INTERACTIVE MATERIALITY

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TU/e - Industrial Design

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INTRODUCTION

This report is a group effort, made by Bram Rutten, Peter Jongste and Dennis Rietveld. It summarizes our views, insights and process within the master elective 'Interactive Materiality' at the Technical University of Eindhoven, faculty Industrial Design. The course was supervised by Simone de Waart and Miguel Bruns Alonso. They provided us with literature on the subject, weekly feedback and gave presentations on the theory.

Our eventual assignment was to formulate a symbolic notion and translate this into the design of an interactive materiality.

LITERATURE POSITIONING

Positioning Dennis
Within this paragraph, I will position my view on Interactive Materiality (IM), related to the literature available on both this- and closely related subjects. I will use the research done by others to substantiate the grounds of- and current perspectives on the IM concept and I will reflect on this to obtain my personal view regarding IM.

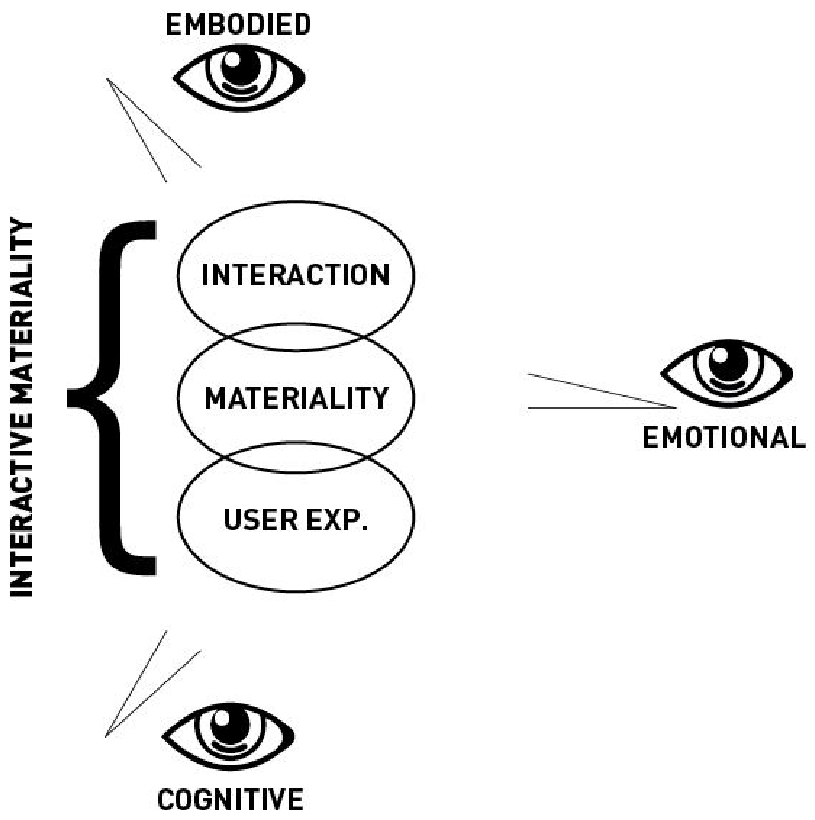
Interactive materiality is a developing concept that is used and researched mainly by interaction designers. The concept was initiated by Stienstra and Bruns [1], who founded the term to "highlight the distinction between static informing products, and the dynamics of interactive and intelligent products and systems"(p.26). The work of Parkes and Ishii [2], which many interaction designers see as the origin of the IM movement, describes the concept of 'Hybrid Materiality' [2]; which is summarized as "an internal material loop that affects the tactile and kinetic feedback offering new perceptual qualities in interactions just outside of the control of the user, yet affected by the user's actions" (p.198). Looking further into the future and the role of interactive materiality in society, Ishii [3] wrote a paper on Radical Atoms. Radical Atoms is herein explained as "a vision for the future of human-material interactions, in which all digital information has physical manifestation" (p. 38)[3].

Rasmussen [4] wrote more generally about interfaces that allow for 'dynamic affordances', which he described as "perceived action possibilities that change with changes in shape" (p. 743). Vallgårda [5], on her turn, looked more into the interaction part of the concept, leaving the 'materiality' underexposed. She describes 'Computational composites' as the substance in which physical and temporal form meet, to eventually form new interaction gestalts [5].

Based on these findings, I divided the concept IM in three categories: interaction qualities (interaction gestalt, feedback, feedforward [6]), material properties (programming, sensing/actuating, shape-change [4]) and user experience (expression, perception). In my view, these are the core areas of research and summarize IM concisely; the action-reaction loop, the programmable material properties and the user perception of affordances and feedback.

Additionally, by comparing the IM research, I found three distinctive perspectives of looking at the concept. These levels are interwoven into IM objects, but can be seen separated partly in research practices. Firstly, one can look at IM from (1) an embodied/exploratory level. This level focusses on respecting all human skills [1] and looking into bodily sensing/perception. A frequently used and highly relevant theme herein is looking at hand gestures and researching 'touch'. Lederman & Klatzky [7] namely state that "direct touch can achieve high levels of perceptual performance" (p.343) and Ishii [3] mentions that it "offers high-precision manipulation with direct haptic feedback from the operand" (p. 47). A Method to explore these hand movements is for example an exploratory procedure (EP) [7]. Secondly, one can look at IM from (2) an emotional/perceptual/ expressive level. This level focusses on the objects' expressions and the users' perception of these expressions. De Rooij [8] mentions that "It looks at the emotional, expressive side of feedback and feedforward: applying abstract expressions inherently in devices to make understandable interactions, playing with basic motion and form features essential to the recognition of emotion" (p.2). Also, it looks into what effect IM's have and how to fine-tune sensitivities and modalities to achieve liminality and just-noticeable-differences for the action-perception loops [1]. And last, there is the (3) cognitive/ ethical/contextual perspective of looking at IM. This perspective is more focusing on reasoning about the subject, the ethical issues and the contextual implementations. This last perspective is more theoretically orientated and is often a base for- or outcome of the other two perspectives. Rasmussen [4] is for example looking into building a base of knowledge on shape-changing interfaces, where Ishii [3] focusses thoroughly on the future implementation with his concept of Radical Atoms.

I think that a society with IM integrated in daily life objects would result in overall higher aesthetical



pic. 1 Visual Perspectives IM, D. Rietveld

interactions. Unlike many physical user interfaces today, IM focusses closely on the details in interaction and pays attention to the perception and corresponding emotions. Instead of mainly looking into the non-aesthetical details of a button (like 'black, circular, large') [9] and providing them with augmented feedback [6] to make them understandable, IM focusses more upon integrating aesthetic qualities (graceful, balanced, powerful) which are gained from the perception of non-aesthetic details [9].

I can only dream of a society where material properties become computational or even chemically programmable. Besides the fact that I can think of many concrete applications, I'm especially imagining opportunities for a new way of learning. When any object can display, embody and respond to digital information as Ishii mentioned in his paper about Radical Atoms, we can directly relate theory to practice and simultaneously teach people through cognitive, emotional and embodied experience. This would radically change the educational system/industry; a core goal that I'm striving for in my career as a designer.

Positioning Bram
Based on theory I explain my view on Interactive Materiality. It raises more questions on ethics. The way people perceive aesthetics in interaction is dependent on their cultural background [9]. People might perceive the general expression of an interface in a similar way, but the association depends on earlier experiences from the person.

Anthropomorphism may help to learn people how to perceive an expression, because they are already familiar with the expression from nature. Many expressions are perceived as they are, because of the relative distinction from what people are used to [8]. The reason for using Anthropomorphic expression in interfaces can be to evoke a suggestion of life inside the object [4]. The suggestion of life can play a substantial part of promoting interactive materiality, because it gives users the opportunity to familiarise with the object. People often look for nostalgia in a product to feel comfortable using it.

Radical Atoms will enable the digital to become tangible [3]. The revolution of flexibility that unfolded in touch screen interfaces opposed to more conventional display interfaces operated by buttons, will be possible with more materials. When the distinction between actuator and material falls, in other words if the material becomes the actuator, the user will be able to get closer to the computation. Material user interfaces can be very disruptive as they realise even more ubiquitous display and interaction with information, both visual as well as tangible. The digital has become tangible and the tangible will become reactive. Reactive physical interfaces create new opportunities for user input. The user can physically interact with the interface and therefor with the displayed information. The interface can memorise the it's shape change initiated by the user and play it back [2]. Designers can also use this to prototype with the physical object rather than from a traditional digital starting point. This can lead to more organic behaving shape changing interfaces, because the user input is more organic through physical input than through traditional digital programming. Computational composites complicate the design process. Designers are used to give shape to static objects, but how do they go to work with temporal form, computational state changes and the interaction gestalt [5]. All three factors are interconnected. The physical form is more often the following factor. Especially when the starting point is the interaction gestalt or temporal form.

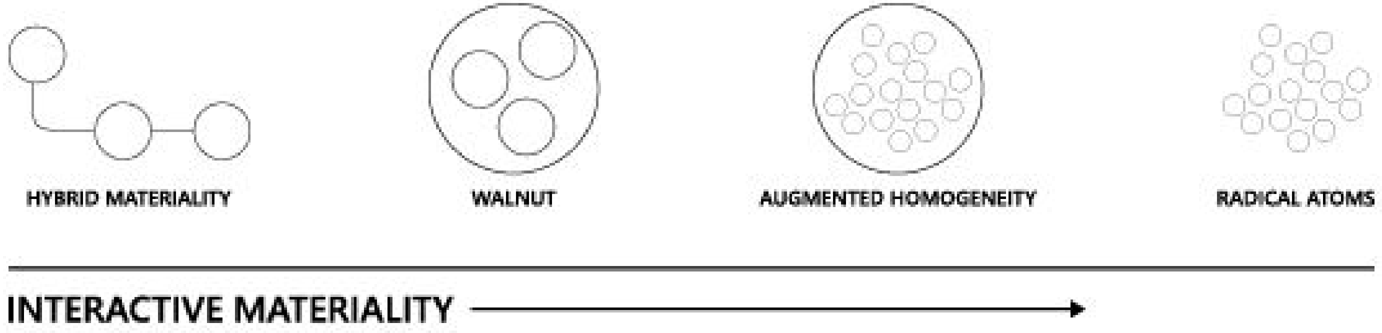
What will happen to the trust people build up with an interface if the interface reacts unexpected? Designing new interactions which do not react to the user's actions as expected may cause permanent behaviour change towards new interfaces [1]. Designers have the means to disrupt daily routine of people by manipulating them through an interaction. The ubiquity of information nowadays has already changed how children learn. It is no longer necessary to learn the topography of your country in detail, because if you know how to look it up you do not have to remember it, so it becomes possible to remember something else instead. This shift has come only from the availability of abundant information. Interactive Materiality is likely to also cause a new way of thinking. Interactive Materiality may lead to a new generation of people who are able to think outside of the box, because the threshold of what is normal to people growing up shifts. Growing up with ubiquity of shape changing objects and computational composites can lead to a generation ready for innovations in traditional areas that have not changed for decades from what is conventional. Over time Interactive Materiality will replace many conventional interactions. The ubiquity of Interactive Materiality will enable abundance of information even more then we are used to. Can people still have their moment to stand still and reflect on their life or do designers allow constant distractions from a cluttered periphery? People developed a hunger for quick information. Constantly checking on their smartphone. Perhaps Interactive Materiality brings opportunities to satisfy this hunger and give at the same time a more in depth experience rather than a shallow graphical user interface, therefor engaging for a longer period of time instead of quick.

Positioning Peter

Through this introduction, I will aim to define the field of Interactive Materiality (IM) positioned from my personal perspective, by using literature related to it. I will build this definition upon current perspectives on IM, and through this will obtain my personal perspective on the subject.

Within the field of Shape Changing Interfaces, the combination of material, sensor, and actuator is used for a variety of functionalities. Where a material in itself mostly exists of a physical form and an Interaction Gestalt [5], the addition of manipulating it through sensors and actuators provides the material with a temporal form; an element not unknown in the field of Interaction Design. Through this temporal form various functionalities can be achieved, through for instance shape change.The ability of objects in to change shape within this temporal form could serve both as a means of input and output, and it could serve both functional and hedonic purposes[4].

A key aspect of shape changing interfaces making them useful and usable, is their ability to transform [4]. One of the ways this transformation could occur, is through manipulation of the interface by the user. Today's shape changing interfaces however, are still designed in a heterogenous manner. Rather than combining material, sensor and actuator homogeneously, the three are mostly designed and implemented separately[3]. The heterogenous design of these elements could provide for an impesion of both transformability and implementability.In some designs however, this transformability is intentionally impeded to ensure the maintenance of controllability in interaction. An example of this is Bosu, where Parkes and Ishii argue that "an underlying skeletal structure combined with organic elements expands the threshold of controllability, pushing both the natural-like nature of an interaction with the designer's ability to control and designate the interaction."[2] Leading from current literature



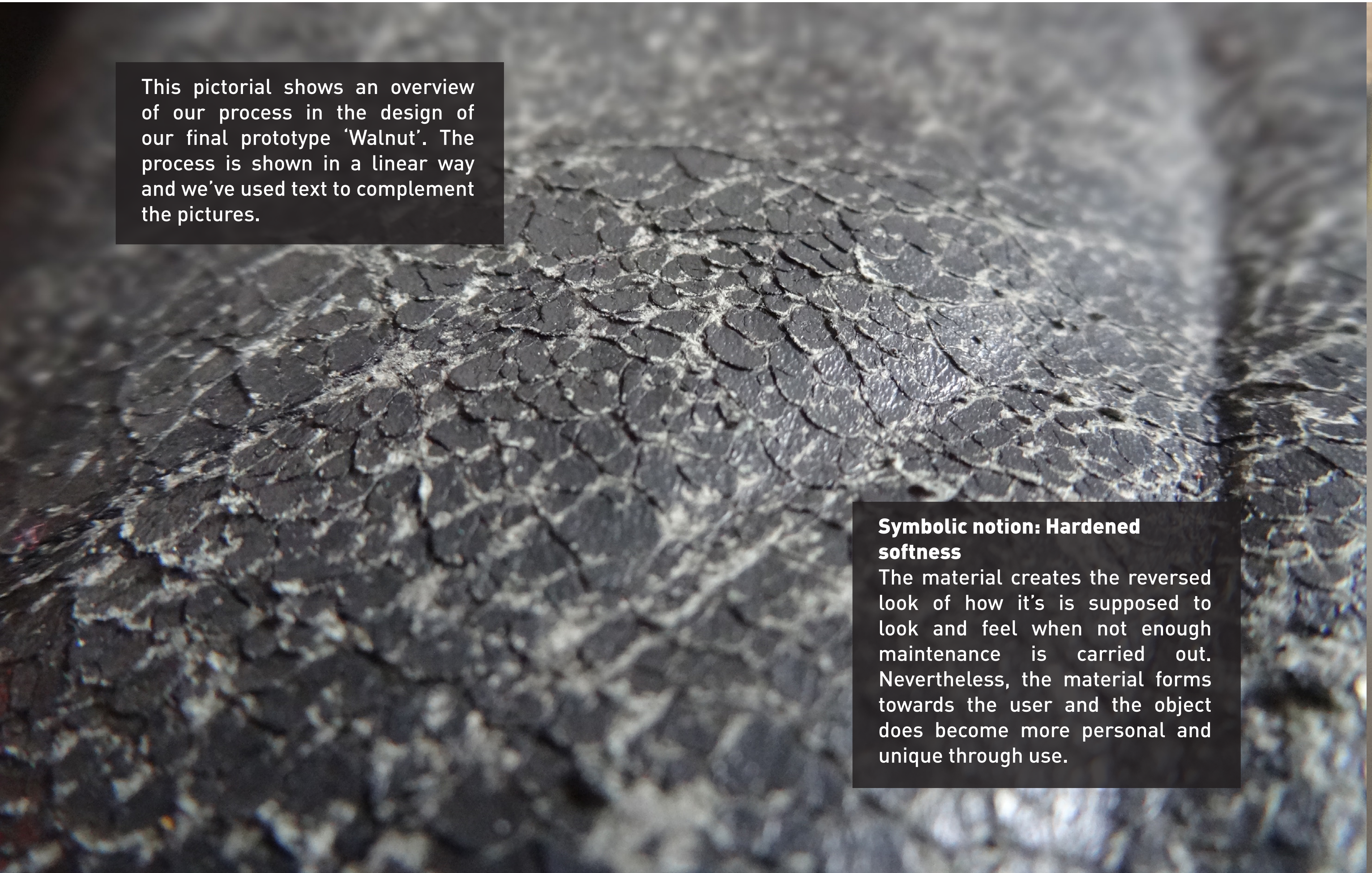
pic. 2 Visual Augmented Homogeneity, P. Jongste

related to the field of Interactive Materiality, I believe this design space could be best described as a vision-driven theory adapting to to both current and envisioned technological advances within the scope of shape changing interfaces. Currently I feel it to be at the reach of achieving a restoration of natural coupling in the relation of function and action as described in Interaction Frogger[6] through materiality. To give a personal comprehensive and airtight definition of Interactive Materiality however would be to limit the field and its capacity to grow. Whereas in its current state it envisions to solve the successful implementation of material, sensor and actuator in a homogenous manner, The evolution of defining Interactive Materiality shows in my opinion both connections to past as to possible future technological developments. I believe this evolution of the design space we call Interactive Materiality to have started with the concept of Hybrid Materiality[2]. This Tangible Interaction Loop, as described by Parkes and Ishii, aims to create an "Internal material loop that affects the tactile and kinetic feedback offering new perceptual qualities in interactions just outside of the control of the user, yet affected by the user's actions". Slowly moving forward from this initial point of view regarding Interactive Materialy, I see the design space progression towards a material state I would like to define as Augmented Homogeneity. I define this state as material, actuator and sensor still being designed and implemented in a heterogenous matter, while both sensors and actuators are actually capable of respectfully sensing and actuating along the same parameters as the material's transformability. This way the idea of a homogenous combination could be hinted at. To measure the successfulness of this implementation, the haptic exploration and object recognition by Lederman and Klatzky could be used[7]; showing that the combination can be perceived as a three dimensional homogenous material with the addition of an internal material loop for transformation of material properties.

Where the example above shows the field of Interactive Materiality dealing with current technological advances and advances in the near future, the theory of Radical Atoms [3] can be seen as an envisioned technological advance pushing the field of Interactive Materiality forward, aiming to implement a computational part within the material in the same homogenous manner as described earlier. Being able to perform this implementation successfully, could provide for a seamless interaction between a physical state of the shape changing interface and its underlying digital model. An example of this implementation can be provided in the concept of "Perfect Red"[3], a fictional clay like material pre-programmed to have many of the features of computer aided design. A concept like this however requires the successful implementation of nanotechnology, showing that the homogenous combination of material, shape, actuator, and computation still lies in the future.

The examples above show my personal view of the conception and progression of a design space called Interactive Materiality from its conception until its current state, and propose future goals. The visual on the previous page summarizes this process. From the context of my own vision and identity, I believe that the field of Interactive Materiality shows great potential to tackling complexity in growing systems and user interfaces, through giving the user highly contextualized and rich information through a continuously transformable information layer.

PROCESS PICTORIAL

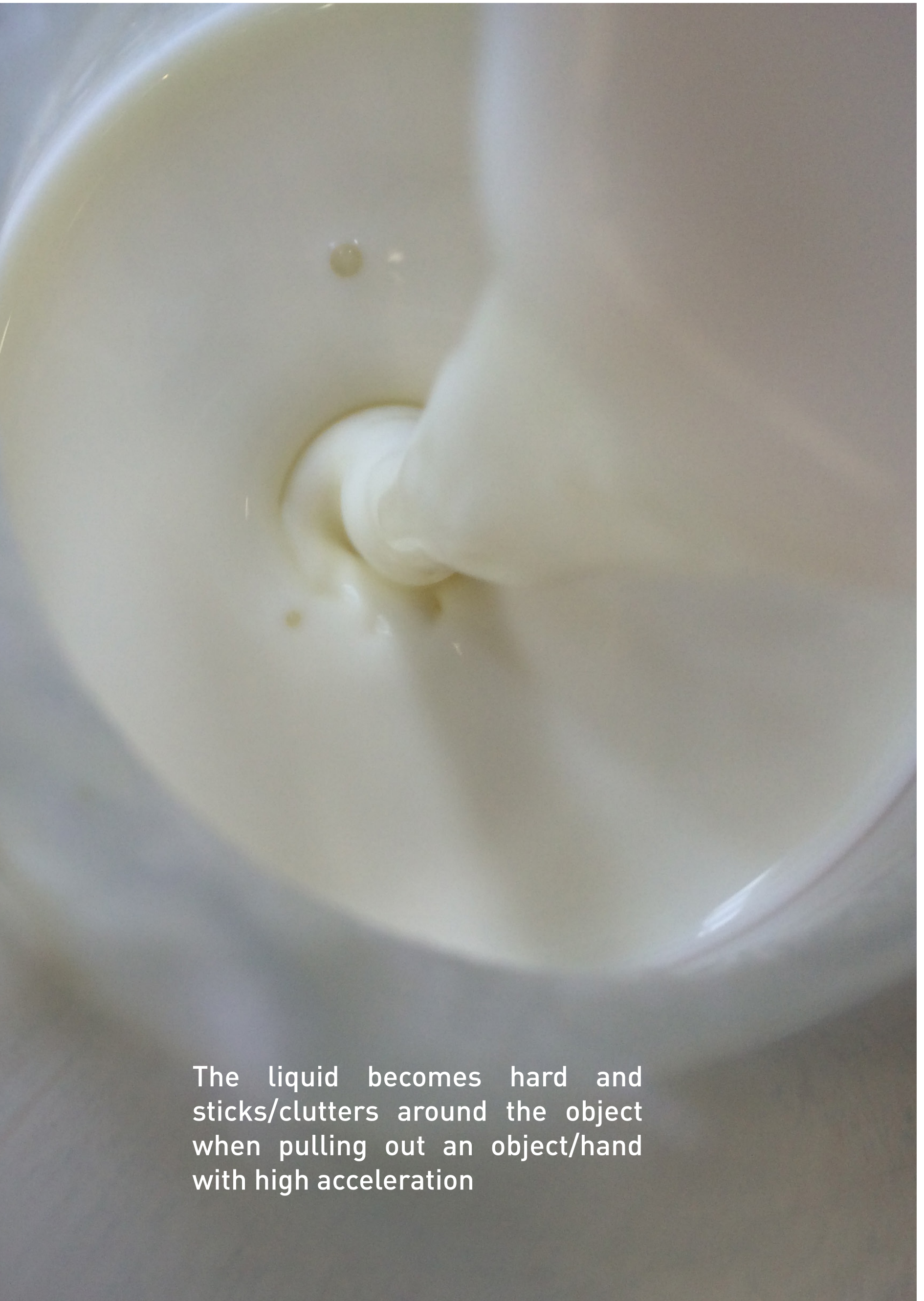


This pictorial shows an overview of our process in the design of our final prototype 'Walnut'. The process is shown in a linear way and we've used text to complement the pictures.

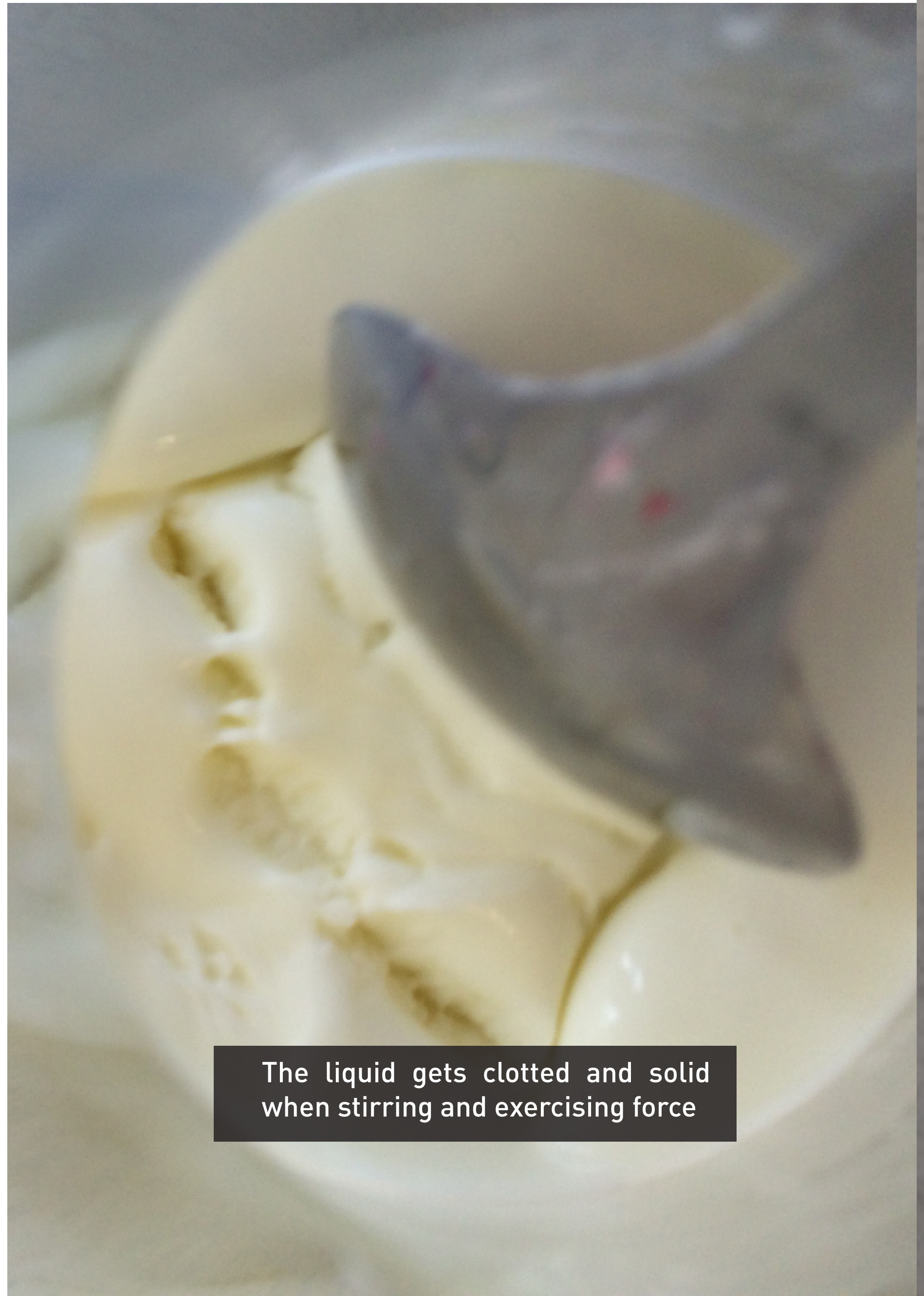
Symbolic notion: Hardened softness
The material creates the reversed look of how it's is supposed to look and feel when not enough maintenance is carried out. Nevertheless, the material forms towards the user and the object does become more personal and unique through use.

Non-newtonion fluid
With the aforementioned symbolic notion, an exploration into materials was executed. The most interesting result of this exploration was the non-newtonian fluid.

The surface of this liquid becomes hardened when pushing down quickly



The liquid becomes hard and sticks/clutters around the object when pulling out an object/hand with high acceleration

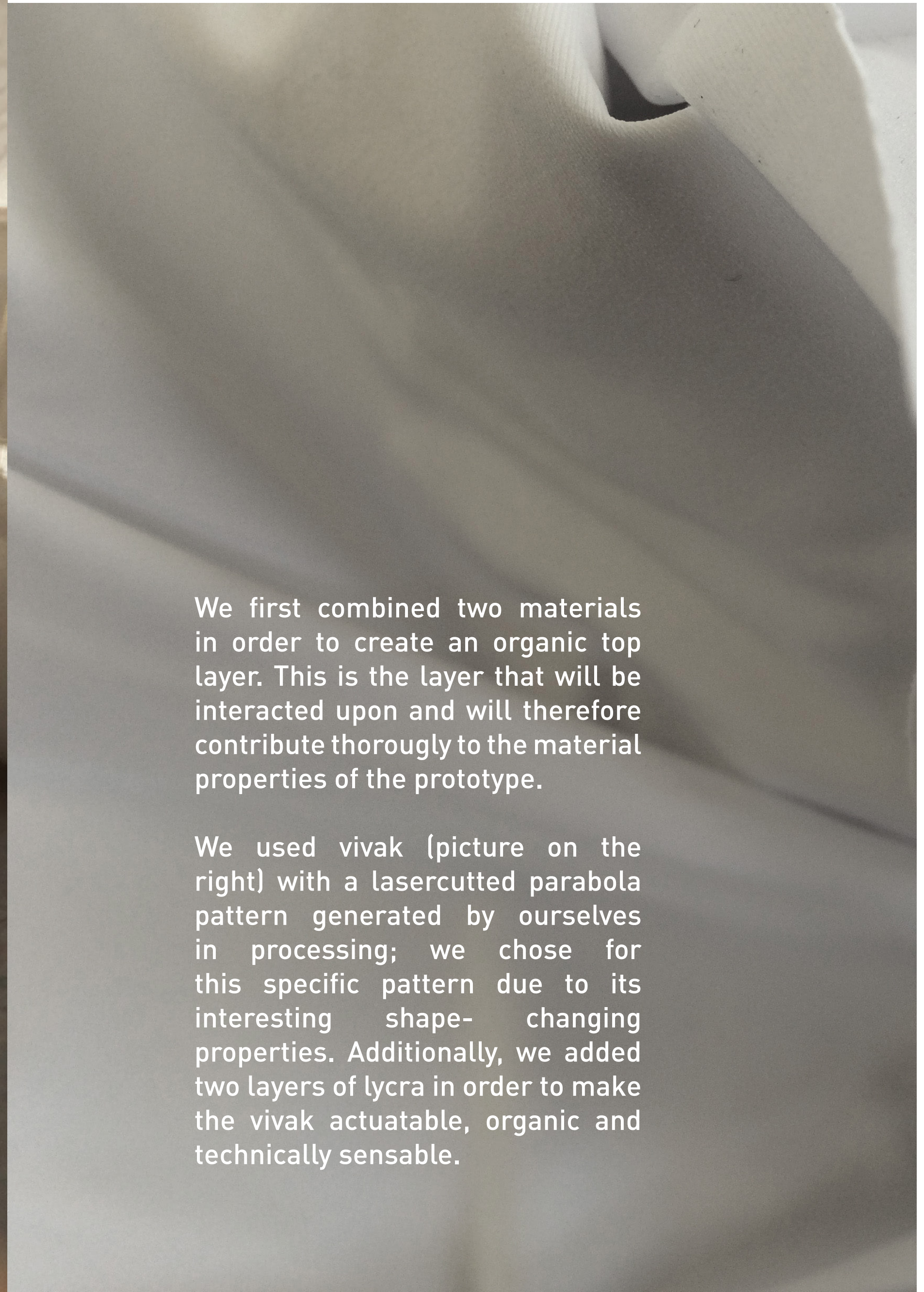


The liquid gets clotted and solid when stirring and exercising force

The liquid allows for objects to sink, as slow movement/low pressure will leave the material in it's liquid form

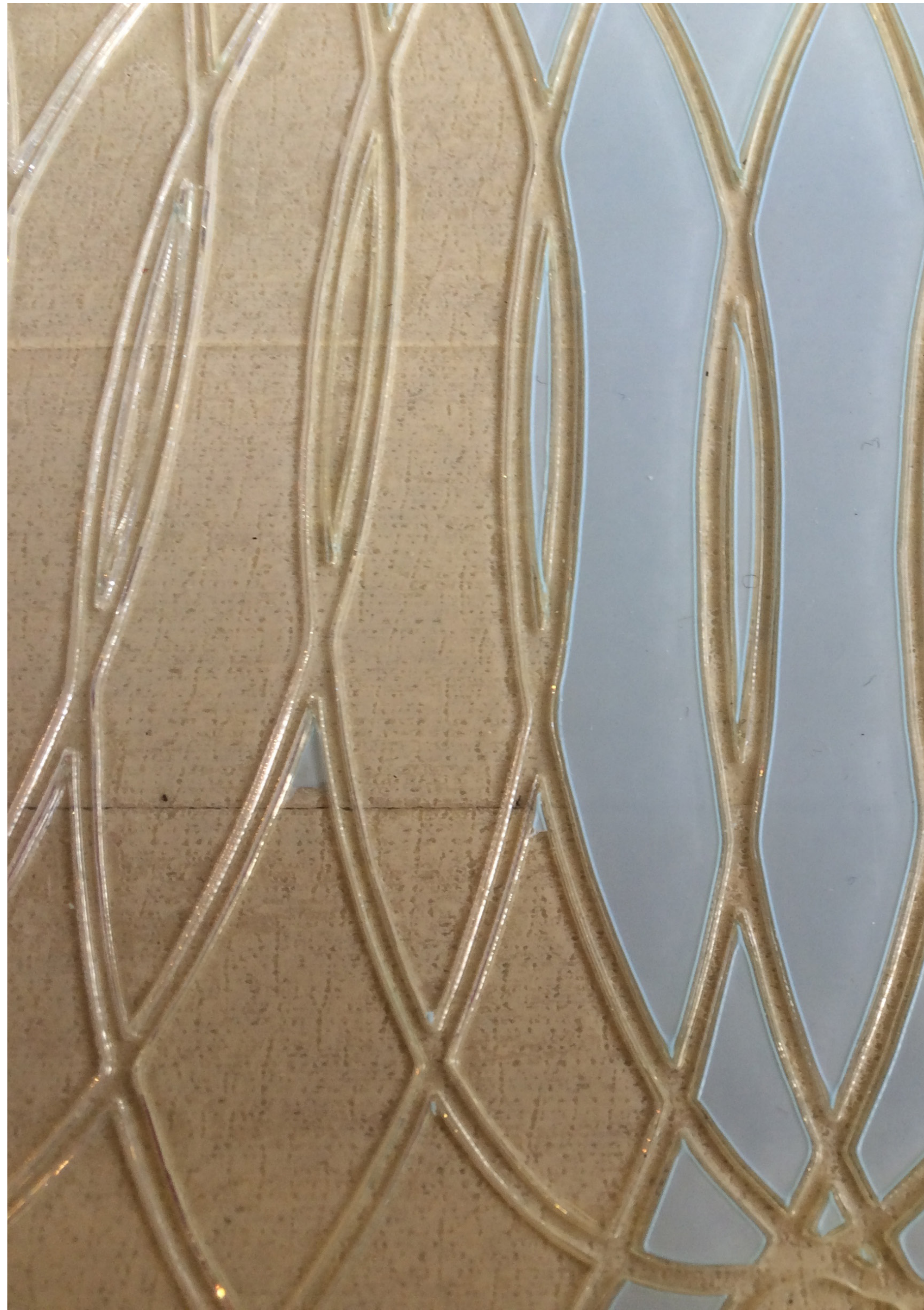
Concluding, the non-newtonian fluid reacts in a reversed way on action as expected. Exerting force will make it physically harder to get through it and will even visually change the substance. The fluid keeps intriguing the person to interact with it by means of its unintuitive response on multiple levels.

We decided to translate this properties into a programmable interactive materiality



We first combined two materials in order to create an organic top layer. This is the layer that will be interacted upon and will therefore contribute thorougly to the material properties of the prototype.

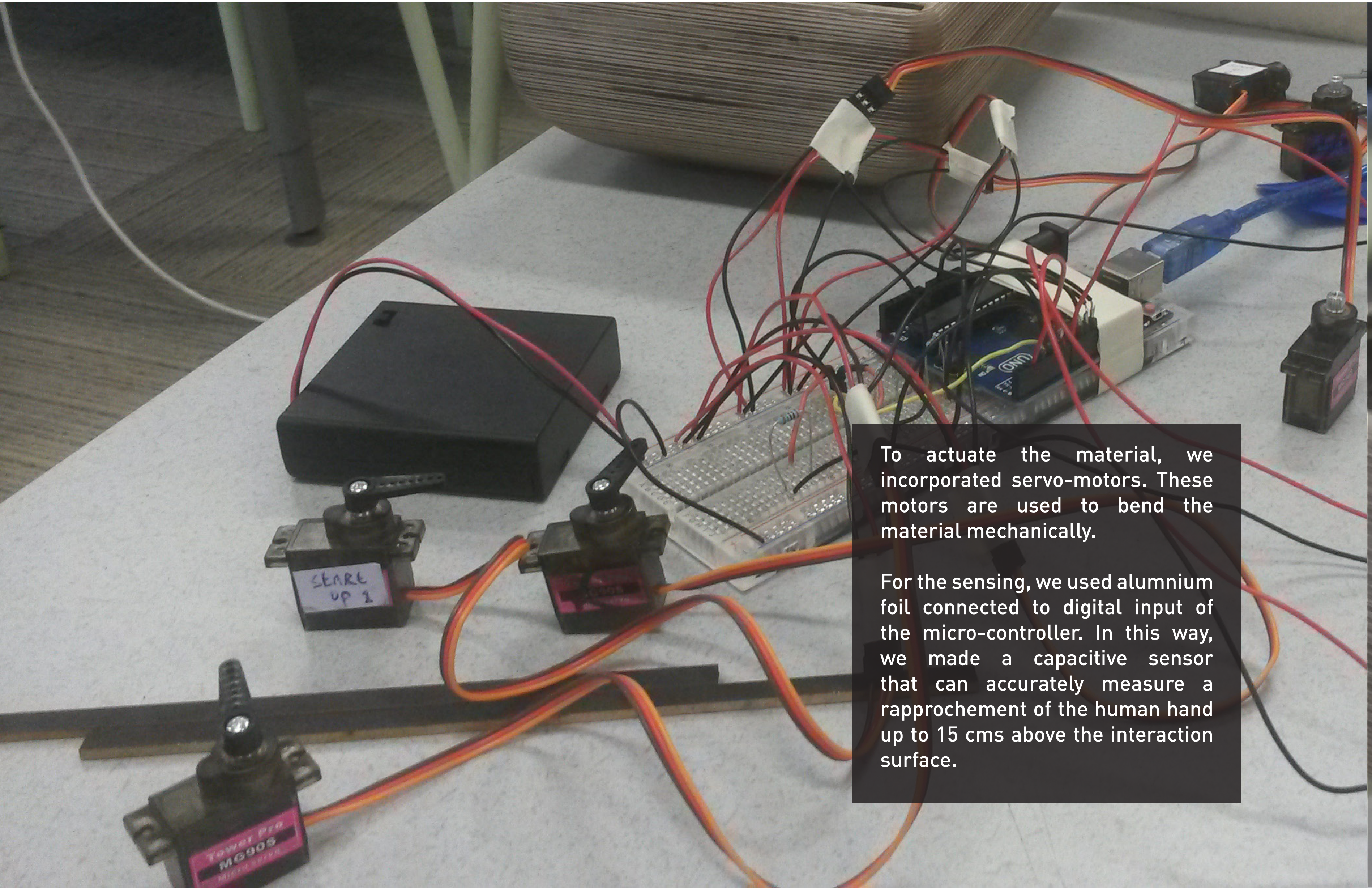
We used vivak (picture on the right) with a lasercutted parabola pattern generated by ourselves in processing; we chose for this specific pattern due to its interesting shape- changing properties. Additionally, we added two layers of lycra in order to make the vivak actuatable, organic and technically sensable.



The two materials are combined by melting them together under a heat press (170 degrees). This combination creates a material which is highly controllable and gives an organic feel

Bending/stretching the new materiality now results into the interesting deformations which we aimed for.

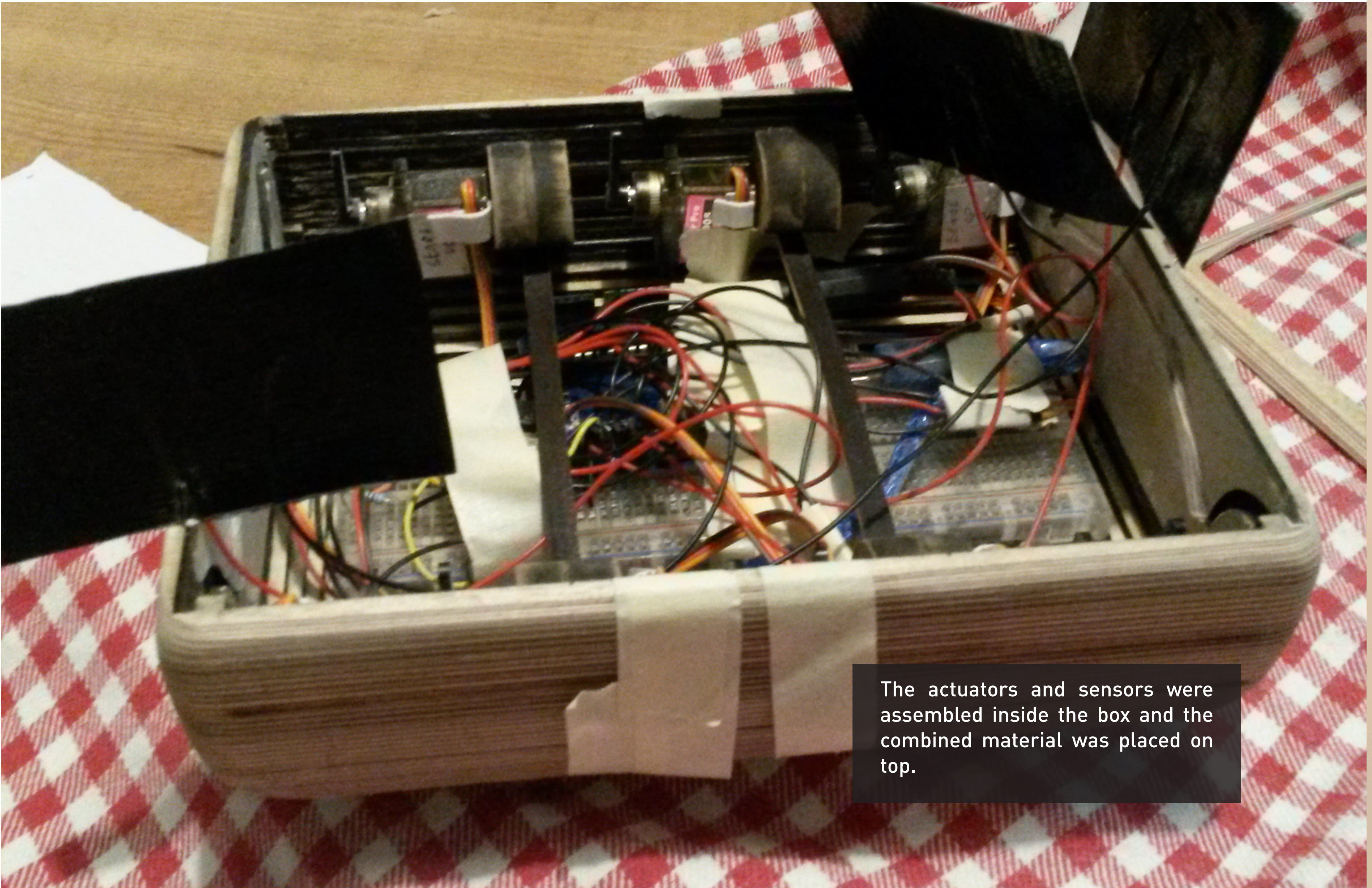
While bended in the vertical postion, the material creates a kind of spikes. These spikes provide for the 'hardened' visual and sensory perception in our designed interaction.



To actuate the material, we incorporated servo-motors. These motors are used to bend the material mechanically.

For the sensing, we used alumnium foil connected to digital input of the micro-controller. In this way, we made a capacitive sensor that can accurately measure a rapprochement of the human hand up to 15 cms above the interaction surface.

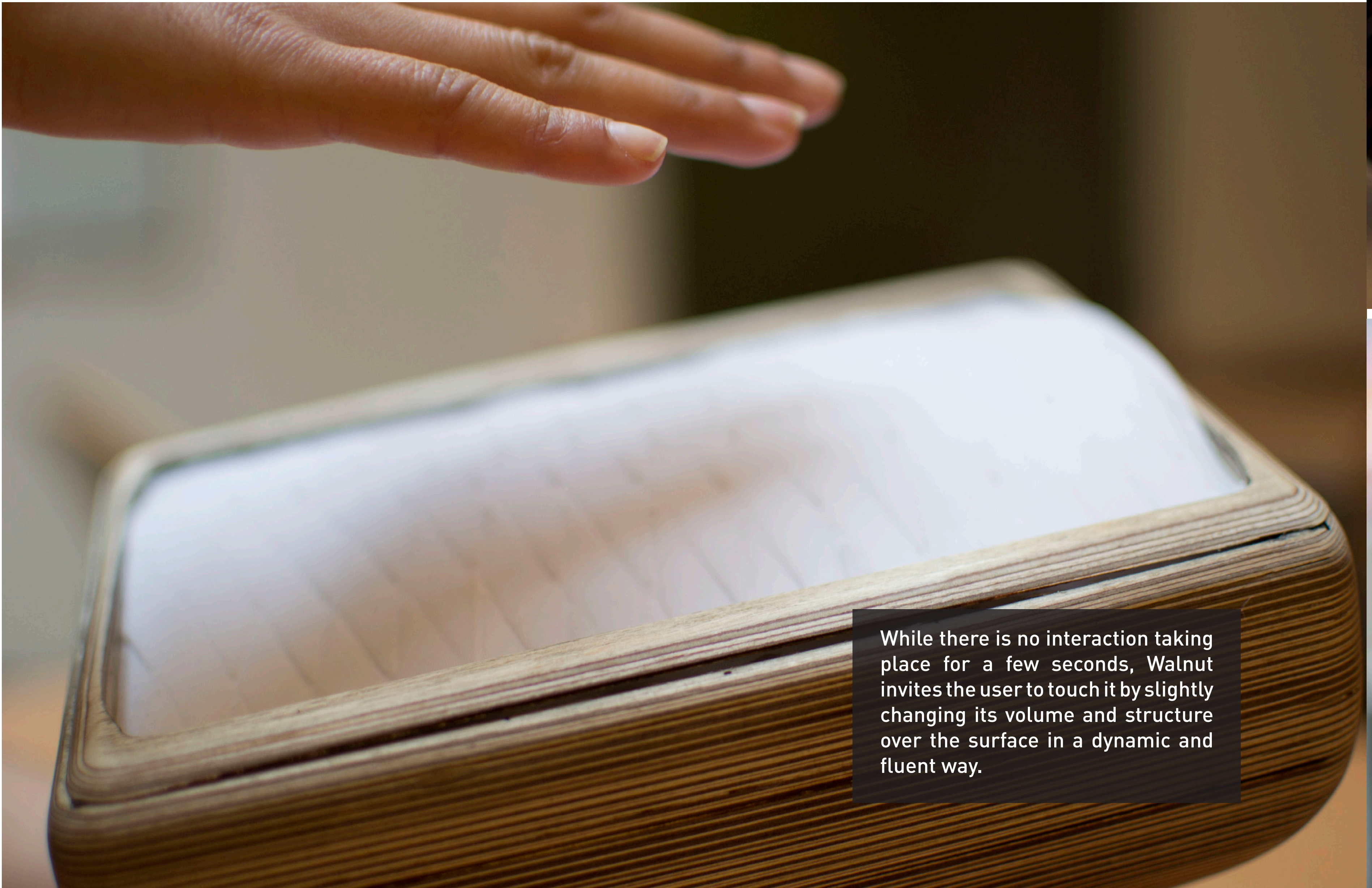
A wooden box was designed to make the device hand-held and cover the electronics, which provokes the feeling of a stand-alone interactive materiality.



The actuators and sensors were assembled inside the box and the combined material was placed on top.

Hereby, we created 'Walnut'. Walnut creates an interaction loop, trying to make the user mis-perceive its material properties.

In rest, Walnut has a soft and flat appearance.



While there is no interaction taking place for a few seconds, Walnut invites the user to touch it by slightly changing its volume and structure over the surface in a dynamic and fluent way.

When the surface is touched, the device will return to its flattened position and stops changing its shape to indicate that it has felt the users' touch.

Subsequently, the acceleration and location of the user's action in withdrawing its hand result into the reaction of the device; this acceleration of the hand and location of touch is directly coupled to the volume and structure change of the device in three different areas (visual). Hereby, the shape-changing reaction (feedback) automatically forms the feedforward for new action.

The user is invited to press the expanded surface-area. At first this touch has little effect due to high resistance, but gradually the hand will sink faster and more easily through the actuated area until it is flattened again and returns to measuring the pullback of the hand (visual). This process described above will automatically form the interaction loop.

Discussion Walnut

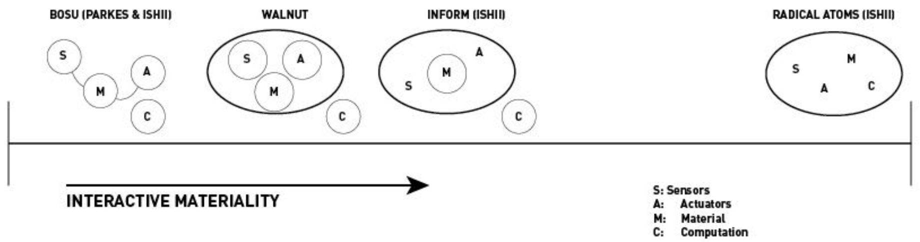
Discussion Dennis
Walnut is a hand-held device, designed to comply with the concept of Interactive Materiality. While designing, we aimed to integrate the symbolic notion of 'hardened softness'; a term that we came up with to describe the feeling of a confusion caused by the perceptual misconception of material properties. This notion was inspired by highly aged/traced leather and the interaction with non-newtonian fluids. Below, I will discuss Walnut based on three categories, which I defined within the literature-positioning, and I will reflect on these looking from an embodied, emotional and cognitive perspective.

Within the process of designing Walnut, one of the most difficult aspects was fine-tuning the input/output subtleties that Stienstra and Bruns discussed in their paper. We wanted the interaction to be initially estimated very rough while, in practice, it should be very smooth/soft and the other way around. We therefore created three variables: Expansion, structure and speed/resistance. On the one side, I think the separate variables worked out quite well. Within an informal user-test, a person said: "touching the expanded spiky areas is not inviting, as the structure looks sharp and fragile; it makes me interact with it very gently." Moreover, Bruns mentioned while interacting with the device: "the gradually decreasing resistance in feedback when pushing the surface feels very nice." These experiences, which focused upon one of the variables and its effect, met our intentions.
Nevertheless, the three variables combined contradicted each other according to some users. De Waart mentioned in her evaluation: "there is a lot going on at the same time and it is hard to grasp; there is the dimensional/volume change, the structure change and the change of resistance/acceleration in feedback." Contradicting, others indicated that they positively felt the complementation of these variables. Here one can clearly conclude the importance of the perceptual difference and uniqueness of the user, pointed out by Stienstra and Bruns [1]. To move towards a more generally equal perceived emotion/expression, I see 'abstraction and playing with basic form features essential to the recognition of emotion', elaborated upon in De Rooij's paper [8], as an important step; we have not explored this within the design of our current prototype.

Walnut, for me from a designer perspective, does not fully feel as 'a programmable materiality' (material = sensor = actuator [10]). The feeling that it provokes to me, although it might be because I designed the object myself and I know the individual separated parts underneath the surface, is not comparable to the dynamic cooperation and fusion between sensors, actuators, material properties and computation within for example radical atoms [3]. I can however strongly empathize with the concise description Parkes [3] gives in her paper about Bosu, who describes this feeling as "a relationship between what can be viewed as 'machine' motion versus the organic motion of our bodies and the natural world" (p.195). She uses the term 'hybrid materiality', pointing at "hybrid material structures in which we can identify an underlying skeletal structure combined with organic elements, which expands the threshold of controllability, pushing both the natural-like nature of an interaction with the designer's ability to control and designate the interaction" (p.197).

Deriving from this feeling and perspective, I tried to position Walnut in research that has currently been done in the field of IM. I herein create a sort of time line, in which the work is categorized from less advanced to most advanced. Bosu, a device that Parkes and Ishii founded in 2010, is hereby placed at the left; within this work, the actuators, sensors and materials are connected but can still be separated from each other. Walnut is placed second, as the actuators, sensors and materials are combined and cannot be separated; for people who do not know the inside, it might even give the feeling as if the material itself is programmable. Next in row, 'Inform' [11] has been placed. Compared to Walnut, this work has a higher resolution of sensing and actuating, as both the sensors and actuators are integrated in the entire interaction surface. In the far future, I've placed the Radical Atoms concept of Ishii, which contains sensors, actuators and materials all fused into one specific 'materiality'. Additionally, even the computation can be done within the material itself and is not a separate process as we see in the first three concepts.

Looking back, I'm satisfied with the team-result. The prototype was a very useful reflecting tool for understanding the literature and translating our findings into practical re-implementable knowledge; e.g. perceptions in designing for emotion, tools to get from cognitive info to practice and a sufficient capability of analyzing tangible interaction. In the end, I would have liked to further fine-tune subtleties and work on a more natural object-shape of our prototype. In my view, we did not achieve this mainly due to technical limitations, time issues and a lack of intermediate literature analysis.



pic. 3 Visual 'Walnut in literature', D. Rietveld

Discussion Bram

Discussion Peter
Within this discussion, I will state the classification of the material created by our group along the definition given of Interactive Materiality in the introduction.

WALNUT as an Interactive Material
In its current state, I have defined the theory of Interactive Materiality as the strive to achieve a homogenous combination of material, sensor, and actuator. However, since this actual combination seems to be hard in achieve in most material, I have proposed a step in between the current state of materials and this reach I called Augmented Homogeneity.

I feel that Augmented Homogeneity has been achieved in our interactive material along certain lines of actuation and sensing, but still needs further elaboration to complete this experience. While the materiality used in the sensor is actually capable of following every movement of the material without impeding its transformability, the sensing part can not distinct interaction within the resolution and along the same amount of parameters present in the material. Next to the actuator, although not impeding the transformation of the material thanks to actuation at the edge of the material, not begin able to achieve actuation along every transformation parameter offered by the material, the low resolution of sensing renders this level of actuation impossible. From the recognition of these limitations, it can be concluded that augmented homogeneity has not yet been achieved in WALNUT. However, the step from its current step to achieving augmented homogeneity could be a small one by for instance incorporating soft robotics (like Bosu) in the material layer of WALNUT.

WALNUT translating non-newtonian fluid material properties.

The act of completely translating material properties of our earlier constructed non-newtonian fluid to our actuated combination of Vivak and Lycra proved to be impossible in the set time and the technology available. Instead, we chose to abstrahere one of the general feelings conveyed through the non-newtonian fluid. The effect of this abstraction actually strengthening the feeling was already described by de Rooij et al.[8], and through an interaction session with the fluid it was found that the strongest emotion conveyed through the non-newtonian fluid was confusion. Through literature, this confusion was tried to be conveyed by deliberately reversing certain aspects of action and function as described by Wensveen [6]. Through exploration with the resulting Interactive Material however, it was experienced that the context of confusion was not as present as it was in the non-newtonian fluid.

I believe the difference between our interactive material and the non-newtonian fluid regarding confusion to be in the disconnection of senses. This disconnection is strongly present in the latter, perceiving a fluid with the eyes while at the same time being able to perceive a rigid material through interaction. In the interaction with WALNUT however, the interactive material proved to offer sufficient coherent visual feedback to give conclusive evidence on the material's touch and feel.

One of the properties in which a confusing interaction was pertained, was found in the reaction time of WALNUT. Since interactions in nature seem to progress rather linear, it was decided to program an exponential reaction to mimic the sudden change between material phases found in the non-newtonian fluid. However, during the exhibition of models this confusion was not perceived as such. The interactive material not being able to convey this emotion could be explained through a remark made by de Waart during the exhibition stating that in the prototype "a lot was happening at the same time". Mapping this remark along the statements made by de Rooij in Abstract Expressions of Affect[8], the emotion of confusion not being able to be conveyed as strongly as expected could have two reasons. Firstly the abstract notion of confusion could have been over defined through the accompanied contextual sensory information from material and sensor (sound and look of the material, sound from the servo motors), resulting in an interaction not as confusing through coherent sensory input. Secondly, it could be that the accompanied sensory information actually masked the essential details of the abstract notion. Either reasoning however resulted in the abstract notion being not as strongly conveyed as initially expected.

Within my introduction and discussion, I have tried to convey my gained knowledge within the field of Interactive Materiality and its related subjects. Through this elective, I have gained more experience in the establishment of my personal perspective based on related literature, and I believe I can put both the gathered knowledge from this literature as my heightened experience in establishing personal stance in my further career as a Tangible Interaction Designer.

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