



# ACTUATORS AS A DESIGN MATERIAL

How to make Kitchen Devices more Expressive

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## ABSTRACT

This thesis is an explorative, design-based research study towards the expressive potential of using actuators as design materials. Over three distinct phases of experimentation –all with their own particular aim– various sketches are developed that showcase different expressive qualities. These sketches consist of a variety of kitchen devices that are expanded with actuators. These actuators do not necessarily add to the functionality of the device, but rather to its expressiveness. The development of and reasoning for the sketches is clarified in an extensive way to clearly present all the insights that are gained throughout the design process. In the end, the sketches are discussed and reflected upon on the basis of the process-insights and relevant design theories.

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# 1. PROJECT OUTLINE

Materials play a big role in the design of artifacts. The material that an artifact is made of is consciously selected, based on certain criteria. These criteria can, for instance, be practical or aesthetical by nature (Ashby & Johnson, 2014). When considering for instance the sandwich iron of figure 1, then the reason for making its handle out of plastic rather than metal is obvious: it would simply get too hot if it was a metallic handle since metal conducts heat well. This conduction of heat is a material property of metal, and it is these kinds of properties that often inform the decision for one material over another one (Ashby & Johnson, 2014).

In the case of interaction design, the designed artifacts usually contain some kind of technology. This technology makes the interaction possible: it allows the artifact to *talk* to the user, and it provides a means for the user to act on the design. The way the sandwich iron of figure 1 is able to *talk* to the user is through the red and green LED. The red light will indicate that the device is heating up, the green side indicates it is ready. This is how most of the typical electronic device in the household behave: simple LEDs are used to indicate the various states of the device. It is possible to see a LED over a distance –in comparison to for instance a vibrating component– which can be considered as a useful quality of the LED in this case. It is possible to see from a distance whether the device is ready. However, not all the qualities of the LED are fully considered. LEDs are only able to be sensed when people are looking in the right direction, in comparison to a speaker which they will hear regardless of the direction their eyes are pointing at. A speaker might be considered more suitable, as a result of certain specific qualities of the speaker.

Just as with the materials traditionally used in design practice, different technologies also have specific qualities. Comparing LED technology to a speaker –as in the example in the previous paragraph– can illustrate this. For instance, the light that a LED emits is in most cases less intrusive as the sound that a speaker produces. While a LED might be perfect to indicate that something is *working*, it is usually less ideal to indicate that something is *finished* because you can easily overlook it. An (alarm) sound seems to be better suited here. Different situations require different solutions, and while this is deployed in the case of materials, it seems that for technologies, designers can improve their reasoning for why they use certain technologies in their designs over others. To be able to make these decisions, (interaction) designers need to be more aware of the different qualities of technologies. Just as how material knowledge can help in decision making for the material, (interaction) designers need knowledge specifically regarding individual technologies, and what differentiates them from other technologies. As Redström (2005) states, “whereas we refer to reinforced concrete and plywood as ‘materials’, we refer to electronics and computers as ‘technologies’” (p.12). Just like Redström does in his text, I am going to challenge this strict dividing line between materials and technologies in this thesis.



Figure 1: the Philips HD2392 Sandwich Iron

Source: <http://www.p4c.philips.com/cgi-bin/cpindex.pl?scy=RS&sly=SR&ctn=HD2392/00>

## 1.1 AIM OF THE THESIS

This thesis explores how different technologies can be used to express certain states of an artifact, where *state* refers to the mode that the artifact is in, such as *heating up* and *ready*. Rather than only focussing on utilitarian states –like being *ready*– I will also consider more aesthetical states –like being *calm*– that focus on non-functional aspects of the artifact. These *aesthetical states* thus do not focus on conveying practical information, but instead on expressing more abstract characteristics that can be *designed in* the artifact. Think of the way in which modern day smart bulbs are switched on. Unlike classic light bulbs, which switch on and off instantly, these newer bulbs fade in and out when turned on and off. While this does not add to the functionality of the lamp –providing light– it does add to the (abstract) characteristic of the lamp: the lamp now expresses itself as being a calm, serene device. In this thesis, I aim at uncovering more of these expressive potentials in devices.

Rather than focussing on technologies in general, the thesis aims specifically at actuators. More precise, at the influence that actuators can have on the characteristic expressiveness of devices. Actuators are defined as technological components that are able to produce a certain output, such as light or movement. Some examples of actuators are LEDs, speakers and motors. While actuators such as motors can also be hidden in an artifact, I will limit my focus to actuators that can be sensed by people. Actuators are an interesting subject of study, because they can be considered as the aspects of a technological device that designers can modify during an interaction: through programming we have full control over the *behaviour* –the way in which technology acts– of the actuators. While other technologies, such as sensors and circuit boards, are important for enabling the interaction between device and person, they do not change, or *behave*, over time. Actuators do have this changeability, or *behaviour*, as one of their characteristics; they can be adjusted over time and thus give a response from the device back to the user, as output.

What to do with the opportunities this characteristic of actuators offers, is part of the aim of this thesis: I will explore possibilities with actuators in an iterative way. The ultimate goal of this thesis is then to construct knowledge on how different actuators can be used to create specific expressions from artifacts. By analysing, comparing and evaluating the insights I gather through the project, I will construct knowledge that can be appropriated in future projects.

## 1.2 FRAMING OF THE PROJECT

The overall research question for this thesis is framed as:

How can I explore the expressive potential of actuators as a design material?

In order to explain the topic for this thesis more specifically, two notions need to be elucidated: the idea of working with *design materials*, and the way in which artifacts have certain *expressions*. Both are key-notion throughout the thesis. They are already hinted at in the previous section and will be further explained and substantiated in section 2. For now, both notions will be briefly explained.

The notion of working with *design materials* embraces the idea that materials are something that designers should be able to explore in an iterative way. Wiberg et al. (2012) explain that a material focus in interaction design places the discipline “*alongside other materials-centric design disciplines, including industrial design, architecture, the fine arts, or glassblowing—areas that have always highlighted the importance of a close understanding of the materials in play*” (p.57). This material focus in interaction design puts the attention on the interactive artifact and the process of making and developing it. The importance of *making* in design-based research is stressed and explained by Mäkelä (2007) and Löwgren (2016). For this thesis, actuators are considered as design materials, which lets me explore their potential in an iterative way.

More specifically, my thesis project can be framed as how various actuators can contribute to certain expressions from artifacts. *Expressions* are understood as the ways in which a design presents itself, how it appears (Hallnäs, 2011; Hallnäs & Redström, 2002). In the context of interaction design, this relates to how the design appears over space and time, how it appears in a dynamic way (Lim, Lee, & Kim, 2011; Löwgren & Stolterman, 2004; Vallgårda, 2014). I will go deeper into this in chapter 2.

This thesis focusses on actuators that generate visual, auditory and tactile output. Output related to smell and taste is disregarded for practical reasons: this is more difficult to involve on a technical level.

In order to have a certain context to work within, I selected the kitchen environment. The kitchen is seen as an interesting context since cooking is essentially a functional activity, while simultaneously there is also a certain delight in it for many people. So both functional and aesthetic aspects are important. Besides this, there are many devices in the kitchen that could be studied for this thesis; kettles, toasters, blenders, ovens, etc. All these kitchen devices are so common in our everyday life that we seem to take them for granted. But can these mundane devices be designed in a more expressive way?

### 1.3 POSITIONING WITHIN INTERACTION DESIGN

This thesis considers interaction design in a similar way as Hallnäs & Redström (2006) do. Comparing interaction design to other design disciplines, they state:

“*The shift of focus that interaction design introduces can be characterised in terms of a specific interpretation of the concepts of functionality and appearance. It is a shift*

- *from what a thing does as we use it to what we do in the acts that define use,*
- *from the visual presentation of spatial form to the act presentation of temporal behaviour.*”

(Hallnäs & Redström, 2006, p.23)

The first of these two bullet points emphasizes that interaction design does not merely focus on the designed *thing* itself and how it operates, but also on the way that people respond to that and use it. For interaction design, people and their way of using are just as important as the design itself. The second bullet points stresses the importance of the (*temporal*) *behaviour* that is already highlighted in the previous section. Rather than focussing on more static objects, interaction design focusses in objects

with a certain changeability or behaviour; a certain interaction. Implied by this definition is that interaction design is about *things*, which is within the focus of this thesis as well.

As explained before, this thesis focussing on actuators. There are multiple studies that focus on (combined) actuators to inform us (Burke et al., 2007; Hoggan, Crossan, Brewster, & Kaaresoja, 2009), however they are more focussing on the capability to display certain information in a very functional way, and not so much on the way the design can express itself in a more aesthetical way. The difference is that even though in this second case there can be a functional application, this functionality is not the main focus: the main focus should instead be on expressive qualities, since that is what this thesis is about.

A good example of a study that is more considering aesthetic capabilities of actuators is Johnson et al. (2016) their work on how heat can be used to evoke certain experiences. In order to study the modality of heat, they adopted a specific context (a Feldenkrais exercise) and tried to enhance it through an adaptable heat-generating mat. Instead of having functional properties –such as information-display– as the main point of departure, Jonsson et al. their approach explores *aesthetic and experiential properties*. As they describe themselves, their approach aims at “*an alternative understanding of heat as a design material that extends the common understanding of thermal stimuli in HCI as a communication modality to instead bring the aesthetic and experiential properties to the fore*” (p.109). Two notions are important in their research: heat as a design material, and how this can evoke certain (aesthetic) experiences. I will go more into detail regarding (the issue with) this focus on experiences in section 2.3 *Expressions & Form*.

If we consider the work on actuators as information-display technologies on one side of the spectrum, and the more user-experience-oriented work on the other side, we can try to identify work that can be placed somewhere in between. Work on *expressions* can be considered as such: it does acknowledge that design can be approached in a richer way than just looking at functional aspects, however it does not recognize a human experience focus as the way to do this (Hallnäs, 2011). Expressions instead focus on the way in which the artifact appears on its own, without considering the more elaborate effect this has on the experience of people using the artifact. As Landin (2009) states, “*it is of course much, much harder to design an experience than a device, since we do not design people.*” (p.25). By focussing on expressions, and thus on the design itself, we try to bypass this issue. Section 2.3 *Expressions & Form* will go more in depth.

The work in this thesis is most closely related to this work on expressions. Examples are the work done by Hallnäs (2011), Redström (2005), Hallnäs & Redström (2002, 2006) and Landin (2009). In these works, both the notions of design materials and expressions are used in a similar way as I do for this thesis. Also, the definition of interaction that will be used from now on, is adopted from their work (Hallnäs, 2011; Hallnäs & Redström, 2006). While defining interaction can be considered as problematic (Hallnäs, 2011) this can be solved by adopting a simplified notion of interaction: “*interaction simply in terms of what I am doing as I use a design*” (Hallnäs, 2011, p.77). In order to look at interaction design both from the user as from the design point of view, the dual notion of interaction-function is proposed: “*function being what things do as we use them and interaction referring to what we do when we use a thing*” (Hallnäs, 2011, p.77). As said, this is a simplified model, but it offers a very effective way to talk about interaction design in ways that might otherwise be difficult.

The notion of aesthetics used for this thesis is also adopted from Hallnäs (2011). Aesthetics in this view is not related to –as in the more traditional view– any value judgement, but instead to a design rationale;

it is thus not used to describe why we do or do not like something (because it is beautiful, ugly, accessible, annoying, etc.) but instead it provides designers with reasoning for why to design something in a certain way. We might design something that is beautiful *because* we want it to appeal to people; we might design something that is annoying *because* we want to drive people off.

## 1.4 DESIGN-BASED RESEARCH

Löwgren (2007) defines four criteria to determine whether a project could be considered a valuable design-based research project: its novelty, relevance, groundedness, and criticizability (p.4). In my view, the first two can be related and the second two can. Novelty and relevance both deal with why the generated knowledge is valuable, while groundedness and criticizability speak more into why the knowledge is trustworthy. Therefore, they are considered as pairs.

The knowledge that this thesis contributes is both novel and relevant, since it tries to fill up a current gap in the knowledge of interaction design research. There has not been much work done specifically aimed at exploring the expressive potential of actuators, a knowledge contribution that seems especially relevant for (product-based) interaction design practitioners. It is considered relevant because actuators seem to have much more expressive potential than how they are often being used, and this thesis tries to expose how designers can explore and apply this potential in their design projects.

At the same time, the knowledge will be conducted in a way that is grounded and criticizable. The insights I gained by experimenting with design artifacts will be clearly presented, together with the specific design artifacts themselves and the overall design based research process. In this way, the constructed knowledge is communicated in a transparent way, showing how it is grounded and thus making external criticism possible on all aspects of the project.

## 1.5 DESIGNING FOR DESIGNERS

Projects that take a design material approach tend to consider users in a way that is unusual within Interaction Design. Therefore I will exemplify the difference here. In her PhD, Vallgårda (2009) states that “Our projects were aimed at developing new expressional appearances from known materials used in new contexts, and in that sense did not address any situation of use or any social or societal concerns. In our case, we found that the value of the experiments was grounded in the material resistance” (p.72). As this indicates, the material focus places the emphasis on exploring material qualities and does not work well together with a typical user focus. Instead, Vallgårda focusses on her own involvement with materials and technologies to develop an awareness of them, and to generate knowledge of working with the materials.

As described by Hallnäs & Redström (2002, 2006), the user is *bracketed*, indicating that the user is not a (major) part of the design process. Instead, the designer focusses on her personal involvement with the design. This is not done as a result of not acknowledging the influence users have on how a design will be used. Instead, it is the other way around. It acknowledges the difficulty of designing for actual people in

real life situations, embracing that we actually cannot predict much about how people will use the things we design (Hallnäs & Redström, 2006; Landin, 2009). Because every person and every situation is different, the possible contexts for which we design is incomprehensible. Instead of trying to do the best we can through user-centered design and empirical user studies, the design material approach changes the focus of actual use to intended use (Hallnäs & Redström, 2006), meaning that we accept the idea that designing for how something will actually be used is too uncertain and complex. The reframed focus on intended use removes this issue, by aiming at defining what a designed artifact is intended to be, and leaving open how it then will actually be used. By not focussing on, and thus limiting oneself to, users and actual use, the designer is freer to experiment in any possible direction.

As Hallnäs (2011) describes, “*Within the design process “use”, “users” and the like are logical notions we define, with “intended use” being the focal notion that determines the design*” (p.75). This indicates that for a focus on intended use, we do not study *use* and *users*, but instead we define how we intend *use* and *users* to be. These definitions thus become design *decisions* that are based on a logical rationale (Hallnäs, 2011) rather than on empirical motives.

Both Landin (2009) and Mazé & Redström (2005) state that this focus on intended use is best applied during the early stages of design, when there is no user to focus on, since there is no situation and designed artifact yet. This could also be framed as pre-design: design that does not intend to produce design artifacts as the outcome, but instead it generates insights and suggestions to inform and inspire future design projects. This pre-design thus only indirectly informs future design artifacts. That artifact is being developed by a (secondary) designer working on a *regular* design project. This designer can work with the insights and suggestions and appropriate those for his/her own project. In such a pre-design approach, the people we are designing for are thus fellow designers. The focus on design materials and expressions results in an explorative study, where the outcome of the work can give rich insights and suggestion for fellow designers, which they can then apply to their own practice. Thus, this thesis does not focus on designing for users; instead, it focusses on designing for designers.

## 1.6 ETHICAL CONSIDERATIONS

While this thesis is an extremely individual project, there are not many direct ethical concerns. However, I extended the reach of this project beyond the scope of the thesis and was able to define two main ethical considerations.

The first is that as a designer, it is important to consider the potential influence of my work on the world. Löwgren & Stolterman (2004) describe “*information technology as a material without qualities*” (p.3) with which they want to say that there are no pre-set qualities for most technologies: we can basically *let it do what we want*. This opens up many possibilities, and thus also many responsibilities. As they state, “*it becomes important to ask questions about what is good and what is bad design, and about the goals to which an interaction designer should lend her skills*” (p.4). Within this thesis, using technologies in an open-ended, explorative manner will do no harm. But as soon as I would introduce others, or start to work for others, it gets important to be considerate of the possible effects that such experimental, unfamiliar designs might have.

The second ethical consideration is that the intended use, as described in section 1.5 *Designing for designers*, will at a certain point be replaced by actual use. When we have explored a material thoroughly, there will come a moment we have to consider to apply it in an actual situation, with users. As Robertson & Wagner (2012) state, "design will always be completed in use" (p.81). Everything up to that, also the design material approach, is a kind of preparation for actual design, with actual use instead of intended use. From an ethics perspective this is important because even when we are designing for designers right now, we might be designing for users tomorrow. Therefore, even when users are not included in the design material approach, the explorations might one day become part of their lives, and thus we have to implicitly already consider them. For this thesis, this was done during the cooperative design review of section 4.4. While I consulted a fellow designer, I also asked some question as if this person would be a user of the design. This duo role of designer–user was easily achieved, and it showed which design artifacts were liked the least, based on negative expressions such as fright and annoyance. It seems that these artifacts should not be developed further in the case I was going to focus on actual use.

In accordance with The General Data Protection Regulation (GDPR 2018), data that has been collected containing personal information has been handled to the best of my abilities according to the guidelines. Further, the Swedish Research Council Guidelines for ethical conduct (2017) have been consulted.

## 1.7 WRITING STYLE & STRUCTURE OF THE THESIS

Throughout the thesis I will switch between two ways of narration:

- I, when I want to emphasize the individuality of my design process as a design material approach.
- We, when I want to emphasize that something could appeal to fellow designers.

The structure of the thesis is as follows. This first chapter, *Project outline*, should be seen as a preview of what is going to be discussed in the rest of the thesis. Key notions are explained and the general approach is presented. Chapter 2 *Theoretical basis* is used to explain the key notions more in depth, and to introduce and relate more theoretical work. Chapter 3 *Design-research approach* explains the overall design approach and methodology, and the more specific methods used throughout the process. In chapter 4 *Design-research process*, the actual design process will be elucidated in chronological order, in a journal-like format. Chapter 5 *Design - research outcome & discussion* illustrates the design exemplars and discusses the insights and knowledge developed throughout the process. Finally, in chapter 6 *Conclusion*, I will respond to the research question in retrospect and suggest some work that could be done to advance the research in the future.

## 2. THEORETICAL BASIS

This chapter is used to substantiate the theoretical foundation on which this thesis is based. The key notions will be explained more in depth, and theoretical work will be introduced and related to this thesis.

### 2.1 DESIGN MATERIAL

As already made clear in section 1.2, the notion of working with *design materials* embraces the idea that materials are something that designers should be able to explore in an iterative way. Schon (1983) talks about a reflective conversation between the designer and the material, which implies that the (design) material speaks to the designer during the making or sketching (Buxton, 2007) process. This reflective conversation is what informs the designer on what to explore (next), on what *fitting* iterations are.

In traditional design practices, such as product design, materials like wood, metal and plastic are the basic elements that are used to shape designs. Different materials are selected for their material attributes so that the properties of the material fit the requirement of the situation (Ashby & Johnson, 2014; Vallgårda & Redström, 2007). In the context of interaction design, these traditional materials are often not the basic elements we are working with. When designing artifacts from an interaction design perspective, the computational side (Vallgårda & Redström, 2007) of the object is often what we focus on, what we *design*. It is this computation that makes action and response possible in the artifact, and thus interaction and function, between the person and the artifact. Redström (2005) and Vallgårda & Redström (2007) propose that we can treat computational technologies as a design material. An example is Vallgårda & Bendixen (2009) their experiment where they combined copper with a Peltier element, which is an actuator that can be used for both cooling and heating up. They wrote a code for the Peltier element in such a way that when someone would try to heat up the copper by rubbing it, it would instead turn cold. It is a simple experiment, but shows clearly how computational technology can be used to seemingly change material properties, and specifically how "*any normal behavior in a material can be exaggerated, moderated, reversed, or in other ways modified*" (Vallgårda & Bendixen, 2009, p.6). The computational technology changes the relation between cause and effect into any cause-and-effect that the designer desires.

The greatest difference to traditional materials, is that computational technologies are in a way *immaterial* (Redström, 2005; Vallgårda & Redström, 2007). These technologies do no manifest themselves in the same clear way as traditional materials do. Computation is something abstract that we often do not directly see, instead we see the interface that we use to engage with the computation *inside*. As Vallgårda & Redström (2007) state, "*computations need to be combined with other materials to come to expression as material*" (p. 513). They call this combination a *composite material* or *computational composite*: a combination of a more traditional material with computational technology, resulting in a composite with specific, sometimes new properties. Think for instance of the way in which modern television screens combine a transparent plastic sheet with LED technology that is capable of lighting up a specific colour over a small area. In combination, they have the characteristic to display moving image over a larger area.

We can thus approach technology as if it is just another material to work with as designers. In this ‘Design Material Approach’, the technology can be explored by sketches (Buxton, 2007) and experiments (Hallnäs & Redström, 2006) in order to look for potential in an explorative and practice-oriented way. As stated before, this thesis, considers actuators as design materials, which lets me explore their potential in an iterative way. The next section goes more in depth regarding the specific actuators.

## 2.2 SENSES & MODALITIES

*“The picture Dewey paints is something like the following: It is through sense organs that living creatures participate directly in the world about them. The sensual thread of experience therefore is concerned with our sensory engagement with a situation, which orients us to the concrete, palpable, and visceral character of experience. It draws attention to things being grasped pre-reflectively as the immediate sense of a situation in which the wonder of the material world is made actual for us in the quality of experience.”*

(McCarthy & Wright, 2004, p.80)

The quote above describes how humans and animals use their senses to experience the world around them. While this thesis does not focus on user experiences, as explained in section 1.3 *Positioning within interaction design*, we cannot talk about the senses, without talking about experience and perception. Rogers captures the close connection very clearly, by stating that “*it [perception] can refer to our experience of seeing, hearing, touching, tasting and smelling objects and individuals in the surrounding world*” (Rogers, 2017, p.1). These five are our senses, the five means through which we perceive the world around us. While the psychologist James J. Gibson considered the senses as individual perceptual systems (Gibson, 1966), later scholars in his field started to accept the idea of all senses being much more related to each other, “*that the senses function as a single, irreducible perceptual system*” (Stoffregen, Mantel, & Bardy, 2017). This is also the way in which the senses are considered for this thesis: while I will explore different senses, they are not examined just individually or in turn, but rather seen as enhancing each other.

As Gibson (1966) states, there are two distinct ways to look at the senses, “*first, to detect something, and second, to have a sensation*” (p.1). This distinction is also very present among interaction design scholars. Looking at the senses as a way to have a sensation fits the notion of experience-design, like the quote that starts this section. Considering the senses more practical, as a way to detect something, fits it with studies such as (Burke et al., 2007; Hoggan, Crossan, Brewster, & Karesoja, 2009) that examine how the various senses can help us to acquire information more efficiently. The emphasis of their approach becomes very clear through the following quote: “*display modality is defined as the sensory channel(s) through which performance feedback, or task-critical information, is provided to the participant*” (Burke et al., 2007, p.109). By slightly changing that definition of modalities, we come to a more widely applicable term; for this thesis, a modality is defined as the sensory channel through which information or input reaches the person. Modalities thus become the way in which the design *talks* to us, that what we can sense. While actuators can in this analogy be seen as the means through which the design can *talk*.

As (Sundström et al., 2011) state, “*In any design process, a medium’s properties need to be considered ... the properties of a technology are often glossed over. That is, technologies are black-boxed without much thought given to how their distinctive properties open up design possibilities*” (p.1561). Therefore, for this thesis, I want to deliberately consider various actuators based on their distinct and combined properties. In a similar way as how (Harrison, Horstman, Hsieh, & Hudson, 2012) examine a single actuator (small LEDs) and how they can make these expressive by focussing on the inherent properties of the actuator.

More about this ‘expressive-side’ will be discussed in the next section.

## 2.3 EXPRESSIONS & FORM

As described in section 1.2 *Framing of the project*, expressions are understood as the ways in which a design presents itself, how it appears (Hallnäs & Redström, 2002). In their words “*the expressions of a thing are its pure appearances as we disregard—or “bracket”—functional and existential definitions*” (p.112). This *pure appearance* should be seen as being independent of how a potential user personally experiences it. Hallnäs (2011) makes that clear by stating that expressions are about “*the way things themselves appear in contrast to the way in which we see them*” (p.73). Expressions are thus intended to be independent of interpretations and value judgements.

In order to clearly understand what expressions are about, it is important to make the distinction between form and expression. Hallnäs (2011) defines “*interaction design form as the way in which the thing or system we design relates function and interaction to each other*” (p.77), and “*interaction design expression as that which displays interaction*” (p.77). The difference is in the way in which they assist the person in using the design; expression relates to how the design shows what we do when we use a design, while form is more about how the actions of both the person and object are made possible through some materialization. The form enables the person to use the design itself as a thing –as a material manifestation– while the expression enables the person to perceive the design and its changing states –as a design with temporal behaviour. Both notions are very much interconnected; the materiality is also important for the expression, while the temporal behaviour highly influences the form. I will now use two examples to illustrate the notion of expressions in practice.

A piece of work that is close to the notion of expressions is the Hedonic Haptics Player (Boer, Cahill, & Vallgårda, 2017; Boer, Vallgårda, & Cahill, 2017), a project where they explored “*the aesthetics of the vibrotactile design space*” (p.903). The Hedonic Haptic Player is a device that lets you ‘play’ pleasurable vibration patterns on your body, through pads that can be attached to your clothes. They “*developed different vibrotactile compositions*” (p.903) that should result in the pleasurable sensation. In this sense, the work still focusses on experience. However, it is more about a generic experience, something independent of context and situation. This is noticeable by the fact that they performed their study without a clearly defined user and context. Instead of studying a variety of users in a specific situation, in order to validate their work, they only tried out the Hedonic Haptics Player on themselves while they were developing the design. This puts the focus less on actual experiences, and more on how the design expresses itself. They applied their design “*beyond the typical functional use of vibrations ... into an underexplored design space where vibrotactile expressions can provide pleasurable experiences.*” (Boer, Cahill,

et al., 2017a, p.298). The main focus was on the expressions of the vibration, while the *experience being pleasurable* was just a lens to look at the expression. In this sense, their work considered the vibration as a design material: as something that can be explored throughout a design process.

Possibly the best example of practical work on expressions, as related to this thesis, can be found in Landin her PhD work (Landin, 2009). In the final chapter, she displays her own design explorations that focus on expressions in a variety of way. The Iron Horse project for instance is described as “*an experiment with what happens if one merged the two very different expressions of riding a bicycle and a horse*” (p.165). It is a bicycle that expresses itself by making all kinds of horse sounds. Another example is The Fabrication Project, that “*explores what happens if one changes the way mobile phones are informing us about incoming calls and messages*” (p.165). Here, textiles are explored in different forms –a bag and a tablecloth– and how these can be used as a medium to express notifications from our smartphones. These projects all explore how we can design things in such a way that we intentionally let them express specific expressions.

In line with the notion of expressions, Hallnäs & Redström (2002) come up with the notion of expressinals: “*Similarly to how we may think of a thing as an appliance—a thing designed to perform certain functions—we may think of the bearer of this expression-identity as an “expressional”—a thing that is designed to be the bearer of a certain expression*” (p.113). A certain device should not be seen as either an appliance or an expressinal, instead they are two perspectives of how we can look at the device, either from a more functional point of view, or from a more expressive one. Looking at a device as an appliance defines its purpose as informing people, for instance that it is *ready* or *working*. The expressional perspective looks more at the device itself and what it *could* express independent of what the user actually wants to know.

## 2.4 ARTICULATE A DESIGN VOCABULARY

When comparing interaction design to more traditional design disciplines such as graphic design and product design, one of the major differences is that these other disciplines have a shared vocabulary that enables them to discuss their work and that also serve as guidelines for what is *good practice* or what *works* (Lim et al., 2011). A clear example is the vocabulary of graphic design –or *vocabulary of visual language* (Krause, 2004)– where notions such as spacing and contrast provide certain guidelines and offer a shared platform for discussion. Such a universal vocabulary seems missing in interaction design. There have been many different frameworks and vocabularies for interaction design developed over time, but having so many at the same time is not a good thing; we will articulate in different *languages* and end up talking at cross purposes. This thesis does not aim –what would be very ambitious– to overcome this. However, this is the argument why I am not developing my own framework or vocabulary for talking about interaction (design), but instead use existing ones, trying to bridge them.

One existing vocabulary to talk about interaction (design) is presented by Löwgren (2006, 2009). He describes the need to articulate certain qualities in design, in order to be able to discuss the design from a shared understanding. These are “*qualities concerning the interaction in itself*” (2006, p.388), such as immersion, fluency, usefulness and identity. Such a vocabulary is useful because it gives us a shared focus

on a specific aspect of the design to discuss, and we can develop knowledge concerning these specific aspects. However these qualities can be still a rather abstract way to talk about the interaction-function duality *in itself*: how do we for instance exactly talk about the identity of an interactive artifact? When we want to talk about interaction design in a more concrete, specific way, we can look at the work of Lim, Stolterman, Jung, & Donaldson (2007). They state that “*the material we need to understand for interaction design is flexible, ungraspable, and phenomenal*” (p.245) which makes it difficult to explicitly *design the interaction* (and function). They tackle this issue through the notion of *interaction gestalt* which they describe as a “*distinctive entity, something emerging between a user and an interactive artifact*” (p.239). It is an immaterial entity that can be articulated through a set of interaction attributes. These interaction attributes enable us to discuss and adjust the interaction gestalt on a concrete level. These attributes – such as speed, proximity and continuity– offer specific ways to talk about certain aspects of a more abstract interaction gestalt. Essentially, what the vocabulary does is dividing the interaction gestalt into parts that are discussable and *designable*, while the interaction gestalt itself is not directly discussable and *designable* (Landin, 2009; Lim et al., 2007). Lim et al. (2007) state that “*this set of attributes will provide a conceptual tool for designers to form a particular interaction gestalt*” (p.247) and therefore be able to concretely design the relation between interaction and function. A related framework or vocabulary is developed by Lenz, Diefenbach, & Hassenzahl (2013). This one is slightly more extensive and more clearly communicated. It offers a clear graph with eleven different attributes consisting of a pair of contrasting values each, such as *slow-fast* and *gentle-powerful*.

The drawback of all these frameworks or vocabularies mentioned above, when relating them to this thesis, is that they aim at evoking certain experiences. While the framing of this thesis is directed towards expressions. A framework or vocabulary that aims at expressions rather than experiences is developed by Hallnäs (2011). It could be seen as a stripped down version of the frameworks or vocabularies by Lenz et al. (2013) and Lim et al. (2007) but then with more relevance for interaction design aimed at expressions. Hallnäs his framework or vocabulary, referred to as *interaction design dimensions*, consists of two parts. In the first part, the interaction, function, interaction design form and interaction design expressions have to be clearly articulated. In the second part, the following four notions are used to specifically articulate the design from four perspectives:

*Timing* – articulate the temporal dimension of the design its use and expressions.

*Spacing* – articulate the spatial dimension of the design its use and expressions.

*Methodology* – articulate the use and expressions from the perspective of the person, from a usability point of view.

*Connectivity* – articulate the use and expressions from the perspective of the design, from the interface. Clearly articulating all elements of this framework enables you to look at the design from multiple perspectives related to expressions, to then to able to reflect on possibilities of how to alter the (expressions of the) design.

A second framework or vocabulary that focusses on interaction design from an expressions point of view is developed by Landin (2009). This framework or vocabulary differs to the one by Hallnäs in that it more specifically articulates the expressions themselves, by words such as *alienation, thrill and thrust*, which describe how the design expresses itself. What Landin her framework or vocabulary does, is relating expression and form to each other in a way that makes it easy to use the duality of the notions to talk

about both individually. So when we want to create a certain expression in a device, we should both pay attention to this particular expression, and also to specific forms. As a result, two designs with a different *type* of expression –say one of thrill and one of alienation– can both have a similar *type* of form; according to Landin they both can be expressed through an indistinct form. However, this does not mean they have the same form. The indistinct form *type* is just a way of articulating how to design the actual form and the specific expression. The framework or vocabulary provides guidelines, not fixed rules, to reflect upon the desired expression in order to design it.

### **3. DESIGN - RESEARCH APPROACH**

This chapter explains the overall design based research approach and methodology, and the more specific methods used throughout the process.

#### **3.1 RESEARCH THROUGH DESIGN & KNOWLEDGE**

The relation between knowledge design artifacts in design-based research is such that the artifacts can be used to generate knowledge (Bardzell, Bardzell, & Hansen, 2015). There are different views on how this knowledge is manifested in the artifact. Some state that knowledge is inherently present within the artifact (Frayling, 1993) and that a skilled designer can adopt the knowledge by *reading* it (Cross, 2006; Goldschmidt, 1991). In the case of design-based research with physical interactive artifacts, this requires the interactive object to be experienceable and thus be physically present. However, there should be a way to communicate without the need of having the prototypes at hand. This importance of communication in research is stressed by Archer (1995) who states that "*research is systematic enquiry whose goal is communicable knowledge*" (p.6). *Communicable knowledge* is the knowledge that is easily transferable to other people, so not tacit (Cross, 2006) but explicit. We need to be able to adopt and communicate the knowledge from the prototype, so that we can develop collaborate knowledge for the academic community (Löwgren, Larsen, & Hobye, 2013).

Höök & Löwgren (2012) use the notion of intermediate-level knowledge "*as a 'midway' between instances and theories*" (p.23:5). *Instances* here refers to particular artifacts, and by abstracting *their practical knowing* one can extract explicit and thus communicable knowledge. Intermediate level knowledge is generated through particular artifacts. So therefore I need to experiment and sketch during this project, to explore the specific artifacts. In order to make the artifacts then communicable through this thesis – a written format- I present them through multiple images and clear descriptions of how they were established and how they work.

While the actual knowledge that this thesis contributes will be presented in chapter 5, I already want to indicate the format of the knowledge contributions. First of all, the different sketches (Buxton, 2007) that I used throughout the process will be presented as a repertoire of design exemplar (Schön, 1983) that can be reviewed to gain insights during related projects. In the words of Schön, we can use the exemplars to *see this as that*, so to relate the new situation to the *exemplar*, in order to gain insights that can be applied to the new situation. And as Cross (2006) states, "*we must not forget that design knowledge resides in products themselves: in the forms and materials and finishes which embody design attributes*" (p.101)

While this way of looking at the specific exemplars can give insightful and inspirational input for designers working on specific projects, I also developed more general and explicit knowledge on how appliances can show expressions, through a discussion of the design exemplars in relation to design insights and theory. This knowledge is intended at design practitioners (and researchers). They are the target audience.

## 3.2 RESEARCH PROCESS

The kind of research I intend to do is within the topic of design materials. Design materials as a research field of interaction design (Fernaeus & Sundström, 2012; Vallgårda & Bendixen, 2009) focusses on experiments with the material under study. “*the material move makes HCI more aligned with central concepts in design, such as what Schön refers to as a conversation with materials*” (Fernaeus & Sundström, 2012, p.487).

When it comes to the design based research process, I envision my process through the notion of *drifting* (Gall Krogh, Markussen, & Bang, 2015) which they consider as the way in which a designer moves through the design based research process, in a purposeful and reflective, yet uncertain way. Two different ways of *drifting* that they describe are relevant to my study: the comparative approach, and the expansive approach. Comparative is seen as an approach to “*explore ... by means of a number of design cases - working from or towards a shared platform of comparison*” (p.8), while expansive is described as “*the identification of an area as-yet uncovered with the ambition to reveal its qualities, ... mapping new areas.*” (p.9). I will combine these two, as figure 2 illustrates. The comparative and expansive approach are visualized in the top corners, while my combined approach is displayed in the middle. The comparative approach entails me to compare different artifacts side by side, while the expansive approach lets me explore these individual artifacts by drifting more freely, exploring the potential within the design space through iterative experimenting and sketching.

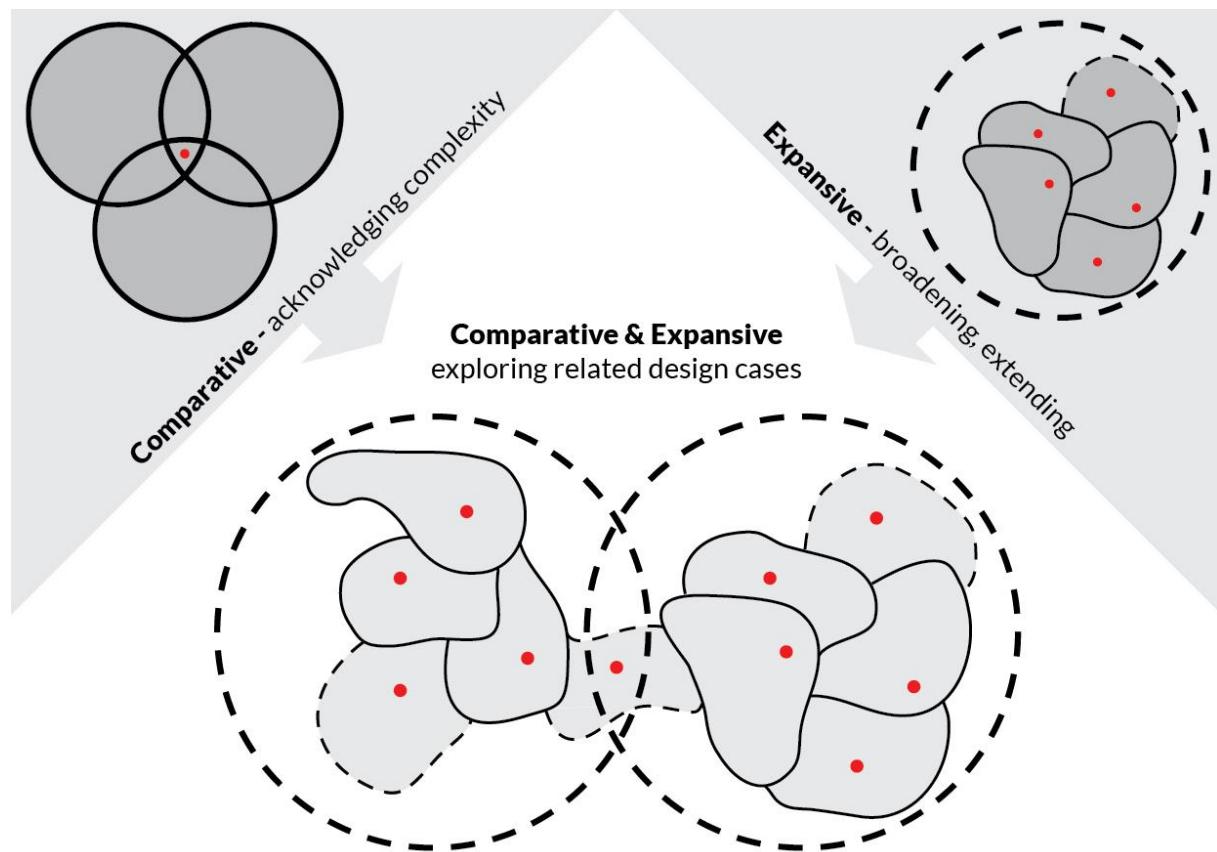


Figure 2: a visualisation of my way of drifting

### 3.3 METHODS

The move towards materials as the focus of study will profit from using methods such as sketching (Buxton, 2007) and experimenting (Hallnäs & Redström, 2006) as design methods to explore the material.

When comparing sketching and experimenting, the second notion is more general, encompassing all kinds of design artifacts: sketches (Buxton, 2007), prototypes (Houde & Hill, 1997), probes (Gaver, Dunne, & Pacenti, 1999; Hutchinson et al., 2003), experience prototypes (Buchenau & Suri, 2000), etc. As long as they are used to explore. Experimenting is not about the specific type of artifact used: it does not describe concrete methods, more an overall set of methods and the specific mindset one should have while applying them. As stated by Hallnäs & Redström (2006) "*In design experiments we investigate given questions from various perspectives*" (p.135-136). As the next chapter will show, I formulated different questions or focuses throughout the various phases of the design process, and I explored these from a variety of perspectives during the phases.

I believe it is important to identify which method(s) one is applying in order to keep the design process structured and systematic. This in order to oversee the overall procedure, and to stay aware of the intended outcome and the *path to follow* to get there. Using specific methods facilitates this structure. Throughout this project I mainly applied the method of sketching, according to Buxton (2007), in an iterative manner. In line with this sketching approach, Goldschmidt (1991) states that "*sketching partakes in design reasoning*" (p.123) meaning that sketching is not just a way of visualizing, but also a way of thinking, of articulating design ideas and decisions. Thus, it is useful within the design material approach: it will allow me to articulate certain expressions by exploring actuators in a variety of ways.

## 4. DESIGN - RESEARCH PROCESS

In this chapter, the design based research process will be elucidated. As described in section 3.2 Research process, I approached/regarded the process through the notion of drifting (Gall Krogh et al., 2015). In order to emphasize the drifting attitude I had throughout this project, this section is written in chronological order, in a journal-like format. In this way, the focus is on how I personally approached the topic, and how I drifted through the process, by reflecting, reframing and experimenting. As an added value, this way of describing the entire process makes the communication transparent.

Generally speaking, this design-based research process consists of three phases. Each phase demarcates a period of the design process where I created a set of sketches in an iterative manner, by creating the various sketches concurrently and developing them by insights gained throughout the sketching process. At the beginning of each phase, a specific focus for that particular phase was formulated; in between phases this focus was reconsidered and eventually reframed, as illustrated in figure 3. This framing and reframing fits well with the notion of drifting.



Figure 3: a simplified overview of the sketching process.

To select the various appliances, a *bricolage* approach (Vallgårda & Fernaeus, 2015) is taken. Instead of building the devices from scratch –which would of course be much too complex and time consuming for the purpose of this thesis– I gathered a variety of existing devices. While this can be described as a loss of control over the devices, Vallgårda & Fernaeus turn this around and describe it as an opportunity to find treasures. In a similar way as the notion of *serendipity*, they state that “*sometime there are interesting connections to be found*” (p.176). For each sketch I had to make, I had a variety of devices at hand that I could select –based on the design situation– and modify, rather than having to make things from scratch. When confronted with a certain design situation, I often automatically associated certain devices with it, because the combination triggered my imagination. The *bricolage* approach thus provided me with inspiration for what I could sketch.

At the end of this chapter, in section 4.4 Cooperative design review, an evaluation is described, where I consulted a fellow designer to review the different sketches. Including someone who was uninformed about how the devices would appear and respond gave me the opportunity to get external, uninhibited feedback.

## 4.1 PHASE 1: INITIAL SKETCHING

For this initial sketching phase, the aim was to explore how the combinations of two different actuators can be used –as design materials– to provide information about the appliance. In this phase, the focus was mainly aimed at letting the appliances communicate their (core) function, while later rounds drift away from this functional perspective. In order to explore this, three different appliances were expanded with two actuators each. The appliances that were used are a rice cooker (figure 4), a waffle iron (figure 5) and a water boiler (figure 6), all of these initially only used LEDs. By adding small Arduino microcontrollers inside and connecting these to the internal wiring of the appliances, I was able to freely control various actuators. The actuators used during this phase are LEDs, (piezo) speakers and vibration modules. I placed actuators outside on the housing of the appliances, to be able to quickly modify the sketches.



Figure 4: the rice cooker, expanded with vibration modules and a piezo speaker.

On the front there is a toggle switch with two options: cooking (bottom) and keeping warm (top). Turning the appliance from one state to the other will be supported by a brief sound. The vibration is activated when the rice is ready.

At first I planned to make a modular setup, where I could interchange the different actuators freely among the appliances to create different setups. However after some experimenting and testing –both during cooking as outside of context– it became clear this would not work as well as I intended. For two three reasons:

1. The material and form of the different appliances have an influence on how the different actuators are sensed. Even when just attached to the outside of the appliance, the actuators become part of its form. A clear example is the case of the vibration modules: the heavier appliances did not vibrate too much, while the lighter ones did.
2. Some of the appliances already provided information about their current state by themselves, through different modality independent of the actuators. For instance the way in which the water boiler makes a sound when it is ready, or how the rice cooker vibrates slightly while it is functioning (while it also gets warm to indicate it is working). Adding additional sound and vibration to these two respectively, is either not noticeable or becomes confusing.
3. The different behaviours and functions of the appliances resulted in the fact that some of the actuators felt more suitable to be used in them. In case of the waffle iron, it was annoying to display a sound while heating up (since this resulted in a continuous sound) and then a light while ready. The other way around felt much more *logical*: a light while warming up, and a sound while ready (which would inform you also when you are not looking).



*Figure 5: the waffle iron, expanded with LEDs and a piezo speaker. The LEDs used here can indicate two colors: red and green. There is a turning knob to set the temperature. If the appliance is heating up, the LEDs turn red to indicate 'not ready'. If the appliance is at the desired temperature, so ready, the LEDs turn green. An alarming sound is played when the waffles are ready.*

It turned out that applying actuators in pairs, without considering the context they would be applied to, and materiality they would be combined with, did not provide insightful insights. Therefore, I combined the actuators into pairs that seemed most suitable for each individual appliance (the combinations are mentioned in the captions below each figure). Then I started sketching by programming the Arduino microcontrollers in a variety of ways, to try out specific behaviours to use the actuators in different ways, based on my experimentation. After some iterative sketching, I came up with final versions for each appliance. These are explained in the captions below each figure. After these experiments, the focus was reframed for the second sketching phase, as will be explained in the next section.



*Figure 6: the water boiler, expanded with LEDs and a vibration module. The LED used here can indicate two colors: red and green. The green light indicates the appliance is ready to be turned on, while the red light indicates that it is functioning. When the appliance is functioning, a vibration is used to indicate this. Here, the actuators are placed on the inside of the appliance.*

## 4.2 PHASE 2: SECOND ROUND OF SKETCHING

The appliances that were used in the initial sketching phase did not seem to alter too much. Instead, they just replaced the already present LEDs with different actuators. While this in some cases gave improvements, such as being informed by sound, which can be sensed while not looking, it felt like a minor addition. While in the previous phase the appliances were considered from a functional perspective, I wanted to approach this second sketching phase more from an expressions perspective, by more actively embracing the notion of expressions. Based on this, I reframed my aim as taking a freer, less limited way to explore how actuators can be used –as design materials– to let appliances express certain states or conditions.

As a start, I asked myself how I could *support* some of the devices I had at hand to express themselves. Instead of informing people that they are *ready* or *working*, I considered the devices as objects that were willing to tell us something, less directly related to the functions they have to perform for people. I thus considered the devices more as expressionals (Hallnäs & Redström, 2002) than appliances. As I stated in section 2.3 *Expressions & form*, the expressional perspective looks more at the device itself and what it *could* express independent of what the user actually wants to know.

I used Hallnäs' framework of interaction design dimensions (Hallnäs, 2011) –as explained in section 2.4 *Articulate a design vocabulary*– as guidelines for developing the sketches during this phase. The complete interaction design dimensions are a bit too much to discuss here in detail; for anyone interested, the appendix shows an insight of how I applied the interaction design dimensions per device. For each sketch below, I will briefly explain how the dimensions contributed to the sketching practice.

Four kitchen devices were selected where I imagined a certain expression to be added. These were a toaster (figure 7), a water boiler (figure 8), an ice cream maker (figure 9) and a blender (figure 10). I will discuss these one by one.

The toaster (figure 7) expresses how it is *feeling*. Of course, the device is not actually feeling, but by expressing certain *behaviours* similar to how living beings would express themselves, I tried to explore an expression of relatedness through this sketch. Based on the interaction design dimensions, I decided to fill up the waiting time while using the toaster, by expressing some of the possible states (on and defrost) in a different, which right now are only indicated by a blue LED turned on or off. The toaster has vibration modules attached inside which are programmed in such a way to express certain behaviours that match to what the device is doing, as figure 7 explains. The two vibration patterns only mimic certain expressions of living beings. The device does not suddenly become a living being, however it might appear as a living being. Are we able to relate to a device when it shows behaviour more close to what we are used to from living beings? I will get back to this in section 5.2 *Discussion*.



*Figure 7: the toaster, which has vibration modules attached to the inside of the casing, which makes it possible to vibrate it and make a sound through resonance. The toaster has two states, on (middle image) and defrost (right image). When the device is turned on, the vibration will express this by mimicking a heartbeat, while in the defrost mode it mimics a shiver pattern.*

The water boiler (figure 8) expresses what it is waiting for. Since we usually do something else while waiting for the water boiler, we can easily get distracted. When we do not notice the mechanical click it produces, we might forget about the water until it is cold again. I wanted to let the device express that it is ready until you used the water. In this situation, the person is not the only one waiting, the device is as well. When it has boiled water for you it keeps on playing a sound –as explained in figure 8– until you actually use the water. Through the actuators, the kettle then appears dependent & demanding. It seems to want you to use the water before it cooled down again, expressing this in an intrusive way. This expression of intrusiveness can both be seen as helpful and annoying.



*Figure 8: the water boiler, which has a small speaker attached at the bottom of the handle. The speaker is activated soon after the water finished boiling, playing the iconic sound of a whistling kettle for a couple of seconds. This sound is repeated every 15 seconds until the device is picked up and (some of) the water is poured.*

The ice cream machine (figure 9) expresses what it is doing internally, which is rotating a spatula to mix the ingredients. It does this over a long period of time, in a slow way, by producing a mild mechanical motor sounds. I decided to enhance this expression of calmness. Next to this, I decided to bring the rotary movement that is happening inside to the surface of the device, as explained in figure 9. In this way the device is not just showing it is functioning (as how a single LED indicates an appliance is turned on), but an expressional layer is added that indicates what is actually happening within the device; the rotatory moment of the spatula. An expression of the internal mechanism is added to the already calm expression.



*Figure 9: the ice cream maker, which has both a (stepper) motor and a circular LED strip attached below the top of the case. The motor rotates a small stance on which the ice scoop can be placed. The circular LED strip is programmed to display a pattern in which the individual LEDs fade in and out in turn, creating a rotary sequence of LEDs lighting up. Both have the same, slow pace.*

The blender (figure 10) expresses what you are doing to it. Not in a functional way –you operating it– but in an expressive way –you making it active– and since this activity of the blender is a loud and aggressive one, I decided to express this through red lights coming from the inside of the device. This aggressive expression of the blender, based on its abruptness and harshness, is in strong contrast with the calmness of the ice cream machine. For this sketch I strengthened the already aggressive expression that the blender has on its own while it is being used.



*Figure 10: the blender, which has a LED strip wrapped up inside which makes it possible to illuminate the white housing as the images show. The intensity of the light is mapped to the intensity of the blender: the blender has multiple speeds and by increasing this, the light will get brighter. The image on the left shows the lower intensity while the image on the right show the higher intensity.*

While these four sketches all focussed on expressions in a free, diverging way, many insights were gathered throughout the experiments. I will get back to this in section 5.2 *Discussion*. One downside of this rather open approach is that there is no clear structure in what to exactly label as the expressions. What makes respectively relatedness, intrusiveness, internal mechanism and aggression the expressions and not something else? In order to go deeper into what *makes* the expressions, I will consult a framework in phase 3 that more specifically articulates the expressions.

## 4.3 PHASE 3: FINAL SKETCHES

As the end of the previous section indicated, I will approach this phase by using a specific framework, to be better able to discuss and design certain expressions. For this, I use the framework for *expressions of interaction* as developed by Landin (2009) which is explained in section 2.4 *articulate a design vocabulary*. The framework offers a vocabulary to discuss and reflect on how to *design* a certain expression, both by reflecting on the expression itself as on the interaction form(s) that might evoke the desired expression.

During this phase, the main focus shifted slightly from the actuators themselves towards the expressions they enable. To support this, I decided to use only one device that I could reuse for multiple expressions. This was done by writing multiple programs that could be uploaded in turn, which made it possible to experiment freely with multiple sketches in an iterative way. In this way, I could use one device to experiment with a variety of expressions. In total, three sketches were created.

The device that was selected for this sketching phase is a coffee machine, which can be seen in figure 11. This is a coffee machine that uses coffee pads to make coffee. There is a handle on top to select between cold and warm water (there are specific pads for cold beverages) and there is a button to start the device. In order to focus more on the expressions and less on the actuators, I decided to only use the actuators that were already present in the coffee machine. Because I spent some more time on this device than during earlier phases, I was able to also control the internal actuators, which are the pump for pouring the water out, and the heating element for getting warm water. The button contained a LED inside that could display both green and red, and by combining the two (resulting yellow light) and turning them both off, I could indicate four states with the LED.



Figure 11: The a Nespresso DeLonghi Dolce Gusto coffee machine, that was used to sketch and explore multiple expressions.

For the first sketch, I focussed on the expression of interaction *alienation*. It is described by Landin (2009) as “*Products designed in such a way that we, even if we use them often, never really see the link between cause and effect*” (p.56). The missing link between cause and effect, between interaction and function, results in alienation or “*a distance between people and the device*” (Landin, 2009, p.55). Landin describes three interaction forms that can result in this expression: an indistinct, illusionary and fragile form. This is how I included these three forms in my sketch, while relating them to the expression I wanted to evoke:

- Indistinct: I made the way in which the handle and button are used unclear. In this sketch, the handle is used to turn the coffee machine on (to the warm or cold side, for respectively warm or cold water), while the button should then be used to turn the device off.
- Illusionary: I programmed the LEDs in the button to switch to a random new colour every time the handle is used. Therefore the specific colours do not indicate anything particular, which is deceptive: we interpret these colour automatically to have a certain meaning.
- Fragile: While the device is making coffee, it jams once in a while, appearing as if it is broken.

The result was a coffee machine where the link between cause and effect was indeed missing. Even for me, the one who programmed it, it was in the beginning unclear how to use the coffee machine.

The second sketch revolved around the expression of interaction *thrill*. This one is compared by Landin (2009) as partaking in an auction. First you act, but then “*the consequences of your actions are not clear*.” (p.65) which might result in a thrill. This expression was mainly connected to the indistinct form. While this form was also used in the first sketch, it came to a different result when relating it to the expression of thrill. The final sketch here was a coffee machine that poured random amounts of coffee each time it was used. Sometimes you would get just a very small amount of coffee, while other times your cup would pour over the edge. When the amount of coffee is too little according to your desire, you can press the button again, however, the risk of overflowing your cup gets higher each time.

The expressions of interaction that Landin (2009) describes and illustrates through her work are only some examples. She explains that designers should formulate the specific expressions they want for their design themselves. The same goes for the interaction forms. Based on this, I defined my own expression and described my own forms in order to evoke this expression. The final expression I am going to explore through sketching is the expression of awkwardness. I see awkwardness as an expression where the design appears clumsy and confusing. Two interaction forms that I envisioned would evoke this expression, are a vague form –*it does not give clear signals*– a clumsy form –*it sometimes does not respond properly*– and an inconsistent form –*it changes slightly over time*– which were included in the coffee machine as follows: each time the machine makes a coffee, it does this in a slightly different way, by pausing for shorter and longer moments while it is pouring the coffee, resulting in what might appear as hesitations. Once in a while, the handle and button will not respond, or result in the wrong effect. This example showcases that this framework offers a way of transforming abstract expression rather quickly into concrete proposals for a design. Not by strict guidelines, but by offering a clear articulation of how to approach it.

At this point in the process I was planning to relate the vocabulary of Lenz to my coffee machine. However, I was unlucky that the device broke down and there was not enough time to repair it. Therefore this step of the process had to be cancelled unfortunately.

## 4.4 COOPERATIVE DESIGN REVIEW

Near the end of the process, a design review was planned with a fellow designer. The purpose was to have the designs be used by someone without knowledge of how they should be used and will appear. The main goal was to gain insights on how the sketches were seen as interesting by other designers. Besides, it gave me insights on how the devices were used as expressinals (Hallnäs & Redström, 2002), and which ones were appreciated the most.

Unfortunately, the device of the third phase broke down shortly before the review so it could not be included. The devices of the first phase had too many open wires –some of them with 230 volts– to be considered safe to be used by other people. So the review focused exclusively on the four devices of phase 2. I will describe the devices in the order in which they seemed interesting to the other designer.

1. Water boiler – The water boiler was liked most because of the character it showed. It seemed to be speaking; the sounds appeared as particular messages. It was perceived as demanding, just as what was planned.
2. Ice cream machine – The ice cream machine came in a close second place. It appeared as something having a calm expression, like intended. The ticking sound appeared nervous, while the green colour light appeared calming at the same time. This was kind of confusing.
3. Toaster – the toaster was rated very neutral. It showed a certain character through the vibrations, but nothing special or interesting. An interesting comment is that if a normal toaster would have the quick vibration, it would probably appear broken. Figure 12 shows another interesting issue with this sketch.
4. Blender – the blender seems least interesting, because it only does one thing. The first time it scares you, after that you know what will happen and it thus loses its power. It appears as “bad angry lighting” which is something disliked. An angry character is noticed, which is also disliked



Figure 12: the toaster showing the red light of the arduino reflected insider, which was interpreted as if it was turned on.

It is interesting to notice that a lot of comments deal with the devices having a certain character, or that it is appearing as a living being in one way or another.

# 5. DESIGN - RESEARCH OUTCOME & DISCUSSION

In this chapter, the different artifacts used during the sketching process will be presented next to each other as a repertoire of design exemplars, and the more generalized insights gained throughout the process will be illustrated and discussed.

## 5.1 REPERTOIRE OF DESIGN EXEMPLARS

The various sketches I developed throughout the process should be seen as a repertoire of design exemplar (Schön, 1983) that can be reviewed to gain insights and inspiration for during related projects. Figure 13 shows an overview of all the sketches I explained throughout chapter 4 *Design-research process*.



Figure 13: these are the 8 devices that were used during the sketching process to experiment with.

In the next section I will discuss all these exemplars in relation to each other, to general design insights and to theory from chapter 2 *Theoretical basis*.

## 5.2 DISCUSSION

Here I will discuss and reflect on all my design work and writings so far in order to develop specific design insights, which will be discussed in order to develop some knowledge contributions. The first remark being discussed is a more general one, about the approach towards working with actuators. After that, some points will be discussed regarding actuators, as design materials. Next, the discussion will move towards the topic of expressions. And finally, the used frameworks and vocabularies will be discussed.

## **Design-Research Approach**

Reflecting back on the first phase, I will argue that a very controlled and structured approach to exploring the expressive potential of actuators does not seem fruitful. A more controlled and structured approach is definitely suitable for studies that have a very specific, clearly defined research goal, such as Hoggan et al. (2009) their study into which modality –sound or vibration– is most suitable to be used as additional feedback to support sight during text messaging in an underground context. But any study interested in using modalities in richer ways than as information providers, should take a more open-ended, explorative and designerly approach, like considering them as design materials.

Treating novel and unusual materials as a design material seems a very valuable working approach for many designers. These can be materials that have not been freely explored too much by interaction designers yet. It is this working approach that lets us uncover their qualities and potentials.

## **Actuators, as design materials**

During the first phase of the sketching process, I used speakers in two of the sketches and then used them while cooking. The speakers were activated loudly over periods of time. This became very annoying. With the LEDs and vibration modules this issue did not arise. It is important to realize that different actuators have different material properties; like any material has (Ashby & Johnson, 2014). It is then important for us to uncover these properties while experimenting, to see how they influence the overall design and expression, and how we can make proper use of the properties, or change to another actuator if its properties fit better to the situation. Harrison et al. (2012) uncover that by using a single LED, we can already express many different states. By focussing on multiple LEDs, or different actuators, even more –and different– expression will become possible. Since the materials and forms we work with are dynamic (Lim et al., 2007), the qualities they encompass are dynamic as well. We thus have to uncover the qualities of actuators in use, by experimenting.

While I was fine-tuning the waffle iron sketch, the code behaved differently as I expected. However, it turned out as a positive surprise. This is just what can happen while experimenting with materials: sometimes it ends up different as you expected, but not necessarily in a bad way. It is important to remain open for true experiments, where you do not know what the result will be. While this applies to working with anything as a design material, I believe it is specifically important to keep in mind while using actuators as a design material. Because programming the behaviour of an actuator is a very logic-based activity it can easily happen that we automatically adopt a more narrow mindset, while for the design material approach we need to stay open-minded. Interesting discoveries might result when we try things of which we do not know what will happen.

In the case of this study, the actuators were added to already existing devices. During experimentation, it became very clear that the devices already had some *actuation* –some output that can be sensed– going on by themselves, such as heating up. However, for any designed object it is important to realize that many different aspects of the design can already tell us something, or express something, about the design. Think of the way in which many cd players show a small window through which we can see the disc rotating, thus knowing it should be playing. A turntable expresses even clearer that it is playing music. We thus do not need an actuator to express that it is the turntable who plays the music we are

hearing. We have to be aware that some things are expressed inherently through the design and thus we should not use actuators to express what is already being expressed; except of course when this is done with a clear purpose.

During the first phase, the actuators were used in a binary way –turning them either on or off– to indicate binary states –*operating yes or no, ready yes or no*– related to functions. While the second phase focusses more on expressions, both on interaction and function, and therefore on aesthetics (Hallnäs, 2011). In this second phase I therefore made more versatile use of the actuators by varying their intensity and creating certain behavioural patterns. This resulted in more possibilities with the actuators and therefore more options for expressions. Letting actuators behave in a variety of ways rather than just binary really improves their expressive potential.

### Expressions

During the second phase I explored both the blender as the ice cream machine in a similar way, by focussing on the already present expression that the devices have on their own. As both Landin (2009) and Hallnäs and Redström (2002) state, each object has an expression, whether it is consciously designed or not. This is important to acknowledge, and results in the possibility to either strengthen the expression or counter it. None of them is better than the other, it just has to be a conscious, well-considered decision, based on what you want to achieve.

Expanding on the previous paragraph, the contrast between both devices –one expressing aggression and the other one calmness– makes them into an interesting case study where the range between these two expressions can be explored as well. Exploring contrasting expressions can result in a rich variety of insights.

While the framing of this project is aimed at actuators as design materials, it is important not to overlook the sensors and rest of the computation. These are just as important for the expression. We cannot focus on just actuators while designing expressions. Processing power, sensor and actuator all need to be considered, since only together they fully express how the design will appear. This claim is supported by Vallgårda & Redström (2007) who acknowledge the importance of talking about, in their words, both *computational processes, input and output streams* as separate entities that together form the holistic computation.

A specific type of expression, that got much attention during the design review, was that of designs appearing as if they are alive. Such expressions were the result when the devices displayed behaviour similar to behaviour that we are used to from living beings. Through specific behaviours, devices could appear as being e.g. cute, angry and sad. By assigning designs such living-qualities, it seems that we can relate better to the devices on an intimate level.

It is important to recognize that even though the expressions are intended as *pure appearances* of the design, they are always defined by the designer. Therefore it is impossible for the expressions to be completely objective or absolute, there will always be some subjectivity as a result of the designer his/her decision on what is the expression. Defining something as a *pure appearance* is perhaps improbable, however, it is good to strive for an expression that appeals to many people, trying to make them as universal and widely recognizable as possible.

## Design Vocabulary

While I was applying Landin (2009) her framework or vocabulary to my design work in phase 3, a rather free interpretation of her work helped me more than a very strict reading of it. Seeing frameworks or vocabularies as guidelines, rather than sets of fixed rules, is how they are used in other design practices; in graphic design, the notion of spacing does not tell you where to place your elements but instead it gives you parameters to work with (Krause, 2004). In Landin her view, “*to say that thrill is an expression of the design is just to say that the system is designed in such a way that thrill can be a description of how someone in certain situations might relate to this way of buying tickets*” (Landin, 2009, p.66). In contrast, I prefer to stay closer to Hällnäs’ view of seeing expressions as “*the way things themselves appear*” (Hällnäs, 2011, p. 73) which places the focus of the expression solely on the object; on that what we can actually design, which was the original purpose of focussing on expressions as defined for this. However, despite this disagreement with Landin, her framework or vocabulary still offered me valuable guidelines to work with, because of the *interpretative reading*.

The difference between Landin her view and Hällnäs and my view offers another interesting discussion point. Landin her expressions relate to the person while using the design, while the view of both Hällnäs and myself relate to the design in use. The different viewpoints –illustrated in figure 14– can be formulated as *Expression in Interaction* in the case of Hällnäs and me, and *Expression of Interaction* in the case of Landin. *Expression in Interaction* refers to the idea that the design expresses something during, *in*, the interaction gestalt. *Expression of Interaction* then refers to the idea that the interaction gestalt itself –which emerges between the design and the person and might be perceived by the person– expressed something. Described in another way: *Expression in Interaction* describes the expression from a design point of view, while the *Expression of Interaction* describes the expression from a personal point of view. While no work on expressions clearly differentiates between these two types, I believe it is important to acknowledge which one you are focussing on. None is better than the other, they are just very different and therefore need to be articulated so it gets clearer what type of expression we are designing.

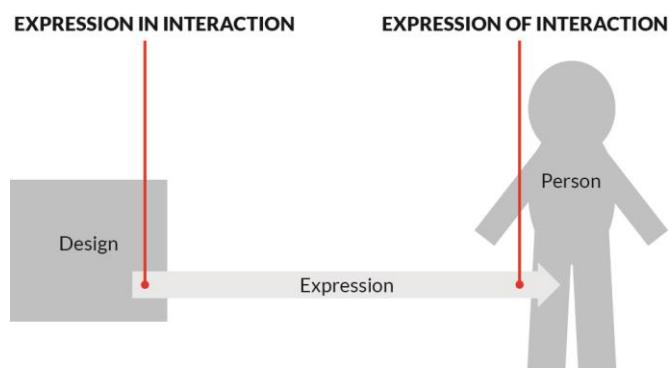


Figure 14: An illustration of the proposed difference between Expression of Interaction and Expression in Interaction

# 6. CONCLUSION

In this final chapter of the thesis I will respond to the research question in retrospect and suggest some work that could be done to advance the research in the future.

## 6.1 RESPONSE TO THE RESEARCH QUESTION

The research question stated at the beginning of this thesis was:

How can I explore the expressive potential of actuators as a design material?

By trying out a variety of approaches towards this topic, I can say that having an open mindset and an interpretative framework or vocabulary to build upon seems like a very promising approach. The open mindset serves the design material approach, while the framework or vocabulary gives you certain guidelines on how to design expressions. Because expressions in interaction design are such an abstract entity, it seems to be beneficial to base them off a framework or articulate them through a vocabulary, rather than to design them from the ground up.

## 6.2 SUGGESTIONS FOR FUTURE RESEARCH

1. When comparing the frameworks or vocabularies of Lenz et al. (2013) and Landin (2009) to each other, there is one clear similarity. Both look at the relation between the interaction (gestalt) in itself, and more *outward-looking (re)presentations*. However, looking on a more detailed level, they approach this in a rather different way. Lenz et al. state that certain interaction attributes are likely to result in certain experiences for a person. These interaction attributes are a very analytical way of describing an interaction. Landin, on the other hand, defines certain interaction forms –in a more holistic– and how these are likely to result in certain expressions from the design. I identify strengths and weaknesses in both approaches and therefore I propose the start of an assembled framework. This is something I was hoping to make a short on, but since the coffee machine sketch broke down I had to cancel this unfortunately.
2. It seems important to study specific actuator more in depth, such as how Harrison et al. (2012) have done with LEDs. So by examining their expressive possibilities in a straightforward manner. A next step would then be to combine specific actuators and study them in a similar, elementary way.
3. It is important to acknowledge that I am the only one that designed the sketches. By letting other designers use actuators as design materials as well, more generally applicable insight might be gained: some of the ones discussed above might mainly apply to myself. However, this can only get discovered by other designers for themselves as well, when they are applying my insights to their own practice.

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# APPENDIX

The interaction design dimensions as developed for section 4.2

## TOASTER

**Interaction** – “Toasting Bread”. We use the toaster to toast bread. We handle and monitor the toaster.

**Function** – “Toasting Bread”. The toaster toast bread.

**Interaction design form** – The device has 2 openings in the top in which slices of bread can be placed. There are ‘platforms’ on which the slices lean, and a handle to lower the platforms with the bread into the toaster. The toaster now goes on, starts heating. When the toast is ‘ready’ (after a certain time has passed), the platforms with toast ‘jump up’ and the heating stops. The heating time can be adjusted by a rotary switch at the front of the toaster. There are also two buttons. One for ‘defrost’ which results in a predetermined, extra-long heating time. The other one for ‘reheat’: a predetermined, extra-short heating time. A final button is to stop the toasting at any desired time. There are LEDs next to each button.

**Interaction design expressions** – The toaster expresses when it is heating by glowing internally (which can be seen when looking in at it from the top) and by lighting one of its LEDs. It expresses that it is heating in one of its specific state (‘reheat’/‘defrost’) by the two other LEDs. It expresses that it finished toasting by a loud sound (the toast ‘jumping up’) and (depending on the heating time) by the smell of toasted bread and maybe even some smoke. Through the handle, it expresses whether the platforms are lowered or not.

**Timing** – Between start and finish there is a clear waiting time.

**Spacing** – We are at the device to turn it on, and come back when it is ready. In between we go somewhere else.

**Connectivity** – The handle is lowered to turn on the toaster. A light goes on to indicate “on”. It is now heating, toasting the bread. It is turned off automatically when the toast is ready. A loud sound is produced when the toast ‘jumps up’.

**Methodology** – I cut two slices of bread. I place them in the opening and lower them through the handle. While the device is ‘functioning’ I have to wait / can do something else. When it’s ready, I take the toasted slices out and eat them.

## WATER BOILER / ELECTRIC KETTLE

**Interaction** – “Boiling Water”. We use the kettle to boil water. We handle and monitor the kettle.

**Function** – “Boiling Water”. The kettle boils water for us.

**Interaction design form** – It is a kind of container with a spout that makes it is easy to pour. There are measurements on the (transparent) side to indicate how much water is in there. There is a platform to place it, a button to turn it on and a LED to see whether it is on. *When the water boils, the kettle turns off automatically. (is this part of the Interaction design form?: YES, this is what the design does as we use it (so its function) and form is about relating function and interaction to each other, in an abstract way: how the kettle expresses that it is turned off in a concrete way, is then (one part of) the expression!)*

**Interaction design expressions** – The kettle expresses that it contains water (only) through the transparent side. It expresses that it is boiling by the positioning of the button, and by turning the LED on. The kettle (and the water itself) makes different sounds while it is boiling, so through these different sounds it expresses how far in the process of boiling it is. When it just finished / stopped boiling, it expresses this by making a “click” sound. It expresses if the water is still hot, by means of steam.

**Timing** – Between start and finish there is a clear waiting time. (*there is a kind of “turn-taking” between function and interaction.*)

**Spacing** – We are at the device to turn it on, and come back when it is ready. In between we go somewhere else.

**Connectivity** – A button is pressed to turn the kettle on. A light goes on to indicate “on”. It is now boiling the water. It is turned off automatically when the water boils. You can now hear the water boiling. A “click” is produced and the light turns off.

**Methodology** – I pick up the kettle to fill it with water. I place it at the base and turn it on. While the device is ‘functioning’ I have to wait / can do something else. When it’s ready, I (should) ‘pick it up’.

*Which insights does this give me? How could a sketch look like?*

How do we control the device? How are we informed when it is ready? What happens in between? Can there be some use in between?

Things that it does not express: it could express when there is warm water being “wasted” / cooling down. This is in a way related to “Timing”. When water is ready, people shouldn’t wait too long, or it gets cold..

Also, none of the expressions above is aimed at the (duality of) interaction. Maybe the device can express ‘Dependance’ (Landin, 2009, p.63) to evoke a closer connection between human and thing.

## ICE CREAM MACHINE

**Interaction** – “Making ice cream”. We use the machine to make ice cream. We handle and monitor the machine.

**Function** – “Making ice cream”. The machine makes ice cream for us.

**Interaction design form** – The appliance consists of a bowl and a cover. The bowl is for containing the ingredients; they are mixed in the bowl. The cover closes the bowl, and has a spatula attached that fits in the bowl. Through a rotary timer knob, the appliance can be turned on, for a certain of time, during which the spatula will rotate slowly in the bowl, mixing all ingredients. Because the bowl should be kept in the freezer, it will also cool all ingredients, making them into ice cream.

**Interaction design expressions** – The appliance performs by very mildly rotating the spatula, which is not visible from the outside, but is expressed by a soft, mechanical sound. It expresses a certain ‘calmness’.

**Timing** – The appliance works over long periods of time without user involvement; it can be set to operate for up to 45 minutes of time.

**Spacing** – During operation, the person has the possibility to move away from the appliance.

**Connectivity** – The turning knob provides the main way of operating the appliance.

**Methodology** – I can use the appliance to create any kind of ice, sorbet or frozen yogurt. This ingredient selection is in a way more interesting and skilful than operating the appliance itself: while I select the ingredient to create a nice desert, the device perform all the ‘hard’ work. It’s easy to create a blended substance and consume this.

## BLENDER

**Interaction** – “Blending”. We use the blender to blend or mix food and drinks. We handle and monitor the blender.

**Function** – “Blending”. The blender blends or mixes food and drinks for us.

**Interaction design form** – It is a base on which a big cup can be screwed (and unscrewed). The cup contains cutting blades which can be controlled via the base: the base has a rotary knob to control the speed of the blades. There are three states that can be controlled via the knob. State 1 is for regular speed, state 2 is for extra fast. Both these states can be ‘fixed’: the knob can be released and the blades keep on cutting. There is a third stats, called state P, we have to hold: by releasing, the blades stop cutting. The cutting speed in this final state is the same as in state 2.

**Interaction design expressions** – The blender expresses that it is working (of course) very clearly by loud sound and ‘aggressive’ pulverization if whatever is in the cup. harsh and abrupt When it is not performing, it suddenly expresses itself as a very calm object.

**Timing** – The blender can be used in two ways when it comes to time. State P makes the timing of use very direct; the blender is on as long as you turn the knob. State 1 and 2 work a bit more indirect when it comes to time: they can be turned on, and operate for a longer period of time without influence / acts of the person.

**Spacing** – In this second situation described above, the person has the possibility to move away from the appliance. In the first situation, the person has to stay there.

**Connectivity** – The turning knob provides the main way of operating the appliance. It’s easy to unscrew the cup from the appliance itself.

**Methodology** – I can use the appliance to blend any kind of food; fruits, yogurt, nuts, etc. It’s easy to create a blended substance and consume this.