even one that was reminiscent of a marble run. I also socialized some of my prototypes and overall conceptual framework with professionals and professors alike. I spoke with Helena Scutt at Synapse Design Studio about this work, as she was the primary mechanical engineer behind a project focusing on IoT controlled reactive physical control interfaces. She gave me a lot of great insights on how to actually actuate these devices. I also spoke with Kuan-Ju Wu, one of my professors in design. He encouraged me to think about these devices from an object-oriented lens to help flesh out their personalities and sentimental nature instead of thinking about how I wanted to make users feel through these devices.

Storyboarding and Final Scoping

I decided to just focus on three of the rhythms/contexts I discovered in my contextual inquiry due to the limited time to execute this work: getting ready, leaving/coming home, and winding down. I started mapping out different interactions that people might have with these devices, as well as

In-progress primed and painted parts for the final models.

Process, *cont*

considering how these objects' personalities might manifest in actuation. I storyboarded how each device and its context might shape its personality. For example, a device designed for waking people up might be groggy or sleepy in the morning; it may require "a gentle nudge" to wake it up. To get an outside perspective from someone with experience in this space, I connected with Gaetano Ling, designer at Google Seed Studio who worked on the Little Signals project. He encouraged me to think about these devices as a family that could interact with one another, rather than being completely independent of each other. This would add to the whimsical and endearing quality of these devices.

Fabrication and Finishing
The final push for this project focused on designing and fabricating three separate devices that would each fit into a single context/rhythm in the home. After I started with sketching and low fidelity prototyping to determine the mechanisms and form factors for each device. The first device, Snor, would help you get ready in the morning and had a sleepy personality. The second device, Toby, would act like a puppy - it would be sad that you would be leaving the house, but thrilled to greet you when you got home. Toby holds your keys and is able to turn the lights on and off for you. The final device, Mum, acts like its namesake; it holds you accountable for getting to bed and encourages you to wind down for the evening by gentle drumming of a mallet on its surface. Each device had its own sets of challenges, especially since I worked with a variety of different fabrication methods and mechanisms. I fabricated the pieces using a combination of vacuum-forming, PLA 3D printing, SLA printing, and silicone casting. The forms were actuated using an Arduino microcontroller connected to a variety of stepper motors, servos, air pumps, and buttons. The final devices were brought to a high fidelity finish quality through priming, sanding with high-grit sandpaper, and painting. A final coat of Plasti-dip was used to achieve a soft-touch and matte finish on the parts. Once finished, a narrative video was shot and edited to demonstrate the context and interactions with these devices.

Constraints

Due to the time constraints in which this project was executed, several parts of the original plans for this work were deemed out of scope. Ideally, I hoped to show how each device would interact with one another to demonstrate the "family dynamics" of these devices. I did not think I would be able to deliver this part of the narrative to the high level of fidelity I wanted and so that will be explored in future work.

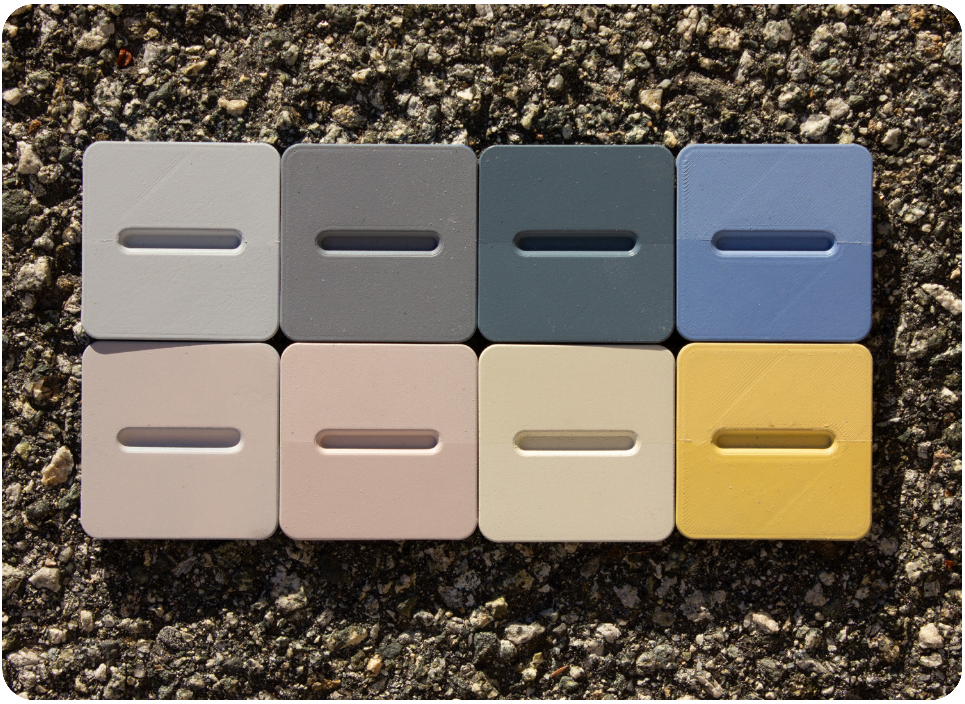
Soft interface interaction prototype.

Anemometer weather device interaction prototype.

Marble maze interaction prototype.

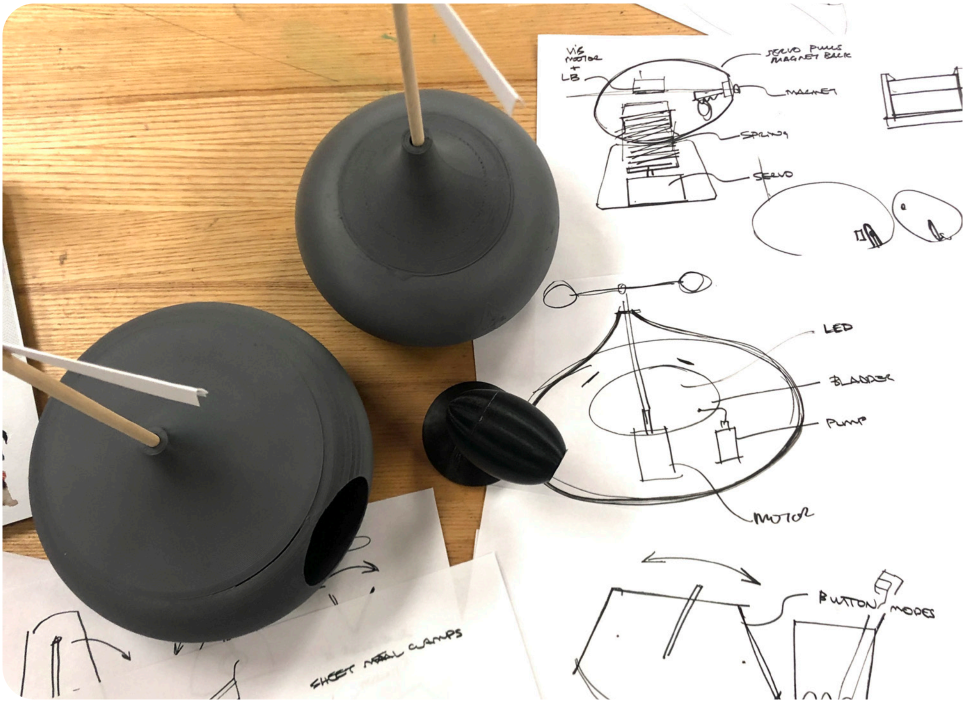
Inflatable knitwear interaction prototype.

Early sketches and low-fidelity prototypes of Snor.

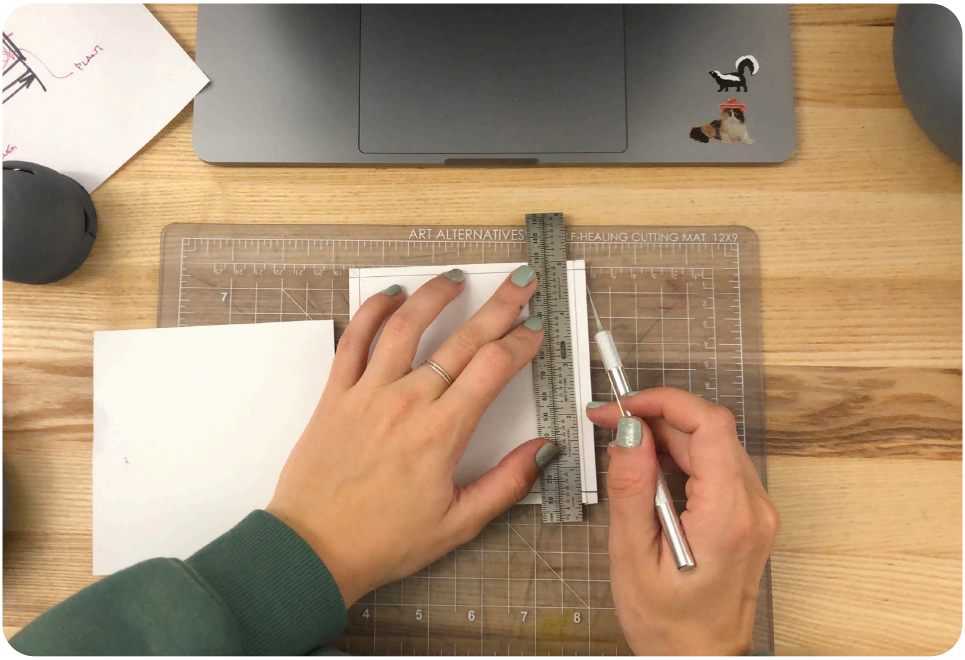


Color and finish swatch tests for the final models.

Early sketches and low-fidelity prototypes of Snor.

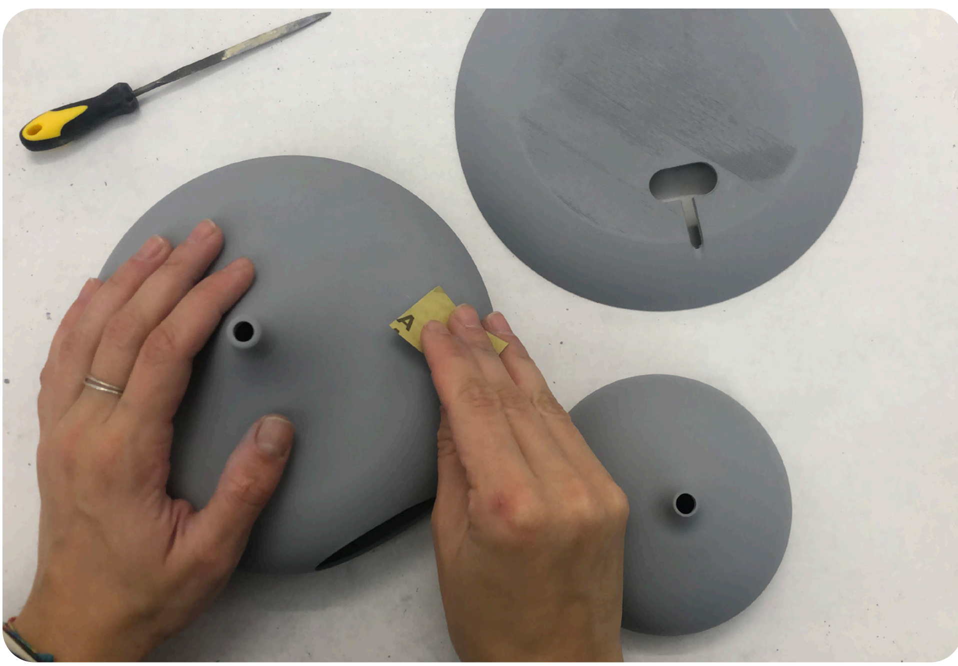


Early sketches and low-fidelity prototypes of Snor.

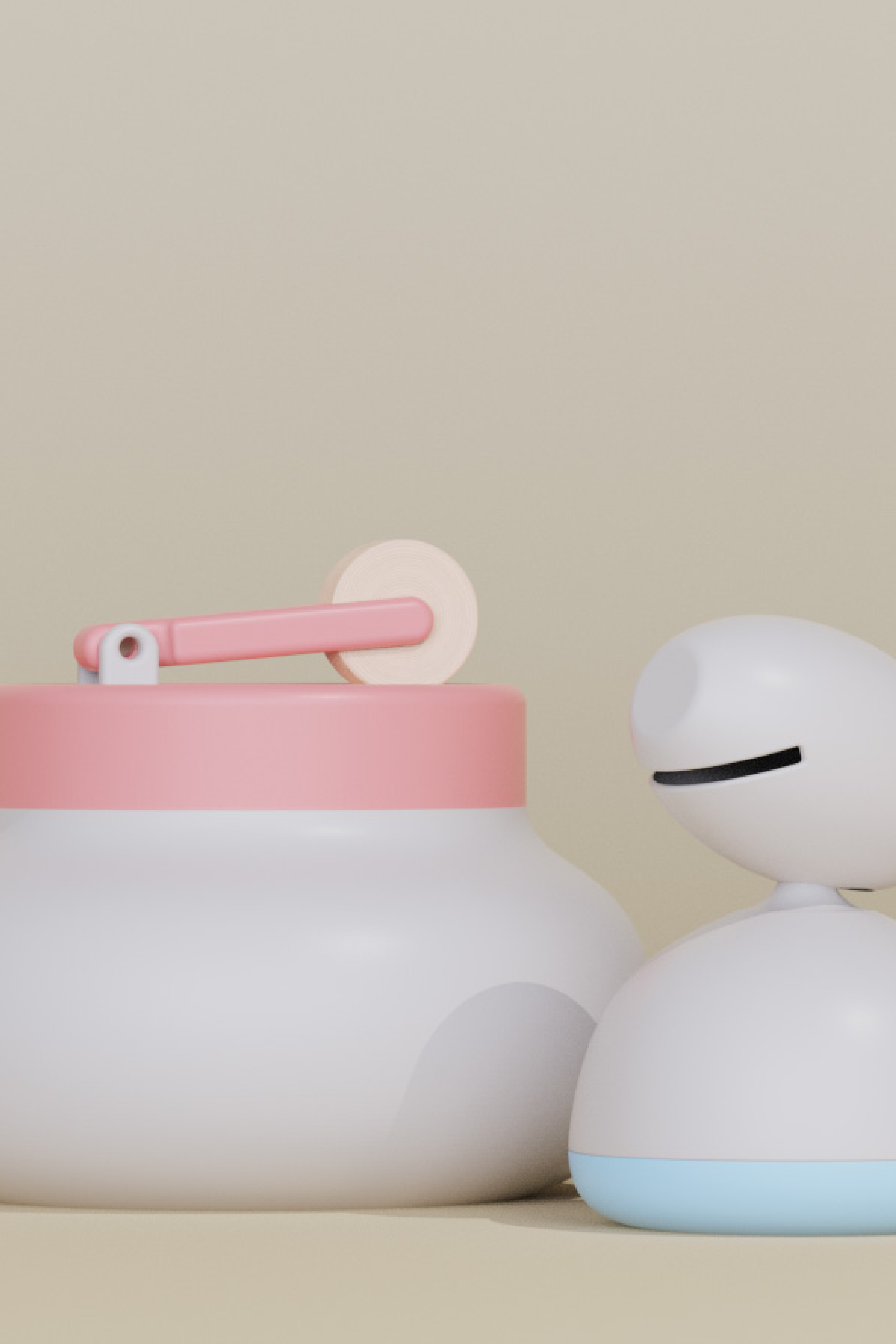


Creating foam core models for scale and interaction.

Applying glazing putty to final 3D-printed and primed models.



Sanding final 3D-printed and primed models using a fine grit sandpaper.



Discussion

Final Design

The final outcome of this work is a set of three smart home devices that each have a highly expressive personality through actuation and form design. Each device lives in a specific context in the home that correlates to one of the "rhythmic moments" discovered in contextual inquiry. In addition, each device has one practical output that maps to its context; for example, the device that gets you ready for the day tells you the weather.

The first device, Snor, lives in the bedroom area of the home and helps you get ready for your day by telling you the weather. Snor is a bit tired and lazy in the morning and demonstrates this through "snoring" via an inflating silicone bladder and slowly spinning its anemometer shaft. To wake Snor up, a user pokes it on its inflatable section and it comes to life, breathing and spinning its anemometer shaft faster. The weather temperature is indicated through the color of an LED embedded in the silicone bladder. Snor's form factor took inspiration from Snorlax, a character in the Pokémon game and television series that has an endearing, yet lazy personality (Snorlax Pokédex). Snor is the most complex device of the three due to the number of motors it operates inside. To create the breathing mechanism, I cast a silicone bladder that is attached behind a piece of knit cloth. The bladder inflates and deflates via an air pump connected to an Arduino Uno microcontroller with a motor shield. As the bladder expands, the knit fabric covering it stretches and expands as well. The bladder is connected to a pressure sensor that detects the change in pressure applied by a press or poke to trigger its "wake up" state. An LED lights up in a spectrum of orange to blue depending on how cold it is outside. The Arduino does not currently draw upon an external data source to display the weather data; this is simulated to demonstrate its function. The spinning anemometer is controlled by a stepper motor attached to the dowel rod using a shaft coupler, which enables it to spin. To create the lobes at the end of the anemometer shaft, I vacuum formed styrene over a custom mold and then sanded it to create a matte finish. The lobes connected to the shaft with a connector I designed and 3D printed in PLA. The high fidelity finish of Snor was achieved by layering several coats of grey primer, sanding with a low grit sandpaper, and then spraying the desired color.

A final coating of Plasti-Dip helped to create a soft-touch appearance on the surface. Imperfections were fixed using a small amount of paint thinner.
The second device, Tobi, holds the user's keys, turning the lights off when the user takes the keys when leaving the house and turning them on again once the keys are returned. Tobi has a puppy-like personality, mirroring how a dog would greet you in the morning and when you return home with exuberance and joy. Tobi is directly inspired by and named after my black lab, Toby, borrowing some of the same characteristics and imbuing them in a smaller form factor. Tobi holds keys in its "mouth" through a magnet embedded in its snout area. It's head pivots 180º using a servo motor connected to a dowel rod attached to Tobi's head; a spring sits on top of this dowel to allow for a slight wobble when Tobi's head turns. This also allows for Tobi's head bob in response to being pat. Tobi's head is designed off-center to add a more endearing and canid quality to its movements. To interact with Tobi, the user approaches Tobi to grab their keys as they prepare to leave the house. Tobi will excitedly wiggle through quick turns of the servo motor. As the user reaches for their keys, Tobi will play "keep away" for a moment before finally giving the user their keys. When the keys are removed from Tobi's mouth, the lights in the home will turn off. The user can give toby a pat on the head and leave their home. Returning home has a similar interaction; giving Tobi the keys will turn the lights back on and Tobi will excitedly greet you now that you've rreturned. Turning the light on/off is controlled by a limit switch embedded behind Tobi's "mouth." As the key is pushed into Tobi's mouth, the limit switch is turned to the closed state and lights turn on; when removed, it is turned to the open state and the lights turn off. The limit switch triggers an Arduino ESP32 microcontroller to send a request to the IFTTT service to turn a Wemo smart switch off. Tobi's external form is finished in the same way as Snor's; several coats of primer are applied, sanded, and followed by a coat of Plasti-Dip.

The third and final device, Mu, is a motherly figure that helps you to wind down for bed. It takes its form inspiration from the motherly teapot Mrs. Potts from Disney's Beauty and the Beast ("Mrs Potts"). Mu sits in your bathroom and taps a mallet gently on its surface when it's close to bedtime to remind you its time to wind down. If you ignore Mu long enough, the tapping increases in frequency to denote its irritation with your laziness. The mechanism for Mu is rather simple; a stepper motor attached to a spool pulls

Final Design, *cont.*

down on a piece of elastic connected to the mallet. With the tension from the stepper motor, the mallet lifts up; when the motor spins the other way, the mallet falls and strikes the surface. The striking surface and the mallet on Mu are both made from wood to create a sound similar to a wooden xylophone. I wanted to ensure the sound it made was not jarring to the user, especially as an object that is meant to prepare users for bedtime. Similarly to Tobi and Snor, Mu was finished using several coats of automotive primer, sanding, and spraying with satin enamel finish.

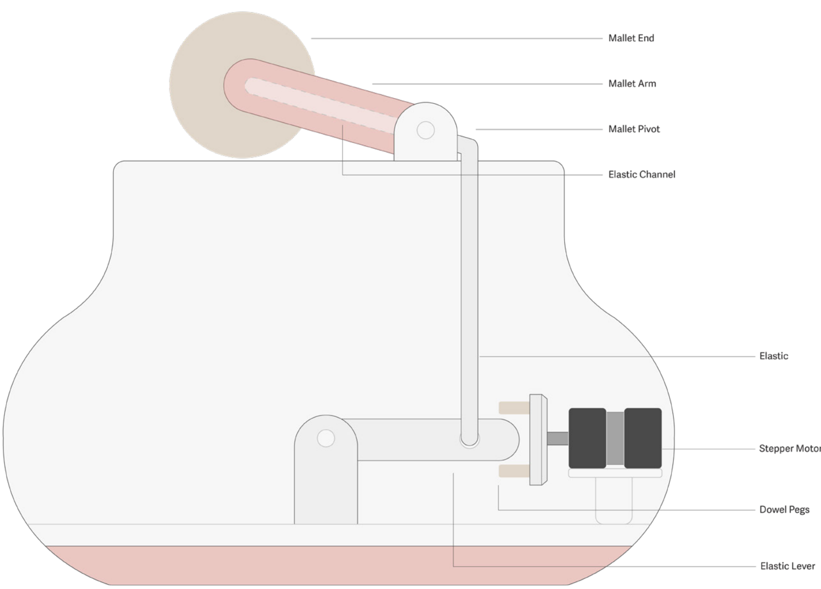


Diagram of the mechanisms actuating Mu.

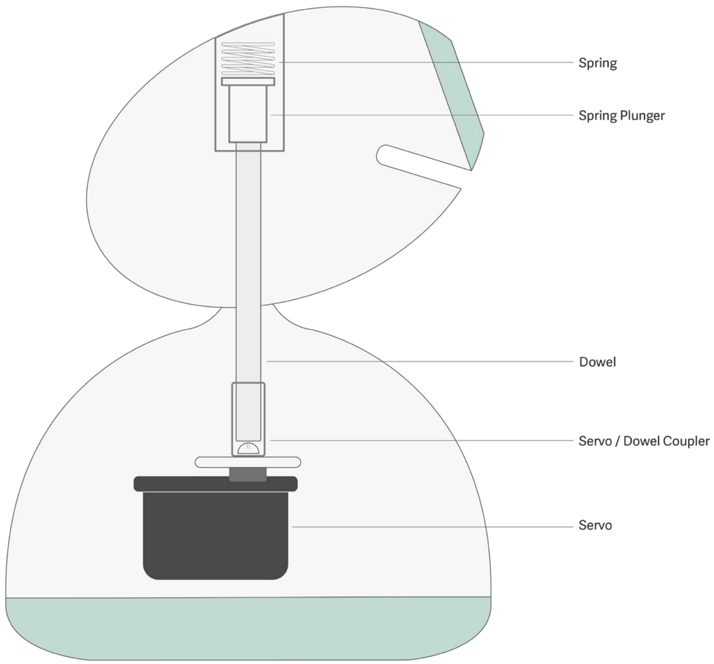


Diagram of the mechanisms actuating Tobi.

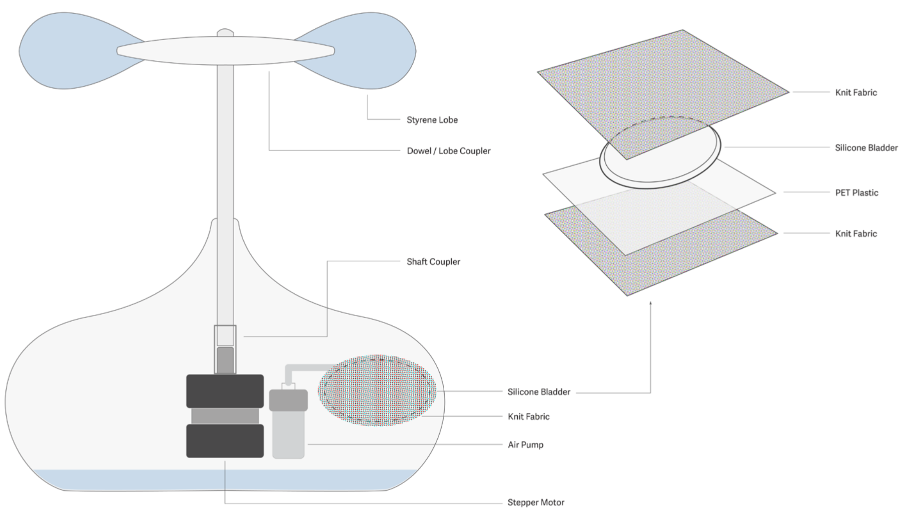
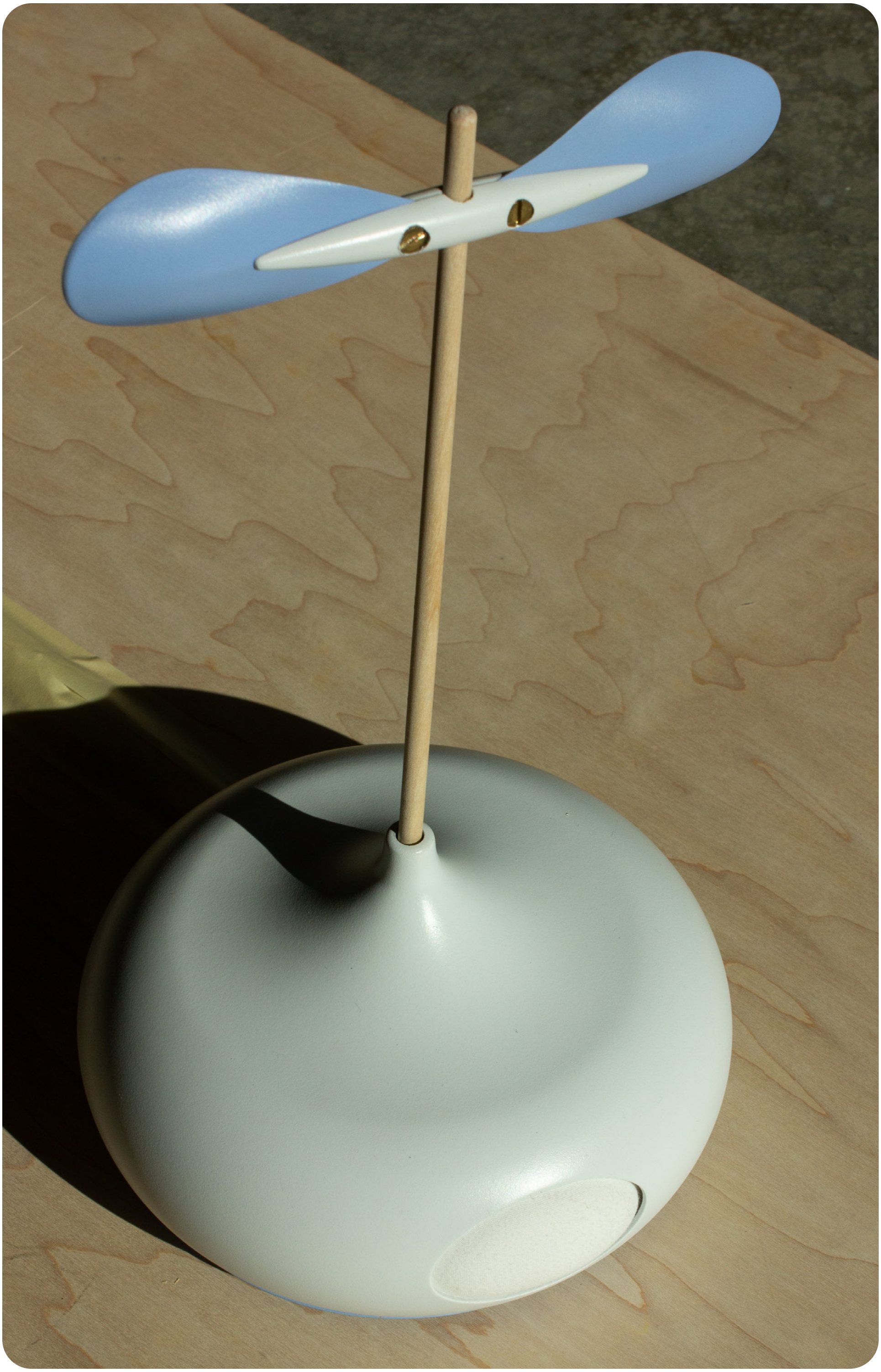
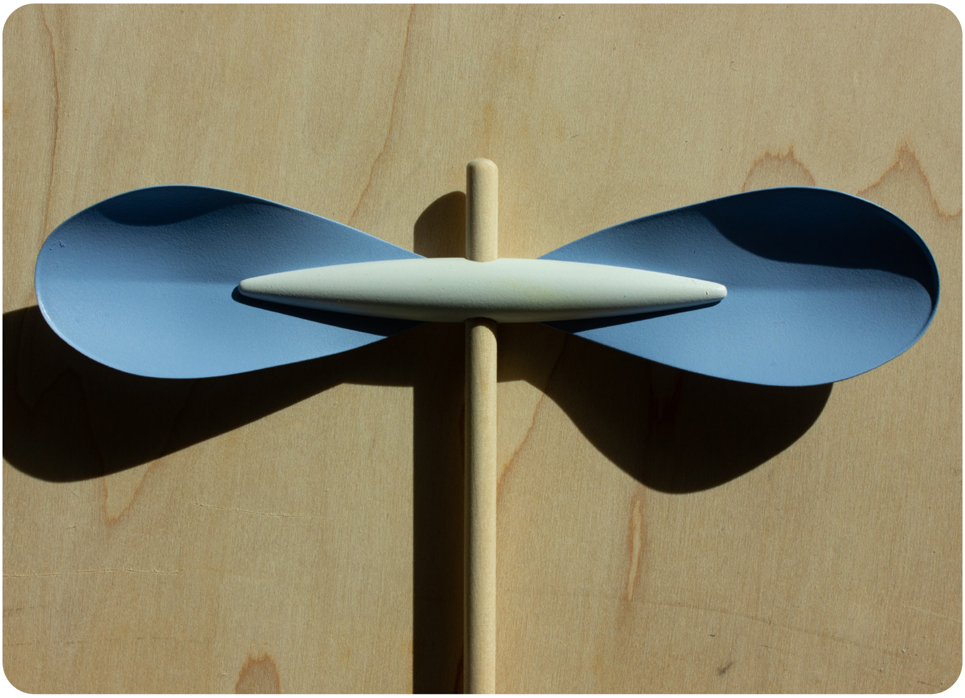


Diagram of the mechanisms actuating Snor.



Final model of Snor.

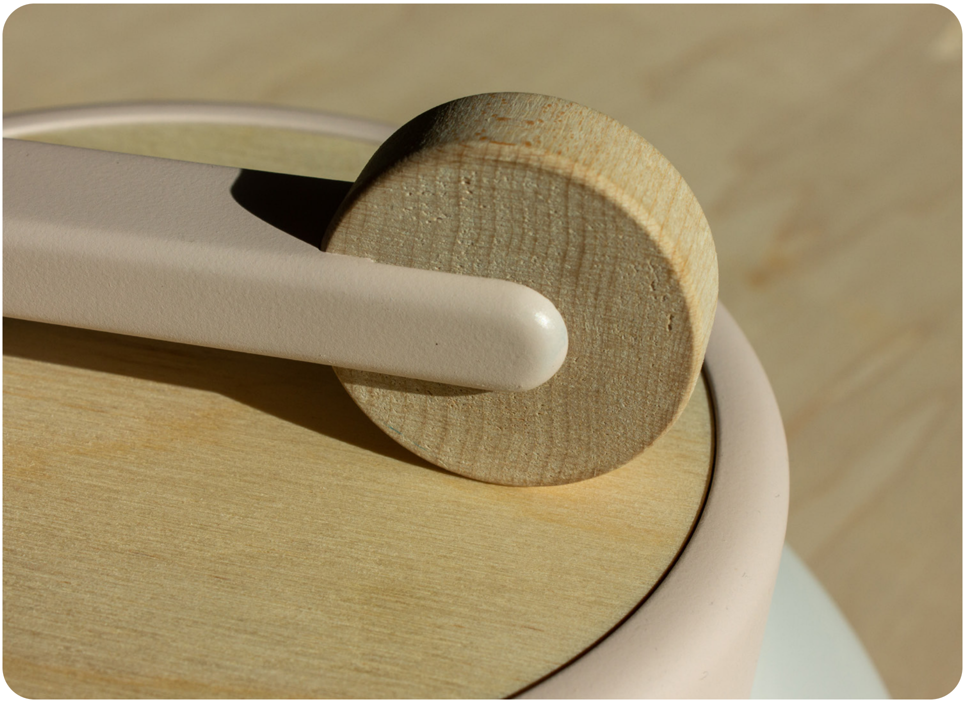


Snor spinner detail.

Snor inflatable bladder detail.

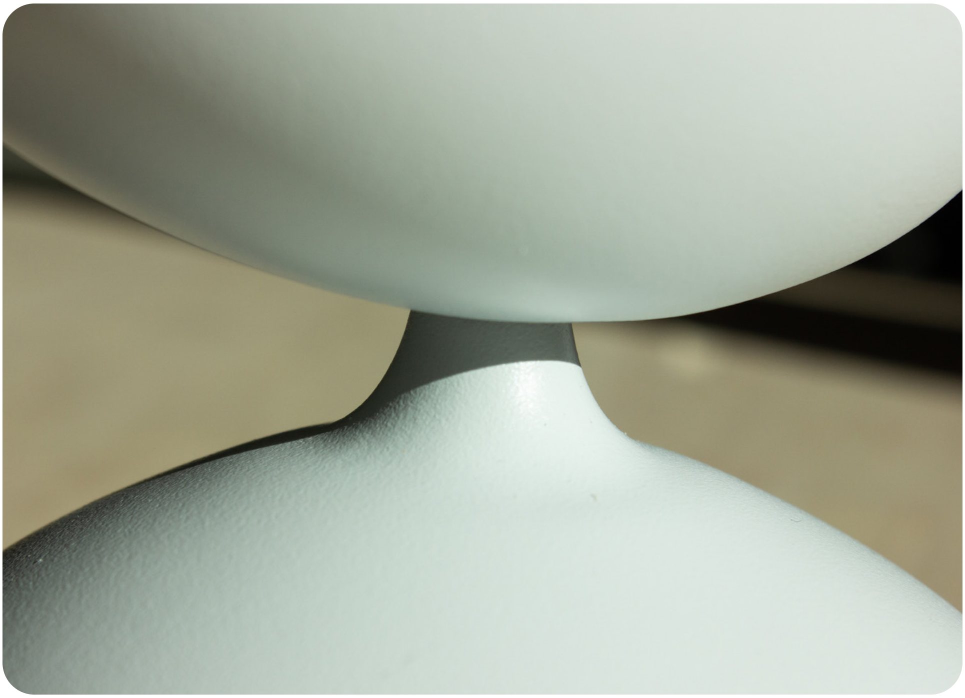
Final model of Mu.

Detail of Mu.



Close up of the mallet on top of Mu.

Final model of Tobi.



Tobi neck detail.

Tobi color detail.

Discussion

Exploration, Not Implementation of Tangible Methods of Control
In my intensive literature review, I found that there are thousands of papers and works that explore tangible methods of control through tangible user interfaces (TUIs) and physical feedback. Many of these works show the benefits of physical interfaces when it comes to completing complex tasks due to their direct methods of control and manipulation (Ishii et. al. 17, Zuckerman et. al.). In conversation with Adam Bernstein, one of the developers of Google Soli on Google's Advance Technology and Projects team, he mentioned that future research and development work at Google focuses on ubiquitous and calm computing, as well as further work into NUIs (Adam Bernstein). This signals momentum away from tangible and embodied methods of interacting with technology despite evidence that indicates this is a benefit to users (Zuckerman et. al.).

Reliance on and Resentment with Technology
During empathy interviews and contextual inquiries with participants, I discovered that all users relied heavily on technology, but were also wary of their reliance on it. Participants preferred to do tasks that they needed to commit to memory in an embodied way, such as taking notes with Post-it notes or writing tasks on a piece of paper. One participant specifically pointed out that crossing things off the list they made gave them more satisfaction than writing things out in a note application and checking them as done digitally.

Enjoyment of Endearing Qualities in Technology
I noticed that whenever I shared my idea with others, there was an immediate draw to the endearing qualities of these devices. Several of my professors and also design professionals mentioned this aspect; Gaetano Ling, a designer and engineer on the Google Little Signals project, specifically pointed out that the actuation made these objects have a whimsical quality to them. Another professor, Yoon Bahk, mentioned wanting these devices to be taken a step further, where they are exceptionally clumsy and require human intervention to function. This is similar to sentiments around the Roomba;

in a study by Forlizzi et. al., they found that participants found the "clumsy" nature of the Roomba cute, leading to a deeper social connection between themselves and the robot (Forlizzi et. al. 125). This demonstrates that there is interest in intentionally designing in "human errors," emotionality, and whimsical qualities into home devices.

Desire for Familial Relationships Between Devices and Their Users
During formal and informal critique sessions, a theme that came up several times was the idea of incorporating a familial relationship between the devices to showcase other aspects of their personalities. How would they interact with one another if brought together? Or when the user was not home? The significant interest in this space made it clear that in future iterations of this work, this aspect should be incorporated; the time limit to execute this meant that this feature would be out of scope. Additionally, several peers I discussed this work with asked if these devices would develop a relationship with the users, relating to their individual needs. This is a question that can most certainly be addressed in a longer-term study with these objects in situ; unfortunately, that fell out of scope for the time period of this project.

Challenges Around Interactions
One of the most challenging parts of this project was around the conceptual framework to map interactions and actuation to personality traits. It is difficult to distill a personality into an abbreviated set of interactions. I especially struggled with the personality of Mu; initially, I envisioned it with a more calming and meditative personality. Upon reflection, I realized that this personality is exceptionally challenging to convey and, if implemented, Mu would present more "product-like" than a smart device with a distinct personality. I decided to go with a more impatient, motherly personality for Mu as a result, allowing me to exaggerate and emphasize its personality.

Future Work & Conclusion

Future Work

This thesis primarily served as a single case study of expressive and embodied interactions with home devices; there are many opportunities for future iterations of this work as a result of the limited time and scope to explore this project. I could envision this work informing future iterations of how domestic technologies and smart homes are designed, especially as we move towards a future with more integrations with robotics in our lives. The expressive and emotional aspect of this project may hold benefits for emotional durability of the devices in our homes, giving technology more staying power due to the relationship formed between people and technology (Chapman, Forlizzi et. al.). One line of inquiry I was unable to explore in this project was the relationship-building potential of these objects with their users. I envision a future where these objects could learn from their users, as well as each other. The relationships formed between people and their technology is actively being studied in research as well as a few consumer products, but these concepts have not yet been explored in the realm of home devices (Anki Labs, Forlizzi et. al., Mennecken et. al.). Social and expressive robotics are already benefiting people when used in the context of caregiving and emotional support for the elderly (Bemelmans et. al.); putting these objects into the context of a home environment could have a very positive impact on the emotional and mental well-being of individuals. In the future, I would like to test this work in situ in a study where users live with these objects for an extended period of time. This would help gauge these devices' effectiveness in the home environment, as well as the sentimentality and social qualities that may arise with their interactions. Finally, in a future study, I would like to experiment with objects across more contexts, as well as a variety of different behaviors and interactions to determine which ones are most and least effective with users.

Render of Tobi.

Conclusion

In a world where consumer technology trends ever further towards screen-based and complex interactions with our devices, where does that leave physical interfaces? What could it look like to challenge the current norms around how we interact with technology by introducing personality, expression, and embodied interaction? This thesis examined these new paradigms of interaction through a case study with three actuated smart home devices set in a few different contexts around the home, each expressing a unique personality. This work has the potential to demonstrate novel ways in which we might design technology, emphasizing usability and enjoyment of interaction over forcing users to adopt new and underdeveloped innovations. Research indicates that expression in robotics leads to increased trust and an improvement of relationships between people and machine; critical reception of these three devices indicated the same sentiments, as people remarked on their "cuteness" and endearing nature (Whittaker et. al.). This work contributes to several fields in the HCI and Human-Robot Interaction space, drawing upon themes such as ubiquitous computing, calm computing, slow technology, and emotional durability to inform its design and execution. I hope that this work leaves a lasting impact on how technology of the future might be designed to facilitate improved interactions between people and technology

Thank you for reading this body of work and I hope you continue to question the role and design of technology in your life. Healthy skepticism is one of the many mothers of innovation.

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