Puffy: Exploring Interactive Materiality from an Experience Perspective

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ABSTRACT

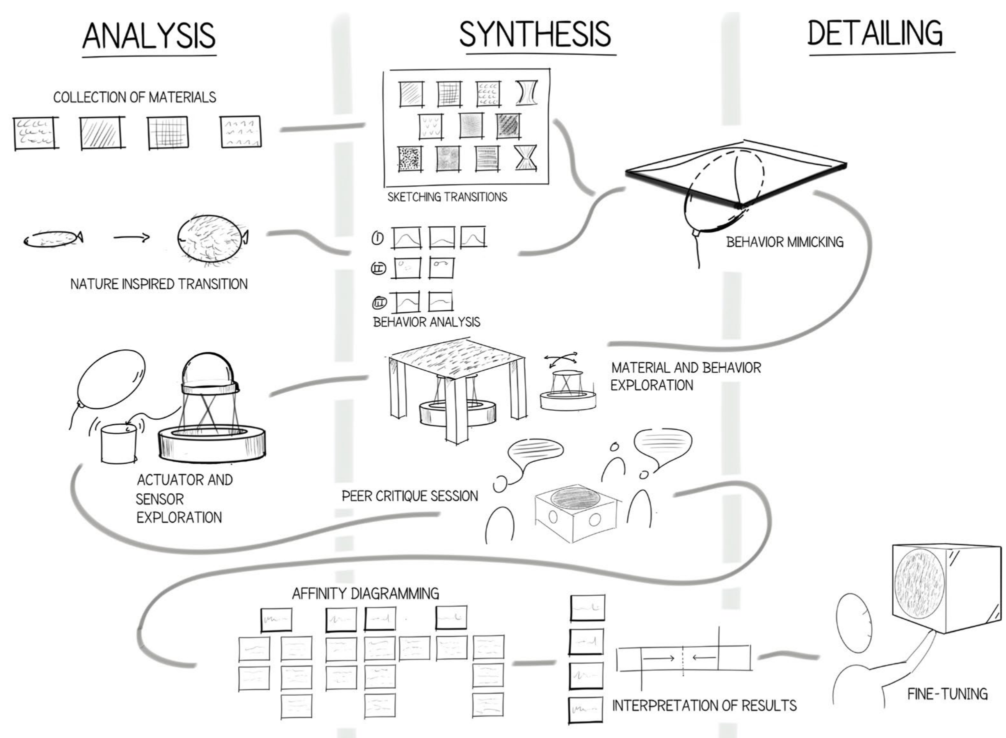
UPDATED—November 2020. In this pictorial, we describe our Research-through-Design (RtD) process through which we explored how to adopt a materiality lens to design sensorially rich, nature-inspired interactions between humans and interactive systems. Our design process iteratively went across three major stages: Analysis, Synthesis, and Detailing. In the Analysis stage, relying on our firs-hand experimentations, we explored a range of materials, nature-inspired shape transition, and sensor-actuator mechanisms. In the Synthesis stage, we re-examined the explorations through critique sessions to bring first-hand implications into a conversational perspective. In the stage of Detailing, we further concretized the details of the interaction design, and fine-tuned the interactive prototype to fully embody our design understandings. Throughout the whole process, the aesthetic qualities of materials are placed centrally in our exploration. Taken together, we contribute a concrete RtD case on exploring aesthetically-centered, sensorially rich interactions through the lens of interactive materiality.

Authors Keywords

Interactive Materiality; Shape-changing interfaces; Haptics; Material-centered Design

CSS Concepts

• Human-centered computing~Human computer interaction (HCI)~Interaction devices~Haptic devices



An overview of our main design activities mapped on the three phases: Analyzing; Synthesis; and Detailing

NTRODUCTION

As the era of ubiquitous computing unfolds, interactive systems are nowadays becoming more intelligent and humanized, which has blurred the boundaries between human and technology [4] and corresponding designs have shifted from designing functionality and usability towards experience design [2]. This encourages HCI researchers and designers to explore how experience would be like in the new era. Many have investigated to attach dynamic physical representations of the digital world, namely tangible bits [7] Yet, current methodological approaches are mainly human-centered, which cannot effectively benefit the design process, while a material-centered method [18] might be an alternative. Therefore, it brings us to explore sensationally richer and more natural forms of human-computer interaction, ensuring seamless integration of technology into our everyday life.

The developments of Interactive Materials lay on the intersection of different disciplines including Material Science, Chemistry, and HCI [8,10,16]. Currently, no material is able to individually complete the path from sensing to actuation and/or communication and many challenges still need to be overcome in order to realize the vision of embedded computation and interactive materials. While these materials are in development, a growing amount of HCI researchers start to explore the possibilities of shape changing interfaces [10]. However, as interactive material is still in its infancy, there needs a clear process and method for guiding designers make the right designs for delivering expected user experiences.

This work aims to setup a novel approach to design interactive materials through Interactive Materiality. During the process, the behavior, interaction, and aesthetic qualities of envisioned Interactive Materials are explored through an iterative Material-centered Design Research process which centralizes material during the design process.

METHOD

As this work focuses on the exploration of the possibilities of Interactive Materiality, a Showroom Research through Design [5] approach was used. This process allows for iterations to be debated, building on the boundary of research, design, and art. Moreover, as we aim to design with a Material Centered focus relying the design direction on debates matches the explorative nature of the process. Inspired by the work of Stienstra et al [14], we use the Interaction Frogger framework [17] as a generative tool. In the process of exploring behavior, interaction, and aesthetic qualities we iteratively use their three defined steps: Analyzing; Synthesis; and Detailing [14]. Over the course of this process, we aim to explore the boundaries of Interactive Materiality providing insights on how to design the interactions with computational materials.

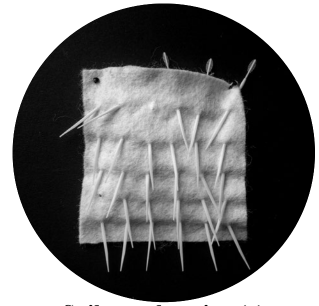
Throughout the process, we took experience perspective and ensured continuous first-hand experiences and reflections. By allowing our design direction to be guided by experiences and using a minimal set of design boundaries, novel design directions could be explored.

During the first step (Analyzing), we explore different (nature inspired) transition moments which we used as the behavior to analyze. Using our selected transitions, we explore non-aesthetic qualities[13] to define transition characteristics. During this step, we aim to understand the behavior on all six aspects of interactive materiality as described by Stienstra et al. [14]. Being inspired by this transition, we explore different (composite) materials that fit our transition, building upon the material's qualities from the start of the process. In the second step (Synthesis), we use our profound understanding to first couple and later map the material's behavior to invite for a continuous action-perception loop. Over the course of several iterations, we aim to match the intended behavior as concluded from the analyzed transition. During the third step (Detailing), we aim to fine-tune the behavior to match human sensitivity to the extent that the interaction could become, in Heideggerian's terminology, present at-hand. To achieve this level, we use peer student critique and thematic analysis [3] to understand the third-person experiences and use their inputs to design the subtleties of the interaction.

ANALYSIS

Instigating our process, we define a design direction based on nature-inspired transitions and aim to obtain a profound understanding of the selected behavior through first-hand experiences. We explore different material qualities to match our selected transition based on our understanding that resulted from the transition analysis regarding its texture and behavior.

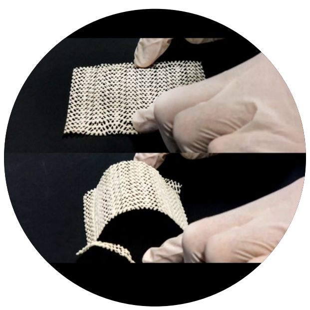
Transition: We first explored and selected several nature-inspired transition moments. While evaluating the visual expression of the selected transition moments, we found that the inflation of pufferfishes had several interesting qualities. First, the shape change of the fish communicates tension as the fish expands. Second, this repelling effect is emphasized by the growth and angle change of the spikes.



Spike exploration (a)

Spike exploration (b)

Texture: As the blowfish expands, the skin of the fish changes in texture due to two reasons: First, the spikes extend in length. Second, the direction of the spikes turns outwards. This change in spike direction was thought to be interesting as the tips of the spikes form a second, projected, surface. This allows for interesting patterns to emerge guided by the expansion underneath. When the center of inflation underneath the material moves, so do the emerging patterns. We explored different ways to express the change in spike direction in materials but found the spike density to limited to express projected layer.



Expansion exploration (a)

Expansion exploration (b)

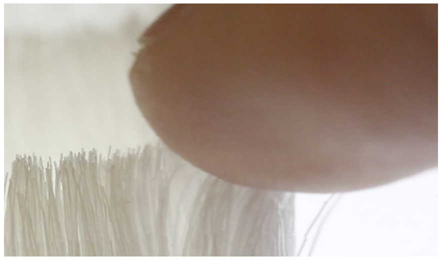
Transition abstraction: We used the pufferfish as inspiration to explore different material expansion techniques. Some explorations focused on manipulating material qualities to allow the material to expand, while others consisted of the combination of multiple materials to allow for expansion. While the manipulated materials became fragile, the material composites remained sturdy. The latter one fitted our transition best, as the 'inflated' material underneath the top layer allowed for a sturdy grip emphasizing the visual expression of an inflated blowfish.

Behavior exploration (a)

Behavior exploration (b)

Behavior and texture: We combined our explorations regarding the expansion and surface texture in a consecutive step. We aimed to slightly diminish the repelling aesthetic quality of the spikes while emphasizing the second projected layer. In order to evaluate the progress from an experience perspective, we used a quick-and-dirty setup consisting of a texture of interest and an inflated balloon underneath. By squeezing and releasing the balloon, the deflation behavior could be mimicked, allowing us to experience and evaluate the aesthetic qualities firsthand. We used this setup to further explore the influence of the material's tension on the interaction gestalt. Playing with the physical and temporal form of the material, we learned how to mitigate the repelling effect of the transition, while emphasizing the emerging patterns.

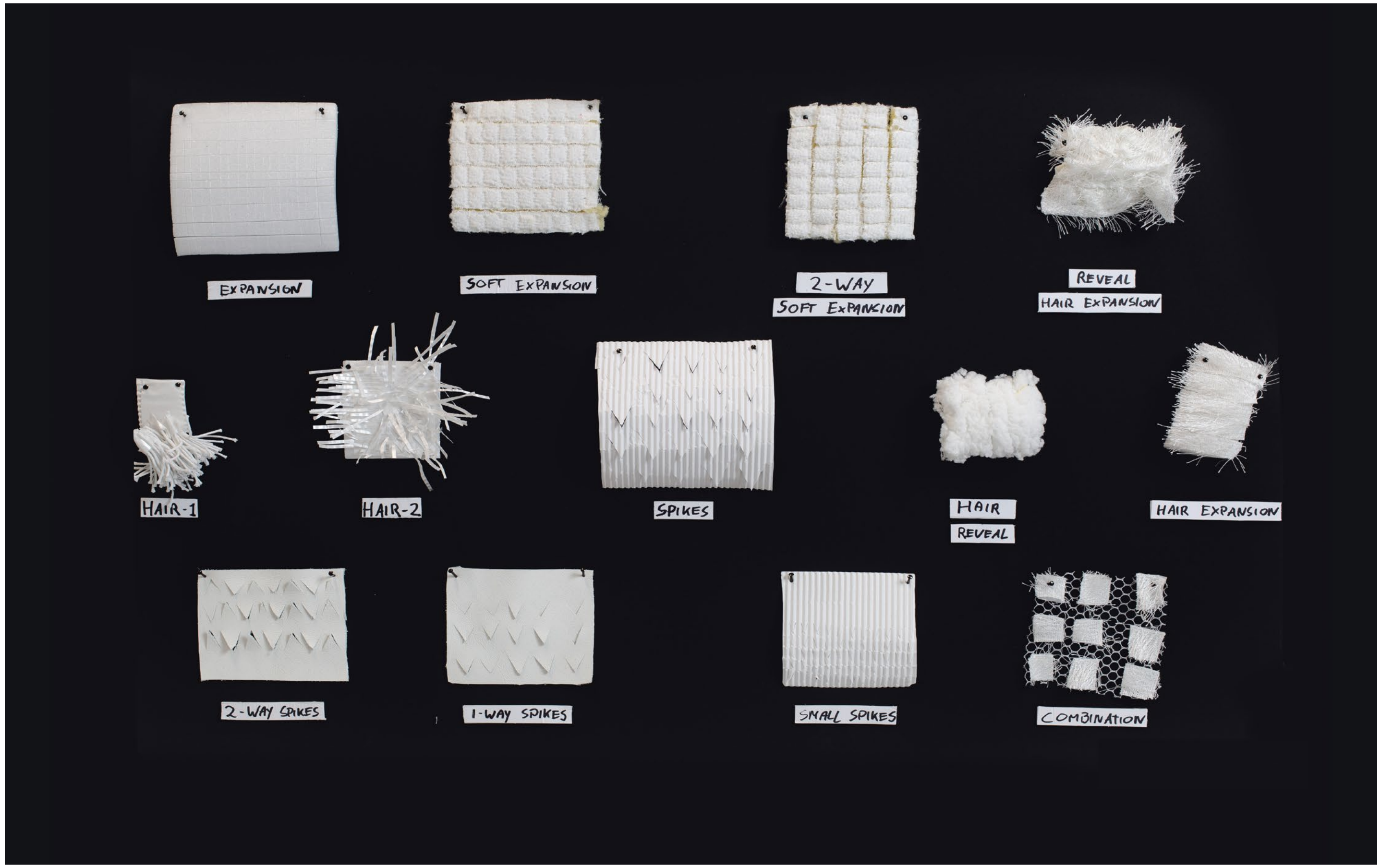
Material Explorations



3D Printed hair [9]

Hairy fabric

Cloudy fabric

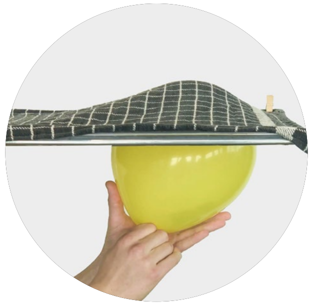


An overview of the material sketches

In our analysis step, we explored several different techniques to express the selected inflation transition while underlining the change in texture. In our exploration, we looked at several ways to achieve the projected layer effect and the resulting emerging patterns. On top of the exploration shown in the image above, we also looked at how we could manufacture our own materials with our specifications (i.e. 3D printed hair, Cilllia [9]). While the exploration provided interesting directions for material adaptation, we found that our transition could be best expressed through an un-adapted, hairy, fabric combined with a solid inflation mechanism worked best as it emphasizes the sturdy visual expression and haptic experience. In the process, we attempted to slightly mitigate the natural repelling aesthetic quality of the transition in terms of physical and temporal form while evaluating the effect on interaction gestalt through observations [16].

SYNTHESIS

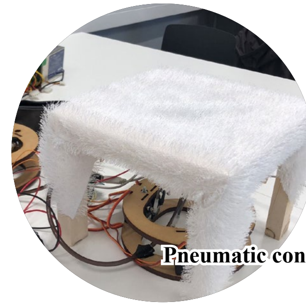
Using the defined transition from the analyses, we abstracted our transition to be expansion based on the found emerging patterns. Through three iterations of making prototype and evaluating the experience through our first-person perspectives, we explored different combinations of materials and expansion techniques to explore the best fit for our transitions. In this process, we build upon our first-hand experiences to explore different interaction mappings.

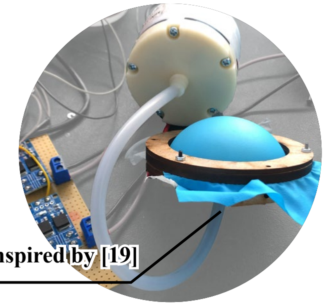


Fidelity Level: ●

Fidelity Level: ●●

Iteration 1: The initial quick and dirty setup consisted of fabric placed above an expandable object, which was a hand-controlled deflating balloon. In this exploration, we learned that the haptic experience and the aesthetic quality were exactly what we were aiming for, which leads to a bit higher fidelity prototype. Inspired by [15], we developed a prototype equipped with 2 Degrees of Freedom (DOF) actuation and an inflatable object as the 3rd DOF. Using the described setup, we further explore the system's capacities in a consecutive test setup where we placed the platform underneath a layer of fabric.





Fidelity Level: ●●●

Iteration 2: As we learned that a balloon was instable, we implemented a rubber-based pneumatic container in the next setup. The container was inspired by PneUI[19], consisting of an elastic and airtight layer made of rubber in between an open-frame and a closed plate with a tube connected to. We used a pair of pumps (one for inflation; one for deflation) to control the inflation level of the container. Through experiencing the design with our first-person views, we learned that the variants and randomness of 'hair' on the elastic textile matched our selected transition

Fidelity Level: ●●●●

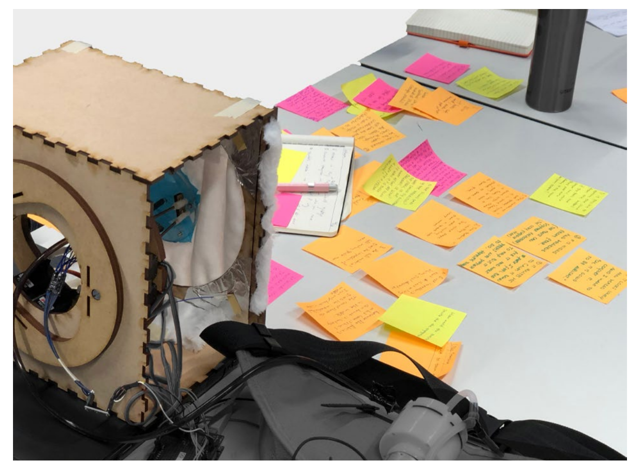
Iteration 3: In the next phase, we integrated the Stewart platform, two pumps, and fabric together within a solid enclosure called Puffy. On the top, there is the main interface of a dynamic fabric. We also used capacitive sensors to detect a user's actions without showing the physical components outside the box. This integration increased the overall experience as it emphasizes the interactivity of the material

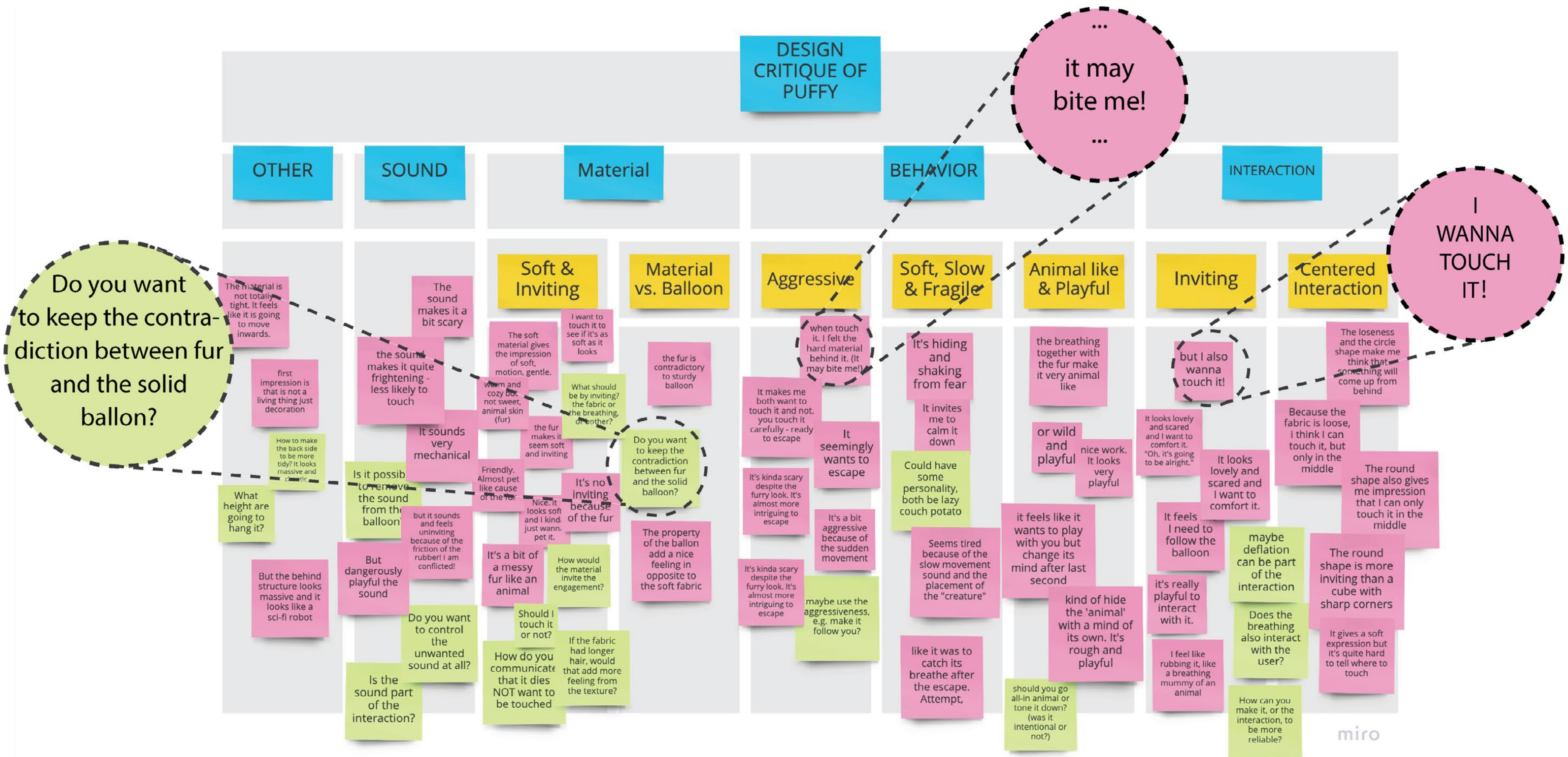
Fidelity Level: ●●●●●

Puffy's Behavior: The behavior of the designed artifact was derived from our selected transition. We used the analogy of a pufferfish to define the human-system interactions: 1) In the idle mode, the material 'breathes' at ease, slowly inflating and deflating; 2) When a user approaches, the 'danger' causes the material to inflate and move away; 3) After he/she leaves, the material gradually deflates as the 'danger' dismisses.

DESIGN CRITIQUE

Before fine-tuning the artifact, two authors of this paper hosted a session of design critique with nine participants who are all masters students from the Department of Industrial Design. They experienced Puffy and reflected their opinions regarding the aesthetical qualities, including 1) the affect: the visual effect and body response of their first encounter; 2) the emotional perception: the emotion a user perceived from the interactions; 3) the symbolic notion: the interpretation of the meanings which the designers intended to be conveyed. Those reflections were written on pink sticky notes; After that, they left questions and constructive suggestions regarding the interactions and behaviors on green ones. Such a critique session stimulates every participant to have thorough experiences and reflect on what Puffy is communicating. This was aimed to help us gain different perspectives of feedback for fine-tuning the designs in the consecutive stage. Later, we used thematic analysis [3] to cluster the participants' notes. As a result, salient remarks were highlighted and clustered into five categories: material; behavior; interaction; sound; and others;

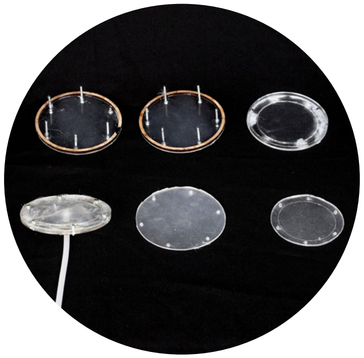


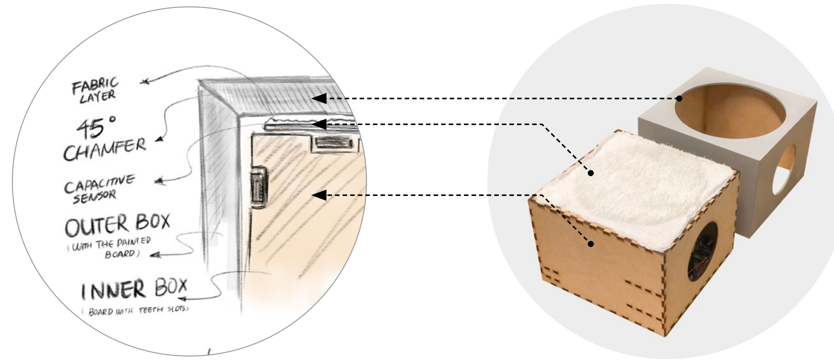


Affinity Diagramming, salient remarks were highlighted and clustered into four categories: material; behavior; interaction; and sound

From the analysis, we learned that the fabric's visual expression and the touching of the pneumatic object underneath contradicted each other. The furry and soft property gives viewers a sense of inviting and touching as stated by one of the participants: "...I wanna touch it...". However, the sturdy pneumatic material underneath the top surface gives an opposite feeling when petting it. A majority of the participants indicated that the initial breathing behavior is calm and humble; but it later became aggressive when they approached the fabric. It might be because the invisible actuation mechanism underneath the fabric reacts too aggressively (mainly the servos and pumps); One user even stated: "...I thought it may bite me!". Moreover, we learned that participants were confused with the delay of Puffy's reaction. In some cases, the fabric and actuators did not synchronize well while reacting to a user's interaction. This was due to the coordination of the input and output as the sensing area of the capacitive sensor did not cover the center area of the fabric. Some participants also remarked that the sound coming from the machine enhances the aggressive behavior. Since all the actuators including six servos and two vacuum pumps are built-in the box, the sound can hardly be eliminated. However, the rubber of the pneumatic mechanism caused a squeaking sound when rubbing against the top fabric layer. Concluding to the analysis, we learned that the invitingness of the surface material and the aggressive behavior conflicted too much. During the final step of our process, we aimed to bring these two conflicting aspects more towards each other. To further align the physical form, temporal form, and interaction gestalt.

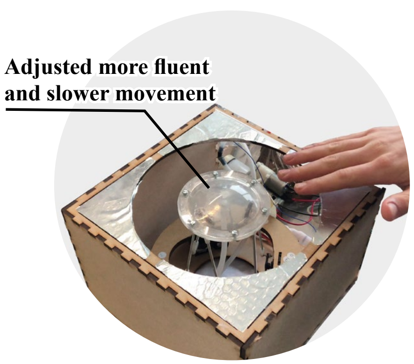
DETAILING

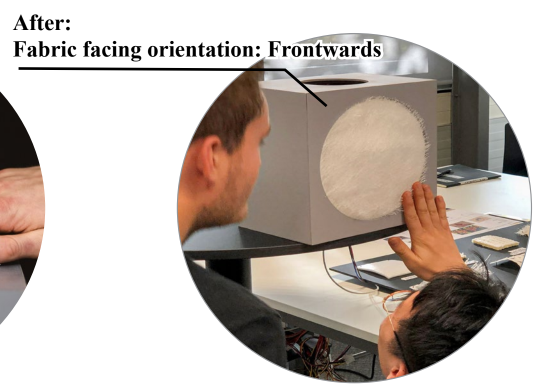


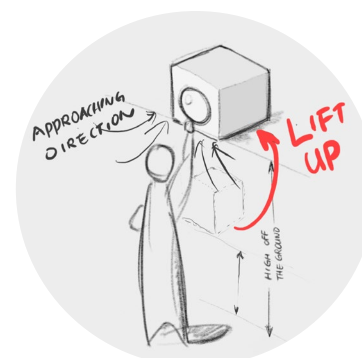


Iteration 4: We aimed to eliminate the conflicting feeling between inviting of the soft fabrics and the aggressiveness of the underneath mechanism. We investigated several types of soft materials and eventually made one with an opaque layer to enhance the independent property. From our first-person experience, this design makes Puffy felt distant and lest inviting. While redesigning the mechanism, we combined the rubber materials with customized molds made by different quantities of silicon. This helped to eliminate the noise and also enhance the sturdiness at the same time. This resulted in several containers with different qualities in terms of expansion, sturdiness, and haptics.

Appearance: To ensure both sturdy structure and remain aesthetic qualities, our final design was assembled with two boxes. The inner box was constructed with teeth slots aimed to provide support and construction mechanisms (e.g. for mounting the fabric, pumps, and servos). The outer box we used 45º degree chamfers to create a seamless box and cover the supporting box without joints, resulting in a seamless finish.







Calibration: As we aimed for invisible sensors, emphasizing the interactivity of the material, sensing central interactions proved to be difficult. Since we intend to create a closed loop ranging from no interaction to approaching and leaving, we decided to vertically place the box high off the ground. So, anyone interacting with the artifact would always approach it from the bottom, improving the detection rate of the capacitive sensors.

Behavior: We adjust the actuators with slower and more fluent movements to reduce the aggressive experience perceived by participants during the design critique aforementioned. Also, the threshold of the capacitive sensors was re-calibrated to avoid mis-operations. This resulted in a robust prototype with smoother, quieter, and less aggressive behavior for delivering pleasant and aesthetic qualities.

DISCUSSION

Design Method

Our Material Centered process allowed us to explore the boundaries of Interactive Materiality to the full extent. As generally, the functionality is considered from the start of the process, designers consider what the material has to do (in terms of functionality), instead of what would be possible using the material's qualities. Moreover, the experience perspective allowed us to constantly reflect and improve the action coupling. We learned that by integrating behavior in the material based on a nature-inspired transition, similar to choreographies in the work Ross and Wensveen [12], a type of negotiation [11] is immediately achieved as their remains a certain level of ambiguity in the interaction.

Evaluating our prototype in retrospect, we depict two distinct coupling aspects of improvement. First, the 'direction' aspect: as the artifact could sense no more than 4 origins of interaction, the materials feedback had a limited resolution. By expressing the interaction direction possibilities in the physical form, instead of exclusively in the temporal form, the coupling would improve [16]. Second, the aspect of 'modality': as the number of internal actuators caused an excessive amount of noise, users received feedback that did not match their actions or visual perception. More explicitly, the deflation behavior of the material was haptically and visually insensible while causing noise over the course of several seconds. Using a lengthier detailing step, this aspect and the consistency of the behaviors could be improved. Moreover, the ability of envisioned computational materials to improve all couplings is self-evident as materials become able to locally sense, compute, and react to input [8].

Fields of application

When considering potential application areas, stimulating certain behavior seems most prominent. While this has been considered by others [14] in a direct user-product relationship, multi-user environments could benefit similarly. By exploiting the ability of Interactive Materiality to steer behavior , behavior in shared-spaces could be dynamically directed instead of using static signs or Graphical User Interfaces (GUI); Besides, one of the notions of Interactive Materiality regarding its applications, is less utilization of human's cognitive attention. Different than GUIs, tangible interactions require a user less cognitive attention and efforts. It also could facilitate the peripheral interaction [1] which a user could perform the interaction without switching their attention back and forth between their center of attention and periphery. He/she could select and execute the functions with the sensorial inputs and gestures. In this pictorial, we demonstrated that the interactive materiality could support designers exploring the properties of materials and make coherent compositions for creating effective peripheral interaction.

CONCLUSION

In this work, we presented our Material Centered Design Research process in which we explored the boundaries of Interactive Materiality and the ability to use materials as the interface between human and interactive products. We used a three-step process, starting from a nature-inspired transition to integrate ambiguity in the form of behavior. Then, we used the Interaction Frogger framework [17] to continuously reflect and improve our action couplings using observations and design critique sessions. Finally, we used our findings that resulted from Affinity Diagramming to detail and fine-tune the interactive artifact. The work contributes by presenting a novel approach to design for Interactive Materiality by placing the material centrally in the process. By doing so, the material's properties are utilized to the full extent decreasing the amount of required traditional actuators to react to user actions. We made a first attempt to alter material properties in terms of material composites, developing the material to match our needs. This emphasized the opportunities that will arise when morphing materials will become more broadly available and improve in terms of resolution, reaction speed, and possibilities. The ability of these novel materials to dynamically change properties will increase the haptic interaction possibilities in a calm way. Our presented process allows to explore the possibilities of materials that couple sensing and actuation and take full advantage of these new properties when these interactive materials will make their entry into everyday life.

Limitation

This material-centered method places material and sensational feelings at the center during the process before a certain functionality is defined or what business value it creates. This would be a challenge to build coherent connections when seeking possible applications for industries; We aim to bring sensationally richer experiences to users. Yet, in the process of exploration, we only explored the possibilities of changing material properties to a limited extent; Our integrated behavior consisted of, relatively, large actuators and movements, which might limit its using contexts.

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