Puffy: Crafting Novel User Experience through the Lens of Interactive Materiality

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Abstract

UPDATED—October 2020. In recent years, research regarding interactive materiality has gained increasing attention in the HCI community, whereas corresponding design implications and instructions for practice are still sparse. In this pictorial we present a concrete case in which we took a materiality approach to design a novel interactive artifact that features rich materiality-based interaction with shape-changing and haptic qualities. Our iterative design process consisted of three key activities (analysis, synthesis, and detailing) interlaced back and forth along the whole journey. Using this approach, we analyzed different sources of input, synthesized self-reflections and peers' critiques, as well as detailed the design with iterative prototypes. By offering a reflective analysis of our approach, we demonstrate a highly embodied design process and a set of practical implications, to inspire future creators to design interactions with interactive materiality.

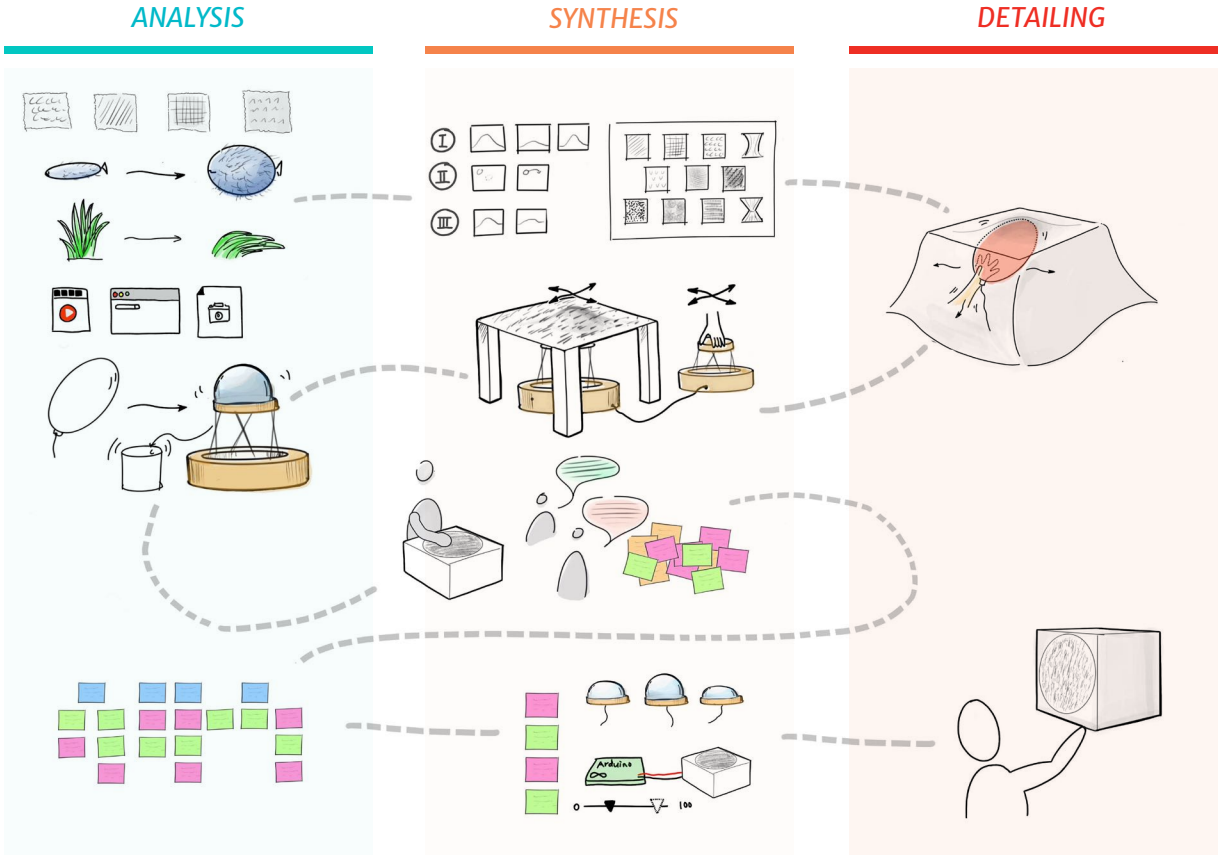


Figure 1. An overview of the main design activities

Authors Keywords
Matierial-centered design; Form-giving; Tangible user interface; Research-through-design;

CCS Concept
•Human-centered computing~Interaction design~Interaction design process and methods

Introduction
In recent years, material-centered design [1] has attracted much attention in HCI community [3, 5, 6], especially in the domain of Tangible User Interfaces (TUIs), where materials play a significant role in forming the interaction possibilities and creating rich experiences [2].

While HCI researchers are still developing the theories to support this emerging field, there are several design frameworks proposed, such as radical atoms [3], materiality of interaction [11], or interactive materiality [8]. One mutual implication among these design frameworks is that they all see the computational elements as design materials (a resembling way how designers see analogue materials), being subject to designerly crafting for creating infinite forms of new interactions. By meaningfully synthesizing the digital and analogue materials, designers are able to create novel and seamless user experiences.

Recently, there has been an increasing number of explorations explicitly taking the perspective of interactive materiality. However, more design cases are still needed in this burgeoning field to generate design implications and instructions for practice. To bridge the gap, in this pictorial we present a well-documented design exploration which yielded Puffy, an interactive artifact that spontaneously changes its materiality to express its emotions and intentions (See Figure 2A-D on p. 3). A user can see and feel its expressivity through its shape-changing and haptic properties. Our design process follows the interactive materiality approach [6], which consists of three key activities:

(1) Analyzing the design context;

(2) Synthesizing the findings and mapping to interaction behaviors; and

(3) Detailing the design artifacts.

With the goal of exploring computational materials and creating novel user experiences, we looked at several transition forms from nature and chose the shape transitions of pufferfish (especially its body texture and rebelling behavior) as our inspiration source. In the follow-up design process, the three activities, as mentioned earlier, were interlaced back and forth in several design steps (see Figure 1 on p.1), e.g., from probing the materials [4] to form-giving [9,10] and user experience evaluations. We analyzed different sources of input gained in various stages, synthesized self-reflections and peers' critiques, and detailed the design through iterative prototyping.

The contributions of our study are two folds. First, we demonstrate a novel design case of interactive materiality and its highly embodied design process. Second, based on a reflective analysis of our approach, we provide several design implications that can inspire future creators to design for interactive materiality.

Figure 2-A: 'Danger' approaches Puffy

Figure 2-B: Puffy starts to inflate and its materiality becames sturdy accordingly.

Figure 2-C: Puffy moves to avoid 'anger'

Figure 2-D: 'Danger' leaves and Puffy deflates

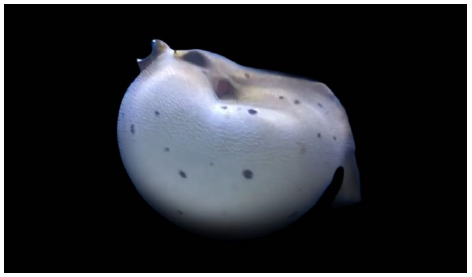
Shape transitions and analogue materials *(ANALYSIS)*

Shape transitions

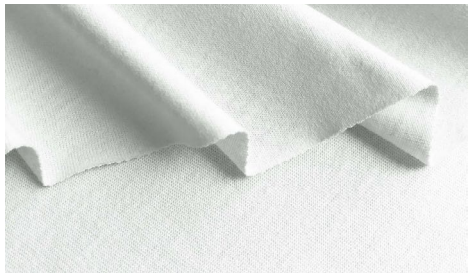
We first explored aesthetic insipration from the nature (animals, plants). We found that the shape transitions of pufferfishes had some interesting attributes: 1) the shape change of the fish communicates tension as the fish expands or squeezes; 2) the growth and angle change of its spikes emphasizes its repelling emotion.

Analogue materials

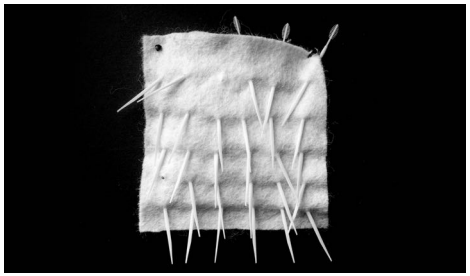
Then, we explored different materials to match the desired shape transitions from the prior analysis. We obtained a profound understanding of the selected behavior through first-hand explorations, emphasizing on the visual and sensorial feelings.



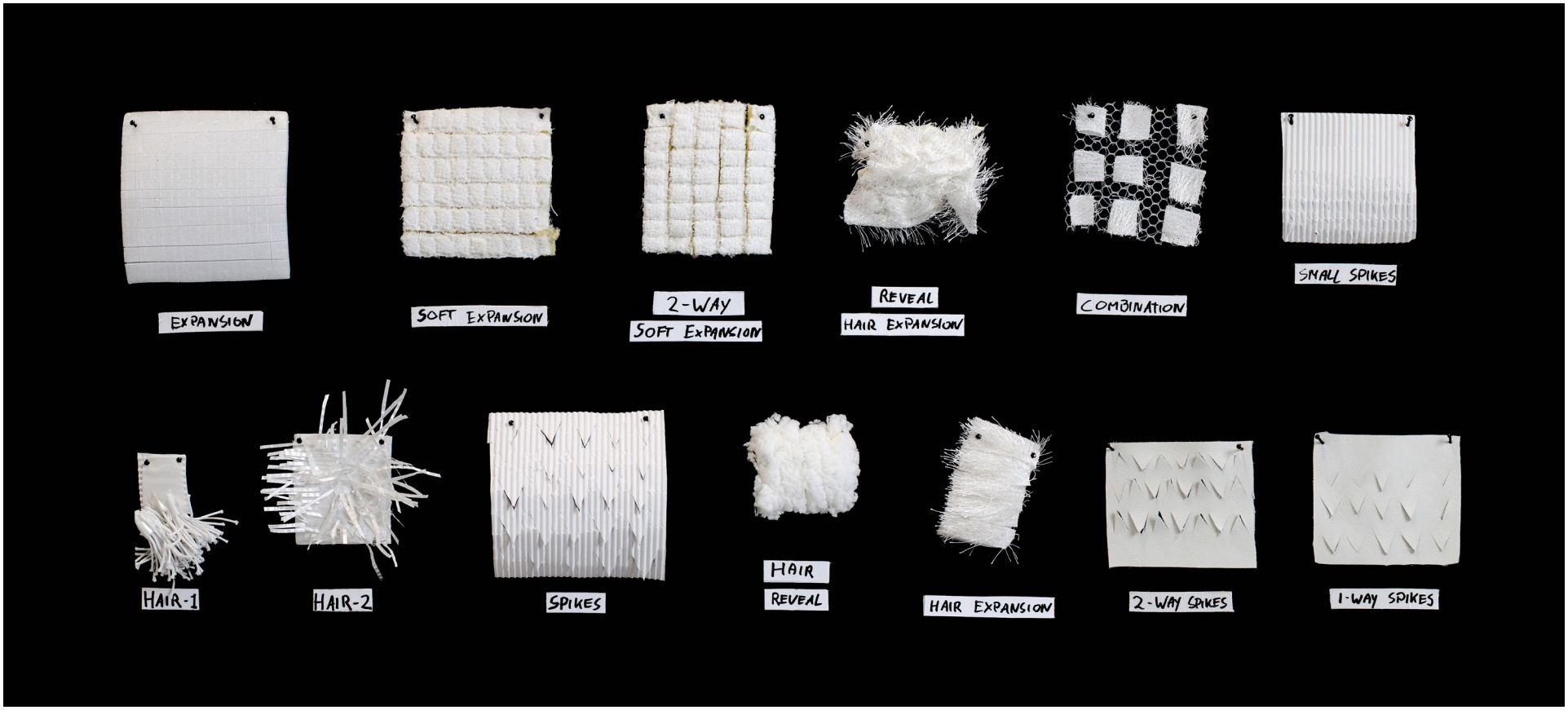


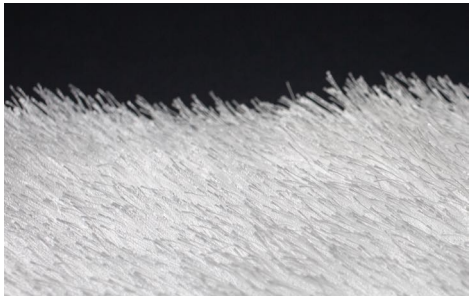
(Puffer Fish Puffing up when caught, 2011. https://youtu.be/ccsvJMkF5Bs)
(Blow me, Beautiful, 2013. https://youtu.be/S7y4quhmMW0)

(Dogface Puffer Fish Puffs Up Like Balloon, 2019. https://youtu.be/-qf5vPq_z7U)

Material *(SYNTHESIS)*



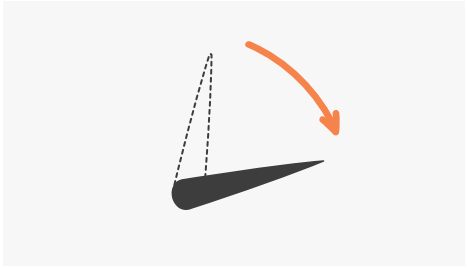
Among the explorations, some focused on manipulating material qualities, while others consisted of the combination of multiple materials to allow for expansion. Besides, we also looked at how we could produce our own materials with custom specifications (e.g. 3D printed hairy material, Cilllia [6]). While the exploration provided directions for material adaptation, we found that our transition could be best expressed through an un-adapted, hairy, fabric combined with a shape-changing mechanism worked best as it emphasizes the sturdy visual expression and haptic experience.



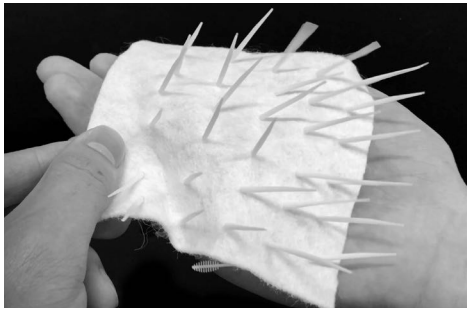
Transitions *(SYNTHESIS)*

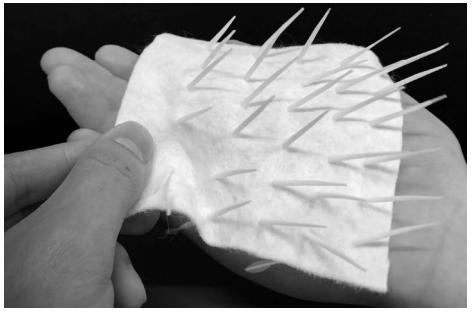
We used pufferfish as an inspiration to explore different transition techniques and aimed to find inherently coupled materials and transitions. We then synthesized our explorations regarding surface texture, shape transitions, and behavior movements respectively.

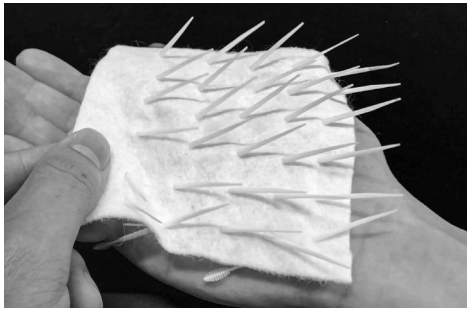
Transition diagram

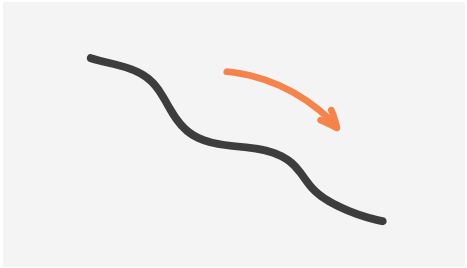


(**Straight** spikes to **flat**)

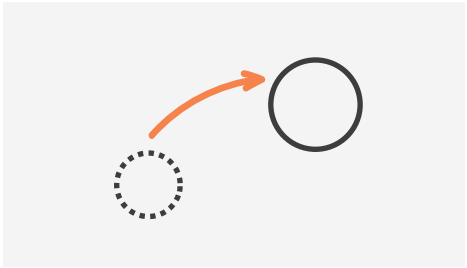






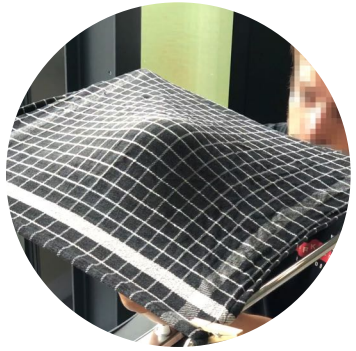


(**Non-linear** deflation)



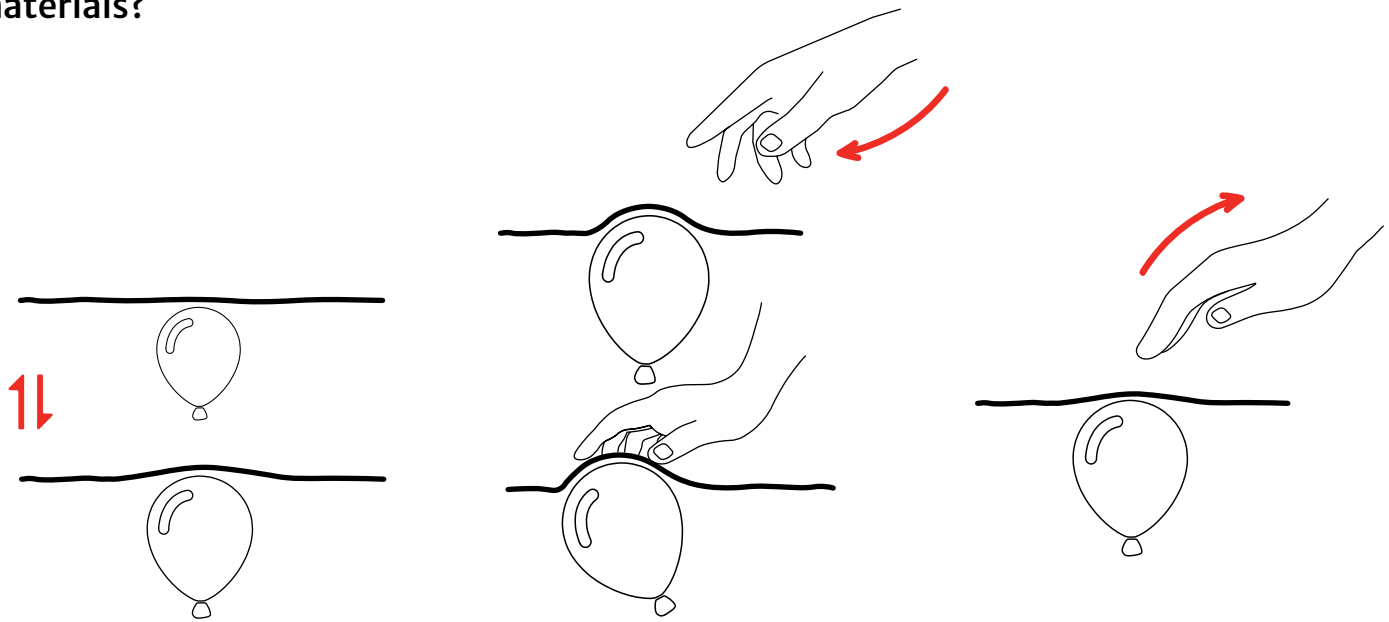
(**Movement** and **expansion**)

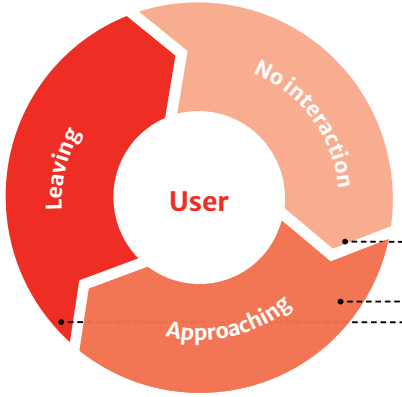
Encoding the symbolic notion of interactions *(DETAILING)*



In order to answer the question from an experience perspective, we used a quick-and-dirty setup consisting a texture of interest and a balloon underneath. By manipulating balloon (i.e. inflating, deflating, moving), the shape transitions could be made, allowing us to experience and evaluate the aesthetic qualities firsthand.

How can the materality react to the user with the synthesized transitions and materials?





Calm

When no human interaction involves, no siginifant changes on the materiality will take place. The object stays calmly in a back and forth looping transitions, just like 'breathing'.

Alerted

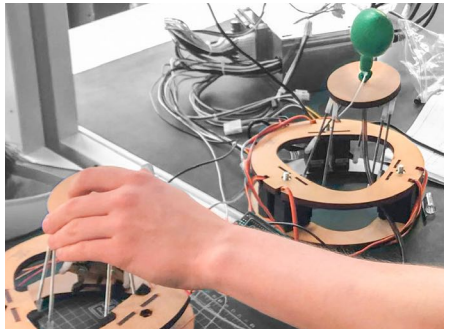
When a user attempts to approach, the object becomes alerted and expands significantly. Its surface becomes more sturdy and consecutively moves aways to escape from the 'danger'.

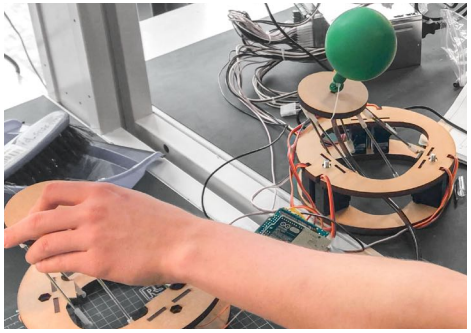
Relaxed

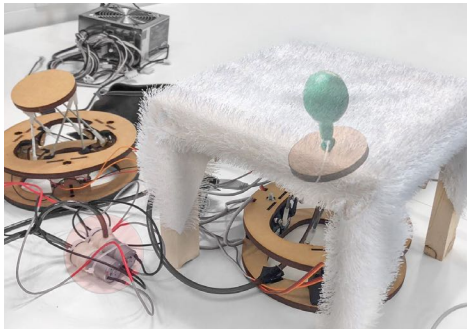
When the 'danger' disappeares, the object becomes relaxed and gradually squeezees itself and returns back to center.

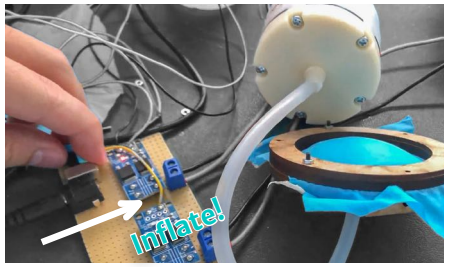
Experience setup *(SYNTHESIS)*

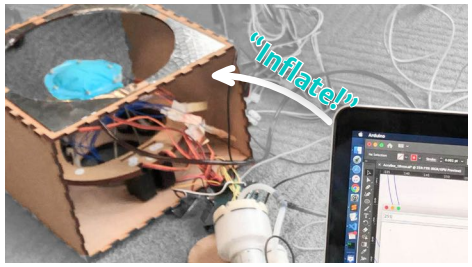
Using the defined transition from the analyses, we built a hand-controlled and servo-actuated prototype, based on the Stewart platform to explore different combinations of material and transition techniques. Through experiencing the setup, we learned that the variants and randomness of 'hair' on the elastic textile matched our selected transition.





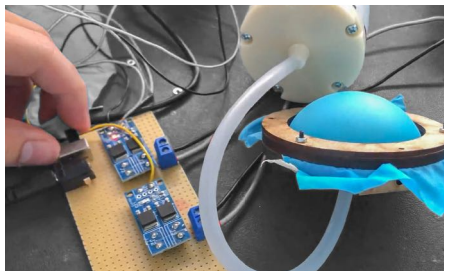


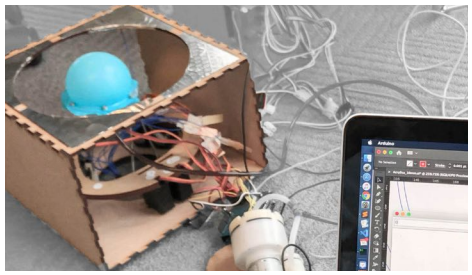


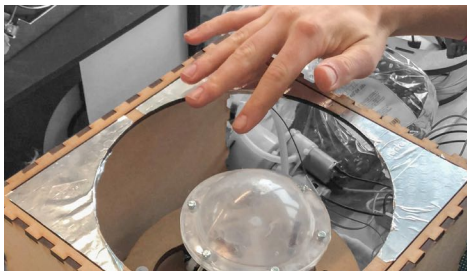


Computational mechanisms *(ANALYSIS)*

In order to have precise and comprehensive control over the materiality, we iteratively explored various computational mechanisms. We introduced pneumatic containers for customizing the shape transitions as well as capactive sensors for human behavior detection.







We iteratively explored different container structure and elastic materials to find the best inflation quality.

Penumatic container

Inspired by PneUI[13] we implemented an airtight pneumatic container that can inflated by a vaccume pump with manual control by a switch.

Acutation integration

Then, we integrated the container with the prior actuating prototype and use it to evaluate the quality of shape transitions and behavior movements with semi-manul control over a laptop.

Sensing integration

Next, we introduced a capacitive sensor for human behavior detection and exposed the sensing connectors with four sheets of aluminum foil distributed at the corners. This way, the prototype knows where and how closed the user is and takes actions spontaneously.

Design critique (*ANALYSIS*)

Before fine-tuning the artifact, two authors of this pictorial hosted a session of design critique. All participants were asked to follow the similar steps as mentioned in the design process. This session is aimed to help gain different perspectives of feedback for improvements in the consecutive stage.

Affirming the artifact

This step intends to grasp and feel the context. Participants leverage all their modalities to sense the artifact. They experienced the visual effect and appreciate their sensational response to the behavior of the artifact.

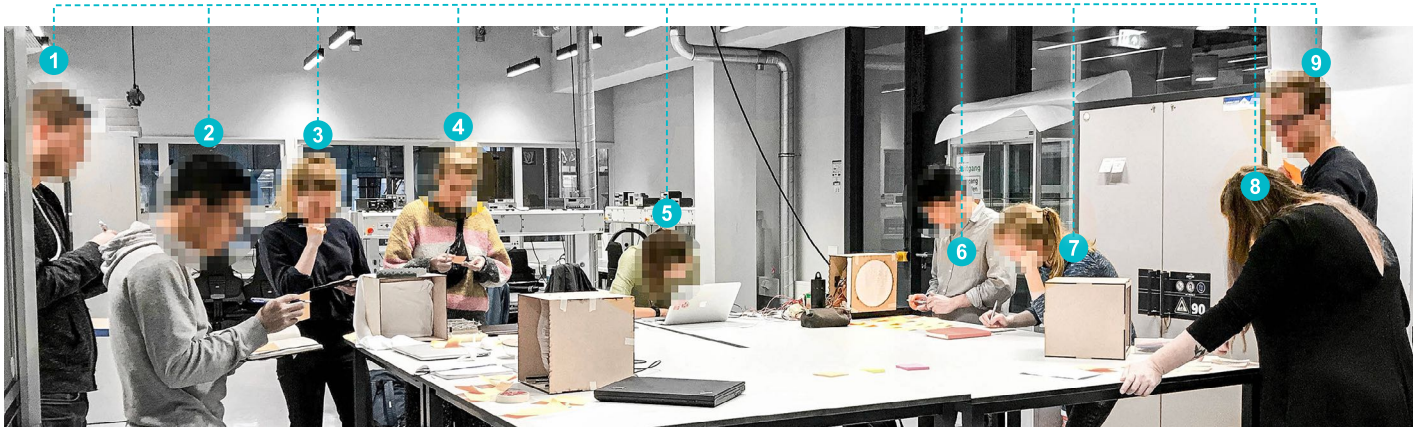
Interpecting the emotion

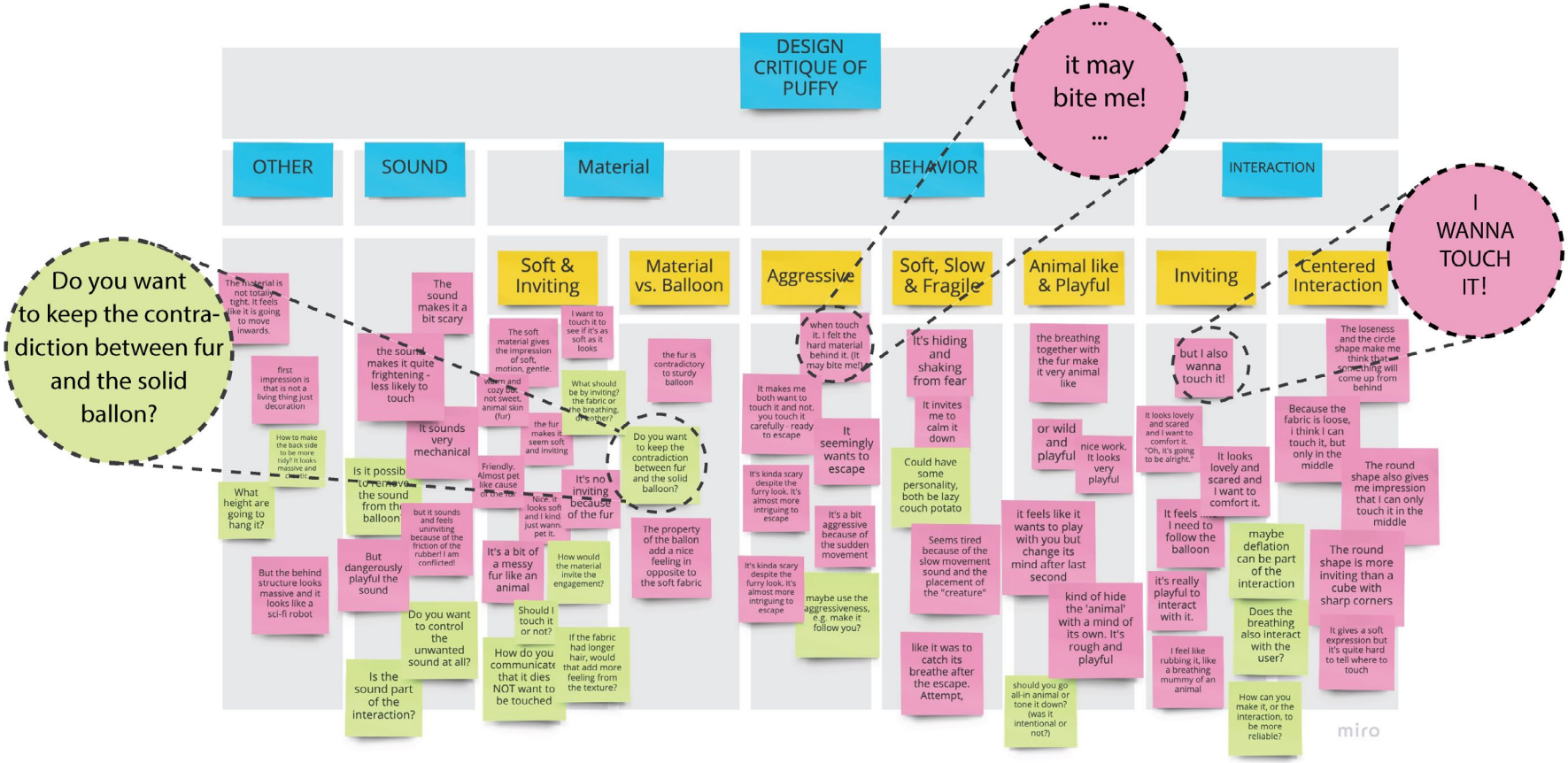
Once their first-person experience with the artifact is gained, partipants interprect the relation between the behavior and the emotion they perceive from the interactions with the artifacts.

Reflecting the symbolic notions

Partipants reflect on what messages the artifact and/or the designer intend to convey. These reflections were written on pink sticky notes. After that, they left questions and suggestions regarding the behaviors on green ones.

Participants with design background at MSc. level





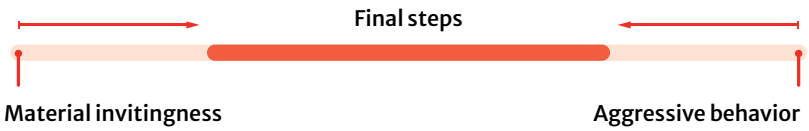
Affinity diagramming *(SYNTHESIS)*

The resulted remarked and questions were analyzed through Affinity diagramming [5] and clustered into five mian categories.

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. 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. 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.

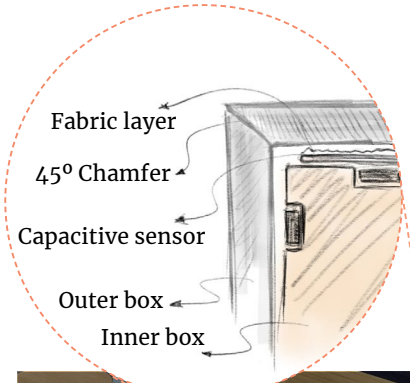
Next step

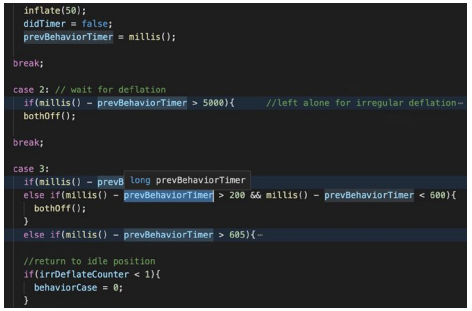
We acknowIedged that the invitingness of the surface material and the aggressive behavior conflicted too much. During the final step of our process, we aimed to bring these two conflicting aspects more towards each other, to further align the physical form, temporal form, and interaction gestalt.

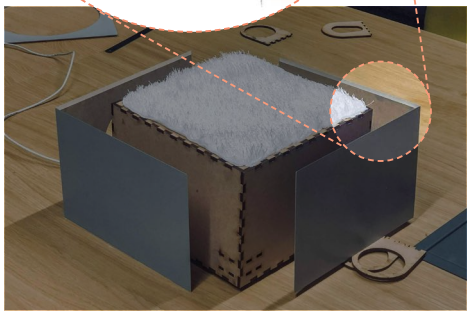


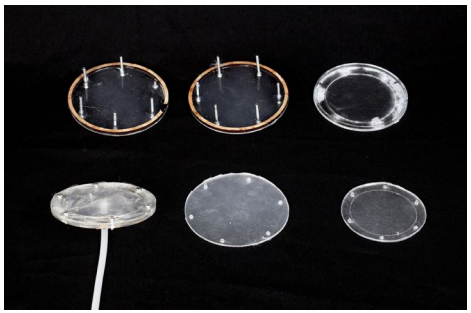
Prototype refinements *(DETAILING)*

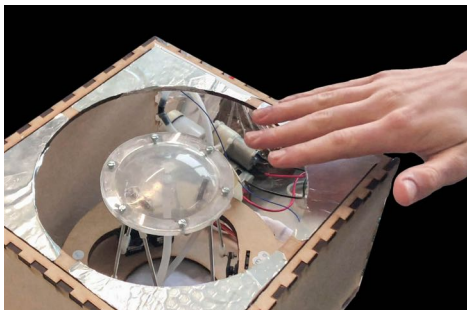
As metioned in the prior session, we aimed to decrease the aggressiveness of the behavior and increase the invitingness of the material. To achieve so, we respectively fine-tuned the prototype in regards to the sturdiness of the material, accuracy and robusticity of the computational system, appearance and placing position of the artifact.











Variants of sturdiness

We explored various degrees of sturdyness with different amounts of silicon 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.

Accuracy and robusticity

We adjust the actuators with slower and more fluent movements to reduce the aggressive experience. 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.

Durable and seamless

Our final design was assembled with two boxes. The inner box was constructed with teeth slots to provide support (e.g. mounting the fabric, pumps, and servos). The outer box was glued with 45° degree chamfers to cover the supporting box without joints, resulting in a seamless finish.

Landscape to vertical

Since we intend to create a closed loop starting from no interaction through approaching to 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.

Reflections

In this pictorial we described the process of creating novel user experiences with a shape-changing artifact using interactive materiality approach. Although our main approach is based on the three steps proposed in [8], from our practice we found that it was not adequate to apply the approach for one round. Alternatively, the Analysis, Synthesises, and Detailing interlaced back and forth several times to deepen our practical comprehension of materiality, as well as to evaluate and improve the user experience and design qualities. The interlacing process is not to simply redo analysis or redesign concepts. Instead, we iteratively tackled the complexity of digital and analogue materials and continually extracted insights to create intriguing user experiences.

Over the course of the study, we found this design process resembles artists' creation process. Firstly, many artists have been cultivating to gain inspirations from the nature (e.g. sketches of humans, animal, or plants). This consequently allows them to build a great repertoire of inspirational ideas. Like the beginning of our design process, we looked for nature analogy and was inspired by the pufferfish's form and behaviours. Secondly, they both do intense analysis and synthesis in the creation process. For instance, when *Pablo Picasso* created the famous painting *The Bull* in 1945, he went through serval iterations to analyse the shape of a bull and portray it from hooved, horned and muscled life-like to an abstract representation without losing identifiability (see Figure 3). Such a process mirrors the 'Synthesis' activity of our approach, that a designer synthesizes the most valuable elements from tons of inspirations. Lastly, they both require careful attention to the subtle expressivity of the materiality and created forms. A sculptor is constantly negotiating the texture and its expressivity with his hands and eyes. Similarly, in our design process we continuously explored the subtle touch feelings with alternative materials [4] and temporal forms [9] to investigate their expressivity through not only the creator's first person view but also the peers' critique.

Based on our practice, we thought such an interactive materiality approach can instigate designers to focus on the emotional or experiential aspects in addition to the pragmatic or functional features of a product. It may involve various creators and researchers who are interested in HCI and TUI to explore new design forms that deliver meaningful and affective experiences. By reflecting on our own journey of design, we now summarize a set of design implications that are intended to inform future design practice taking a similar approach:

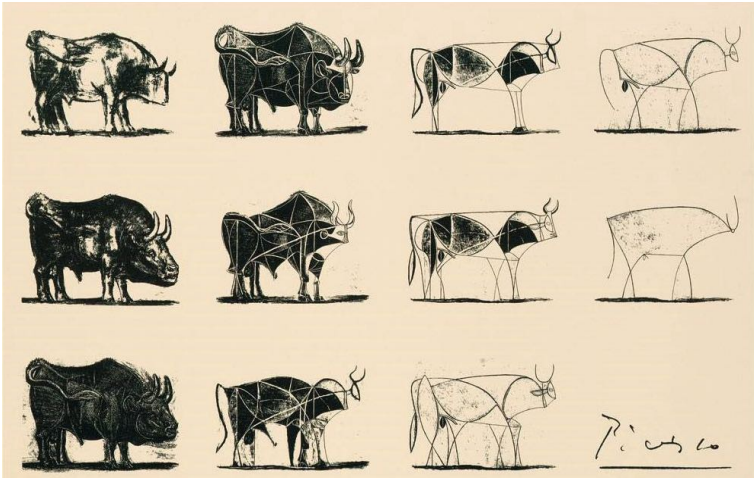


Figure 3. Pablo Picasso, *The Bull*, 1945

Leverage the open-endedness and unfinishedness in the early stage.

As describe previously, in the early stage of this design approach, we started with extensive freedom for design explorations. While such a large amount of freedom also created uncertainty, in the end we recognized the benefits of having multiple open-ended directions to explore. Actually, such open-endedness might be a key to success in interactive materiality design. Just like other designerly or artistic process of crafting (e.g., with clay or wood), interactive materiality design also heavily relies on the designer's embodied comprehension, or the tacit feel for the computational and analogue materials. And the freedom for exploration in the early stage ensures that the designers could conduct broad experimentations along various open-ended routes, which enables them to develop sufficient feel for the crafting materials at hand. And this will extensively benefit the later design stages in which they need to make decisions on which materials to use or how to further polish the chosen materials. And in such early open-ended experimentations, we also recommend that practitioners should not pursue the 'perfect' design samples, but feel comfortable with the unfinishedness of the samples (e.g., taking a quick-and-dirty technique), so that the experimentations could yield richer design possibilities or options.

Enable rich visual documentation throughout the exploration.

Another implication we gained from reviewing this project is the importance of having rich visual documentation, for example, in forms of videos, photos, or sketching. The purpose of having rich documentation is not only for post-hoc analysis or inspiration for future practice. But rather, rich documentation is also very much needed in supporting sensemaking and decisions throughout the design process. As mentioned earlier, our design process has been constituted by multiple rounds of Analysis, Synthesis and Detailing. In each round, we also heavily built upon the design rationales generated in previous rounds. However, much of our design experimentations, evaluations, and decisions cannot be fully communicated by texts along, but need to rely on visual communication as well. On the other hand, visual documentation can also help designers review how their decisions were made, since design decisions can sometimes go intuitive and unconscious. Rich visual documentation using video clips, photos, or sketching could therefore benefit communication and deliberation throughout the process.

Emphasize the hedonic and experiential aspects in the exploration.

As demonstrated in our approach, our exploration has been heavily focused on the nuances of the hedonic and experiential aspects in the designed artifacts. And we recognize this as an advantage of such an interactive materiality approach, which could complement the design approaches that focus on the pragmatic aspects of design (e.g., utility, usability, or efficiency). With our addressed approach, much of the designer's attention could be effectively directed to the subtle differences of the sensorial, experiential and aesthetic aspects of the interactive artifacts, with the very depth that is often not likely to achieve in pragmatic approaches of design. From our own experiences, such an approach could meaningfully shift the problem-solving mindset of designers to a curiosity-driven mindset, and help them to get immersed in the playful, embodied, and purposeless experimentations with computational and analogue materials at hand. Therefore, we recommend that such an interactive materiality approach could be more widely adopted as a complementary, or additional method to traditional interaction design processes, so that the designers could be equally facilitated in both exploring the pragmatic qualities and the hedonic qualities.

Conclusion

As material-centered design approach becomes popular in HCI community, materials play an increasingly important role in forming the interaction possibilities and creating rich experiences. Nonetheless, design cases that show designerly ways of crafting infinite forms of new interactions are still needed for instigating more design implications and instructing practices. This pictorial presents a concrete case of designing a shape-changing artifact using the materiality approach. The approach consists of three key activities (analysis, synthesis, and detailing) interlaced back and forth along the whole design process. The 'analysis' activity gains nature-inspired analogy and iteratively explored from shape transitions through analogue materials and computational mechanisms, to gain understanding of the design context; The 'synthesis' activity synthesized findings regarding digital and analogue materials, both self-reflections and peers' critiques, to navigate the consecutive activity; The 'detailing' activity encoded the designers' symbolic notions of the interactive materiality as well as the synthesized critique from the audience into a set of iterative prototypes. Our reflection surfaced the value of having such an interlaced iterative process. As a result, by offering a reflective analysis of our approach, we demonstrate a highly embodied design process and a set of practical implications, to inspire future creators to design interactions with interactive materiality.

REFERENCES

[1] Tanja Döring, Axel Sylvester, and Albrecht Schmidt. 2012. Exploring material-centered design concepts for tangible interaction. In CHI '12 Extended Abstracts on Human Factors in Computing Systems (CHI EA '12), 1523–1528. https://doi.org/10.1145/2212776.2223666

[2] Sarah Hayes and Trevor Hogan. 2020. Towards a Material Landscape of TUIs, Through the Lens of the TEI Proceedings 2008-2019. In Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '20), 95–110. s://doi.org/10.1145/3374920.3374944

[3] Hiroshi Ishii, Dávid Lakatos, Leonardo Bonanni, and Jean-Baptiste Labrune. 2012. Radical atoms: beyond tangible bits, toward transformable materials. Interactions 19, 1: 38–51. https://doi.org/10.1145/2065327.2065337

[4] Heekyoung Jung and Erik Stolterman. 2010. Material probe: exploring materiality of digital artifacts. In Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction (TEI '11), 153–156. https://doi.org/10.1145/1935701.1935731

[5] Andrés Lucero. 2015. Using Affinity Diagrams to Evaluate Interactive Prototypes. In Human-Computer Interaction – INTERACT 2015, Julio Abascal, Simone Barbosa, Mirko Fetter, Tom Gross, Philippe Palanque and Marco Winckler (eds.). Springer International Publishing, Cham, 248. https://doi.org/10.1007/978-3-319-22668-2_19

[6] Jifei Ou, Gershon Dublon, Chin-Yi Cheng, Felix Heibeck, Karl Willis, and Hiroshi Ishii. 2016. Cilllia: 3D Printed Micro-Pillar Structures for Surface Texture, Actuation and Sensing. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16), –5764. https://doi.org/10.1145/2858036.2858257

[7] Daniela Rosner, Jean-François Blanchette, Leah Buechley, Paul Dourish, and Melissa Mazmanian. 2012. From materials to materiality: connecting practice and theory in hc. In CHI '12 Extended Abstracts on Human Factors in Computing Systems (CHI EA '12), 2787–2790. s://doi.org/10.1145/2212776.2212721

[8] Jelle Stienstra, Miguel Bruns Alonso, Stephan Wensveen, and Stoffel Kuenen. 2012. How to design for transformation of behavior through interactive materiality. In Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design (NordiCHI , 21–30. https://doi.org/10.1145/2399016.2399020

[9] Anna Vallgårda. 2014. Giving form to computational things: developing a practice of interaction design. Personal and Ubiquitous Computing 18, 3: 577–592. https://doi.org/10.1007/s00779-013-0685-8

[10] Anna Vallgårda and Tomas Sokoler. 2010. A Material Strategy: Exploring Material Properties of Computers. International Journal of Design 4, 3: 1–14.

[11] Mikael Wiberg. 2016. Interaction, new materials & computing – Beyond the disappearing computer, towards material interactions. Materials & Design 90: 1200–1206. https://doi.org/10.1016/j.matdes.2015.05.032

[12] Mikael Wiberg, Hiroshi Ishii, Paul Dourish, Anna Vallgårda, Tobie Kerridge, Petra Sundström, Daniela Rosner, and Mark Rolston. 2013. Materiality matters---experience materials. Interactions 20, 2: 54–57. https://doi.org/10.1145/2427076.2427087

[13] Lining Yao, Ryuma Niiyama, Jifei Ou, Sean Follmer, Clark Della Silva, and Hiroshi Ishii. 2013. PneUI: Pneumatically Actuated Soft Composite Materials for Shape Changing Interfaces. In Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology (UIST '13), 13–22. https://doi.org/10.1145/2501988.2502037