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Design and Craft Thinking Analysed as Embodied Cognition

Abstract

Through the concept of design thinking the act of designing is presented as an intellectual activity, and the act of planning the design is elevated over the making process. However, the importance of materiality and the embodied sense-making that occurs in this context should not be forgotten. In this study, embodied cognition in design and craft practices was investigated through three case studies. The study takes on an enhanced tactile perspective as a methodological platform; thus, the cases involve 1) deafblind makers in ceramics, 2) a practice-led self-study report on tactile experiences while working with clay and 3) a study on design students' use of their tactile sense during material exploration. The results show that the act of thinking design involves the body as a knowledge provider.

Keywords: design thinking, craft, practice, embodied cognition, case study.

Introduction

While research in interaction design for some time has utilised the theory developed within embodied cognition in relation to tangible interfaces (Dourish, 2001; Hornecker & Buur, 2006; Höök, 2010; Hornecker, 2011; Trotto & Hummels, 2013; Hummels & Van Dijk, 2015; Wilde, Tomico, Lucero, Höök & Buur, 2015), this theoretical framework has only quite recently been touched on within general product design or craft research (for examples, see Poulsen & Thorgensen, 2010; Rompay & Ludden, 2013; Rompay, Hekkert & Muller, 2005; Fredriksen, 2011; Kangas, 2014; Ojala, 2013; Tin, 2013; Nimkulrat, 2009, 2012; Ramduny-Ellis, Dix, Evans, Hare & Gill, 2010) and has been slow to influence the concept of design thinking. Moreover, the term 'Design Thinking' (Brown, 2009) has become ambiguous, since the latest developments have furthered the concept towards a business and organisation innovation method (Kimbell, 2011). What was traditionally understood as a study of the cognitive processes of the designer (i.e. design cognition), Design Thinking is now more popularly seen as a way to understand customer needs through the use of methods from design practice (Kimbell, 2011; Johansson-Sköldberg, Woodilla & Cetinkaya, 2013). Although conserning the same concept these separate directions may be described as two distinct discourses (Johansson-Sköldberg et al. 2013).

This article refers to the traditional understanding of the term, and it is extended to include the making of artefacts as well as the planning of designs. Traditional research in design cognition (Cross, Christiaans, & Dorst, 1996; Cross, 1982, 1984, 2001, 2011; Dorst, 1995; Dorst & Dijkhuis, 1995; Purcell & Gero, 1998; Akin, 1997; Akin & Lin, 1995; Rowe, 1987; Goldschmidt, 1995, 1997, 2001) has developed models around problem solving and strategies for framing the 'wicked' (Rittel & Weber, 1984; Buchanan 1992) or ill-defined (Goel & Pirolli, 1992) design problems (for an overview see Seitamaa-Hakkarainen et al., 2016 in this special issue.) Designing is thus presented as a predominantly intellectual activity, in contrast to its practical nature. This view, although plausible in the way it portrays the designer as a thinker, separates designing and making into two entities, leaving making behind as merely part of the implementation phase. Making or crafting the design idea is thus situated at the end of the design process (Cross, 2011, p. 4), seemingly not requiring intellectual activity.

However, the act of *making* is still an integral part of design and craft practices

(Nilsson, 2013). As the theory developed within design cognition studies are refered to when describing both the designer's and the craft practitioner's design process, it is necessary to develop it to include also the more material based aspects that recuires embodied sense-making. Similar critique has been aimed at both discourses of design thinking by design researcher Lucy Kimbell, (2011).

The results of this study suggest that the physical making and crafting of a design involves the embodied mind. It further claims that also the act of *thinking* or planning a design likewise depends on accumulated embodied knowledge. Through our physical experiences of the material world, we create mental images that we rely on in the design process, thus the body provides information also in the planning phase of designing, even before material manipulation (Groth & Mäkelä, 2016). The philosophical theory on embodied cognition (Merleau-Ponty, 1962/2010; Johnson, 1987, 2007; Varela, Thompson & Rosch, 1991; Lakoff & Johnson, 1999; Noë, 2004, 2009) supports this notion as it includes the perceiving body in sense-making and claims that human cognition is dependent upon its interaction with its environment, thus pointing to action and perception as keys in knowledge formation.

While literature on design cognition also mentions reflective conversations with material or reflecting-in-action and reflecting-on-action as proposed by Schön (1983), the role of the body and embodied knowledge is not elaborated on in this context, other than in terms of tacit, implicit or experiential knowledge. Although describing a very similar way of engaging with materials, these concepts do not clearly articulate the body as a contributor to knowledge.

Only recently the theory of embodied cognition has been recognised in the field of design and craft. Cognitive scientist and design researcher Henrik Gedenryd (1998) criticises design cognition studies and claims that they follow a traditional research paradigm with a focus on the isolated mind and intramental processes rather than taking into account perception and interaction with the environment (Gedenryd, 1998, p. 8). He further argues that "designers go to some length to even avoid having to work intramentally, as the usual theories claim they should do" (Gedenryd, 1998, p. 17).

However, there remains a lack of a comprehensive empirical model for how the designer or craft practitioner uses his/her embodied knowledge in his/her design or making process. This is understandable, as the topic is not easily approached. Any skill or prolonged practical knowing involves a great deal of tacit knowledge that is not explicable (Polanyi, 1958; Niedderer, 2007; Biggs, 2004), and this makes the subject difficult to research (Niedderer & Townsend, 2014). In addition, embodied cognition theory has only recently gained credibility and thus developed quickly in the recent decennium. Although traditional design cognition theory has a line of discourse close to phenomenology it has not been as articulate on the aspects of materiality and subjective bodily experiences of the practitioner.

Another reason for this gap in knowledge might be that design practice, and especially crafts, have tended to be researched from outside the practice itself. Although benefiting from these studies, the research done in the workshop provides another perspective (Keller & Keller, 1996, p. 21). Now that designers and craft practitioners are also included in higher academia, they have the opportunity to conduct organised research on their own practice. The researcher-practitioner has an intrinsic motivation to reveal his/her experiential and embodied knowledge; thus, design and craft research gain access to the practitioner's point of view (Groth, Mäkelä & Seitamaa-Hakkaraien, 2015, p. 57).

Erin O'Connor is an example of a practitioner who has researched her own craft practice through examining the embodied and experiential aspects of the process. She trained as a glassblower for two years while reporting on her learning experience through very vivid accounts of her personal experience (O'Connor, 2005, 2007). Another example is a group of

metalsmiths (Almevik, Jarefjäll, & Samuelsson, 2013) who physically re-enacted the sequence of a video documentary on metalsmithing from the 1970s in order to understand the making process of an object. By re-enacting the process themselves, they were thus also able to reflect on their own haptic and experiential knowledge of the same process. The research at hand is a contribution to this growing tradition of researcher-practitioners who research their own practice, through practice and for practice, with an emphasis on the haptic and embodied aspects of the design and craft process.

Although not yet defining a model, this research presents some initial findings of embodied sense-making in the process of handling material in a design or craft context. The guiding research question is: *How do design and craft practitioners think through their hands?* Being a relatively poetic question, some may feel that its logic is questionable: thinking happens in the brain, hands do not think. Yet anyone who works with material by hand may identify with the notion of some of the sense-making happening through the making process, via the contact with the material and through the hands rather than only in their minds (see Poulsen & Thorgensen, 2010, p. 30).

In the field of crafts, a sense of *thinking through material* has already been acknowledged in research (Anttila, 2006; Mäkelä, 2007; Nimkulrat, 2009, 2012). The research position that I take is therefore not a critical one; I am not questioning whether there is a notion of thinking through the hands within the practice of design and craft. Rather, I seek to investigate *how* embodied cognition is enacted through practice in order to better understand the relationship between the embodied mind and making in material.

Methodically, this research takes the perspective of an enhanced tactile experience as the platform for investigation in order to highlight the bodily aspect of the design and craft practice. The research may be seen as a sensory ethnography as outlined by visual anthropologist Sarah Pink (2009), although it focuses on the haptic viewpoint rather than a fully multisensory point of view. To be able to research such tacit knowledge, it was necessary to use multiple methods, such as participatory workshops, ethnographic and auto-ethnographic methods (Ellis & Bochner, 2000) as well as qualitative content analysis of interviews and video material. The research was conducted using a multiple case study research design (Yin, 2009).

I first arranged a series of workshops with deafblind makers in ceramics. The aim was to study the context of making in an enhanced tactile setting, learning from people who would be true experts in the use of their tactile sense. Having gained experience and inspiration from these participants, the next case involved a practice-led self-study in which I spent several days blindfolded in my studio throwing clay cylinders on a potter's wheel. This was done in order to reflect on my own experiential knowledge, which was more easily available due to the blindfolding. In particular, aspects related to tactile knowing and emotions that were present at different stages were useful for the investigation. The last case involved a study of students' use of their tactile sense and embodied knowledge in their material exploration, design and making process. From two groups of 19 students in total, two students were studied closely and interviewed for this research, and their own documentations, diaries and artefacts were analysed.

The research shows aspects of embodied cognition in these three settings and emphasises the need for a continued research effort into embodied cognition in the field of design and craft. As a result of this research project, I found that embodied cognition theory lends itself well to informing design and craft research since much of knowing is situated in action and in relation to previous experiences and material skills. Thinking design relies upon these embodied skills; therefore, the conceptual separation between making and thinking in design is not realistic. In the following section, the theoretical framework is introduced and the three cases are described, followed by a discussion on the findings.

The Knowing Body

The crafting and making process provides us with an opportunity to investigate the interaction between material and the embodied mind. In this research, extra emphasis is placed on experiential knowledge by including the body as a knowledge-provider in practice. To be able to research this body-based knowledge, it was necessary to adopt a theory that supports this type of meaning making.

Embodied cognition is grounded in phenomenology, which is the philosophical strand that most strongly argues for the knowing body. In contrast to the Cartesian dualistic and hierarchical view of the mind and body, phenomenology claims that we are restricted to a view of the world seen from the perspective of our situated body, thus we perceive the world through our senses. However, through our ability to move our body to a new position we may perceive the world from a new perspective. Thus we accumulate knowledge through interaction with our environment. This theory has been taken further by writers such as Maurice Merleu-Ponty (1962/2010) who specifically elaborates on perception in relation to meaning making and, more recently, Mark Johnson (1987, 2007), George Lakoff and Mark Johnson (1999), who show how the embodied mind is revealed through language and image schemata.

As we are now talking about the way we *think* or make sense in design and crafts, cognitive neuroscience also plays a part. Enactivism is a philosophical strand of neuroscience that has embraced the idea of the embodied mind. The orientation suggests that a person learns in action and accumulates knowledge through his/her embodied experiences with his/her environment; thus, the body is fundamental in all knowing (Varela et al., 1991; Noë 2004, 2009). This means that we create our minds through our experiences, and the more experiences we have of a certain action or interaction, the better we are able to anticipate and predict possible outcomes from future similar actions and interactions. Many aspects of design and crafts based knowledge can be explained by the theory of the situated and embodied mind, especially when it comes to material exploration and manipulation. In this context, the practitioner is using her embodied preknowledge of these materials.

Three Case Studies

The case study methodology developed by Yin (2009) has been used as a frame and general design for this research, yet each case uses a variety of methods. The *multiple* case study methodology was chosen in order to study three aspects of the research question in parallel. This allowed me to first visit a group of makers with a special condition, then to investigate the same research question from an auto-ethnographic perspective, and finally to visit a group of students, thus gaining three different perspectives and environments for the same research question. The point is not to compare the cases but to show different aspects of the same issue: How design and craft practitioners think through their hands.

Case 1: What can we learn from experts in tactile knowledge?

The first case involves three ceramic workshops with deafblind makers conducted at the IIRIS Service and Activity Centre for the visually impaired in Helsinki and the Tampere Resource Centre for the Deafblind. The main task of the study was to investigate unique processes related to creative working in a setting where the tactile sense is enhanced. The workshops were followed up by a discussion seminar at the IIRIS Centre, where aspects of embodied knowing and the "abstract" were explored. Two to six participants were usually present in the three workshops and the seminar, all with differing degrees of dual modality impairment. They brought their translators, and some also brought a personal assistant. All communication was thus translated using either tactile sign language (Figure 1), sign language or aided by an inductive hearing aid.

Figure 1. Tactile sign language. This image shows how one of the participants communicates with his interpreter through tactile sign language. (15 May, 2012. Screen shot from the video by the researcher. The participant has agreed to his image being used).

During the video- or audio-recorded workshops, I asked semi-structured questions in situ; this was done in order to gain accounts on the participants thought processes while working. Due to the difficulty in communication, these workshops intuitively became participatory workshops, especially the one in Tampere (Groth, Mäkelä & Seitamaa-Hakkarainen, 2013). I decided to use my own hands in the making of ceramics together with one of the participants as this was the most direct and useful way to communicate at that moment.

The participant wanted to try throwing clay on the potter's wheel, but I needed to communicate the instructions for throwing to him through his interpreter. Since the participant needed his hands to communicate through the tactile sign language and his hands were busy with the clay, I started throwing the clay *with the participant's hands*. I then discovered that in the act of throwing clay, tactile communication was sufficient to pass over my embodied and tacit knowledge about the throwing practice to the participant (Groth et al., 2013). The participant later tried throwing clay by him self and was unusually successful in his attempt.

Following the workshops and discussions with the deafblind participants, I learned that they had gained a new ability, which some of them reported to be very positive. They gave various accounts of how they used their haptic and tactile sense in their everyday life, from measuring the size and weight of objects to communicating with their loved ones. Some of the deafblind reported on a new relationship with their bodies, having become braver in their use of touch. This was also clearly noticeable in their brave way of handling the clay material.

Inspired by these workshops and the enactivist theory, I created a new research setting in which I sought to enhance my own tactual skills and sensitivity in order to research the possible benefits. The underlying theory was the plasticity of the brain and the assumption

that the brain reorganises itself according to our actions in order to enhance the skills needed for repeated actions, an ability thought to help in skill learning.

Case 2: Tactile augmentation in ceramic craft practice

The second case involved a practice-led self-study on tactile augmentation in ceramic craft practice. I documented a five-day blindfolded working process, developing a method for studying sensory experiences, haptic and tactile experiences in particular. The main task during the throwing process was the ability to judge the shape and form of the piece using the hands only (Groth, Mäkelä & Seitamaa-Hakkarainen, 2015, p. 59). The aim was to throw a cylinder that would meet the general technical requirements within ceramic craft practice.

In order to document the event and the sensory experiences, I made use of several research methods: firstly, a diary method was used, in which I answered specific questions and prompts just before starting the throwing session, and again just after finishing. Secondly, I used a contextual activity sampling system called Cass Q (Muukkonen, Hakkarainen, Inkinen, Lonka, & Salmela-Aro, 2008), which allowed me to create a portable questionnaire that was completed on a mobile phone before and after the event; it also allowed for the inclusion of images or videos if necessary. Thirdly, a video camera was used to record the event; this was also used for recording think aloud accounts (Eriksson & Simon, 1993). This meant speaking to the camera and trying to explicate everything that I was thinking and doing that could possibly be related to the event (Figure 2).

Figure 2. Blindfolded and thinking aloud. This is a screen shot from the video during the throwing events. (12 April, 2013).

The act of blindfolding helped me to reflect on the haptic experiences of the throwing situation, which usually go un-noticed. I experienced that my tactile skills were enhanced

over the five days, and on the last day it felt quite natural to trust my hands in the throwing process.

More importantly, I also noticed that the feel of the clay and the conditions of the material affected my emotions in either a positive or negative way. For example, when conditions started becoming unfavourable and the clay was getting too wet and soft to shape anymore, this was experienced as a negative emotion, and I knew that the available options for action were reduced and a decision had to be made whether or not to pursue certain actions or whether these could be considered too risky (Groth et al. 2015, p. 76). This indicated that emotions guided me in my risk assessment and decision-making during the process, and thus they also guided me in the problem-solving processes.

As emotions were initiated through the manipulation of the material, I made the hypothesis that emotions were guiding the throwing process to a large degree. In order to investigate this aspect further, I made a new separate video analysis (Groth, 2015) using the *Interact* video analysis software. I specifically analysed the so-called 'critical incidents' (Flanagan, 1954); these are the situations in which the process is in some way changing direction or is being jeopardised in some essential way. All video material (10 hours) was initially analysed to detect the critical incidents of the throwing events; this came to 23 critical incidents over the five days of data collection.

When analysing the video data, it became clear that the critical incidents had different degrees of severity. Some were not very severe and the problems were solved easily while others were of a more serious kind. The incidents were also either expected or not expected, some started abruptly and some were developing over time.

The haptic or tactile experiences that were found in the analysis of the critical incidents were to do with the density of the clay material, i.e. how hard or soft it was, and the wetness of the surface, i.e. the stickiness of the clay at different times during the throwing process. Also the position of the clay on the wheel, if centred or not, was a clear factor in the critical incidents and that would affect emotions in a negative or positive way. When it came to emotions, the most central were to do with confidence, stress levels or spirits, such as high or low) (Groth, 2015). The video analysis software gave me the opportunity to link the tactile experiences to the felt emotions and actions (Figure 3).

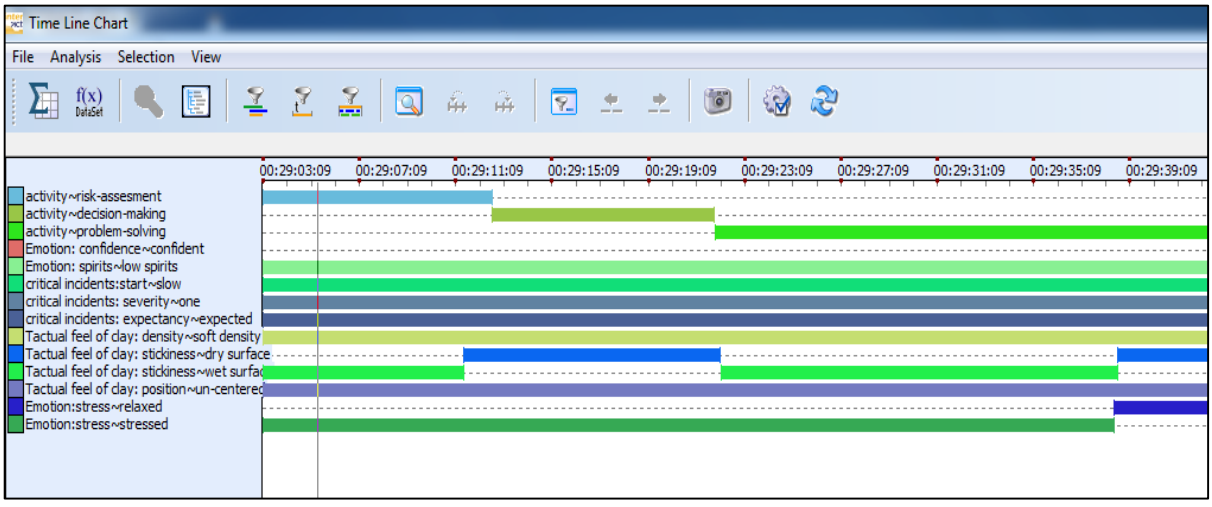

Figure 3. Tactile experiences and related emotions and actions. A screen shot from the video analysis process showing the timeline of a slow starting, severity one, critical incident, and with tactual experiences coupled with actions and emotions.

Case 3: The role of the knowing body in design students' material exploration

The third case was examining students' use of their tactile sense during a design and material exploration process. For this research, data gathered from the Design Exploration and Experimentation course given at the Department of Design in Aalto University was utilised. Each year, around 12 Master degree students participate in an eight-week intensive course. During the course the students travel to another city or area in Finland to gather inspiration; they also document their process in working diaries that they share in their weekly reflections (Groth & Mäkelä, 2016). Finally, an exhibition is arranged that shows the produced designs and artefacts from the course.

Data from 19 students was gathered and from this data, two students' cases, whose work was closely linked with the theme of tactile experiences, were chosen for deeper analysis. The data consisted of the students' diary notes, their drawings, photographs, weekly reflections and the final reflections produced during the courses (Groth & Mäkelä, 2016). The two students were also interviewed. The analysis was conducted according to a thematic content analysis (Fereday & Muir-Cochrane, 2006).

One of the students put great effort into finding the right "feel" of material that would fit her purpose. The emotional feeling that the finished piece should awake in the audience was a feeling of disgust and meanness, but also of wealth and luxury (Groth & Mäkelä, 2016, p. 12). The student made four physical models in velvet, satin, leather and plastic (Figure 4). In the interview, she describes these tests as her most important material tests as, they were used to test and compare the tactual experience and feel of the materials.

Figure 4. Four material tests made by the student. Photo by the researcher.

She explains further that they aided in evaluating the emotional connotations of the materials as she was able to let her friends and fellow students feel and evaluate the materials and in

this way also confirming the social and ethical value and general understanding of the material (Groth & Mäkelä, 2016, p.12).

The other student explored the different connotations of materials when used in unconventional contexts; testing the embodied expectations of the different materials (Figure 5).

Figure 5. Knives in different materials made by the student.
Photo by the researcher.

A mental material exploration was detected to precede the physical material exploration. In their diaries, both students list materials that they try out in their imagination before deciding which materials to try out physically (Groth & Mäkelä, 2016, p. 16). In the interview, one of the students reports that she actually did most of her material exploration in her head. Without previous bodily experiences of these materials, there is no pre-knowledge to judge these experiences against; therefore, we may assume that she was reverting to her experiences of these materials that she had gained in other, previous contexts (Groth & Mäkelä, 2016).

Both students chosen for the interview and deeper analysis had backgrounds in other craft practices, metalsmithing and textiles, before joining the University. Their previous skillset set them apart from some of the other students, who had less or no previous experience with handling materials in a design context. Students with less embodied experience with materials had more difficulty in choosing materials, and they became frustrated with their design process even before their actual material exploration.

In the case of one student, the awkwardness of moving into the material realm hindered him from advancing his design from drawings and concepts into a material prototype. In a video-recorded workshop session taken during the course, the student talked about his frustrations with materials as the reason for not being able to progress. He said: "my hands were not skilled enough to manipulate the material," and he later said, "I could not make what I wanted, so I made something else" (Groth & Mäkelä, 2016, p. 18). This particular student did not come to terms with the changed image of what he wanted to make, but instead repeatedly restarted his project, and he felt continuously frustrated through the entire course.

Discussion

The three case studies provided an opportunity to first gain inspiration and a deeper understanding from experts in tactile knowledge, then to turn the attention inwards to study one's own experiences in making, and lastly to turn the gaze outward again to study what the findings mean for design students. Although quite different settings, these three cases all focus on tactility and the body as an informant in sense-making with a material.

The general research question was to find out how design and craft practitioners think through their hands, and the specific research questions for each case were:

Case 1: How do experts in tactile knowing use their enhanced tactile sense in a making situation?

Case 2: a) What methods may be used in the study of embodied and experiential knowledge in crafts? b) What is the role of emotions in connection to tactile experiences in a craft practice?

Case 3: How do design students use embodied knowing in material exploration?

How do experts in tactile knowing use their enhanced tactile sense in a making situation?

Case 1 highlighted that sensory experiences or skills may be developed and augmented through an impairment of another sensory modality; this made me realise that although the making practices are predominantly tactile, we take much of our tactile experiences for granted, and that we have much to gain by listening to our sensory experiences. The deafblind makers may inspire research into embodied knowledge and the possibility of enhancing one's tactile sensitivity by closing one's eyes and exploring material from a new perspective.

The act of manipulating material is also a way of connecting oneself with the physical world; the following passage is from the analysis of the first case (Groth et al., 2013, p. 7-8):

> When we touch a material, we simultaneously feel ourselves and become aware of 'being'. In this sense, making can be considered a way of being in contact with oneself. Our body is in contact with a material that bends to our will, but the material also has its own will; thus, there is a struggle between our will and the material. We make concessions to the material and we make compromises with ourselves, due to the will of the material. It is as if there is communication with and through the material, and the outcome is an expression of this struggle or collaboration. Therefore, the outcome of this process is not a pure expression, but rather evidence of that process. In other words, it is an artefact that embodies the self and the material. This struggle was evident in both Olavi's and Laura's [deafblind participants in the research] processes as they familiarised themselves with, and eventually won the struggle with, the new material.

Emotions seemed to play an important role in the connection to the felt experience of material; this was an aspect that featured strongly in all three cases. In Case 1, emotions were connected to the deafblind participants' anxiety over technical skills as they embarked on working with a new material. The participants were new to the porcelain clay that was used in

the workshop, and they expressed anxiety and a disbelief in their making abilities, as the material was difficult to use and did not comply with their previous experience of clay. When continued efforts with discouraging results finally became positive through an internal learning process, the emotions of the participants grew equally positive and a "catharsis" was experienced. This was usually linked with the acceptance of the new result even though it did not comply with the initial plans or mental image aimed at.

From experiencing tactile communication in the first case study, I would also like to point to the possibility of tactile skills being taught to another person by 'hands on' tactile instruction, even without the use of language. In some cases, this might even be more effective than only visual or vocal teaching methods, as deaf and blind Olavi (his name has been changed) was able to receive my embodied knowledge of the throwing process through us throwing together even though he could not see or hear anything during the process. The exact muscle and limb pressure and timing of the hand movements were conveyed from me to him entirely without language (Figure 6). As he got the idea of how to act with the clay, I could feel a gradual transition of him starting to lead the throwing process.

Figure 6. Olavi throwing clay while being aided by the researcher.
Screenshot from the video by the researcher.

What methods may be used in the study of embodied and experiential knowledge in crafts?

While participating in the making process with the deafblind, I also realised that it is not as feasible to study someone else's sensory experiences, as one's own. This is perhaps also why research on practitioners done by theoreticians can only come so far; research on practice is more feasibly conducted *through* practice, in a practice-led research setting, where the researcher and the subject of the research are the same person.

The study of experience also poses the challenge of trying to catch and store events that are fleeting and consists of moments that constantly change and involve multiple sensory modalities. The idea of blindfolding myself helped in studying and articulating my haptic sensory experiences and my embodied knowledge of the throwing process, but needed support from more traditional methods of researching practice. By combining different methods from the practice-led tradition, such as the diary method and general documentation of the working process, with methods such as an event sampling system and a video-aided protocol analysis combined with think aloud accounts, I managed to collect multiple types of data for my case (Groth et al., 2015).

After the data collection, the videos were analysed through protocol analysis, which means looking at each second of the video separately, noting both what was said and the actual action that was made. During this process, I felt that I knew more than I could say, at the time of making (Groth et al. 2015, p. 70). This notion is familiar from the concept of tacit knowledge (Polanyi, 1958). However, the protocol analysis provided the opportunity to reflect on the events in slow motion, without simultaneously having to control the material in a making situation. This elicited the need to add a column for reflections-on-actions (Schön, 1983) which included all the sensory experiences of the process and became the in-depth analysis of the event. I found this account the most informative as it was essentially a detailed description of my experiential knowledge, an account that could not possibly have been produced by an outside researcher, but only by the practitioner-researcher alone (Groth et al., 2015.)

The video was particularly useful in this research as it made it possible to reflect on actions in hindsight. Pink (2009, 2011, 2012) has used video extensively in her research, which aims to take the sensory realm into consideration. She has found that video enables the viewer to either recall previous experiences in a multimodal form if personally experienced previously, or to recall similar experiences if the videoed events are not subjectively experienced (Pink, 2012). This supports the findings in the research at hand as I was analysing videoes of events that I had experienced myself, but blindfolded; therefore, I had no visual memories of the events, but my sensory experiences were recalled through the recorded video footage. Emotions connected to these events were similarly revisited and were thus also available when later analysing the critical incidents of this case (Groth, 2015).

As with Pink's research, video was here found to be useful as a medium for researching knowing in action on three levels (Pink, 2012). Firstly, it was useful in collecting the data in the form of moving images connected with the audial reference, as I was able to revisit the lived experience of the event and thus tap into my embodied memories of the event. Secondly, the video was useful in the way it could be analysed in slow motion, be reversed and skipped forward in order to take multiple actions into account and to distinguish critical incidents for separate analysis. Thirdly, the video has been effective in presentations of the research, as it also provides a situated and multisensory experience of the research events to the audience, who can better understand the sensory experiences involved by relating to their own embodied knowledge of similar previous experiences, or imagine such experiences.

What is the role of emotions in connection to tactile experiences in a craft practice?

Touch was linked to emotions in all three cases of the study and in different contexts. Emotions have been connected to sensory experiences, and even decision-making, in for example cognitive science (Damasio, 1994, 1999). However, the way that the tactual feel of the material affects emotional feelings in the process of making is perhaps known to practitioners, but little elaborated on in research. Emotions have previously not been seen as valid informants in research practice, or even in craft and design research (Niedderer &

Townsend, 2014); however, researchers in design have recently begun to include this aspect. Through this investigation, it seems that emotions also play a part in the manipulation of materials.

The second case study made me particularly aware of how emotions linked to tactual experiences served as contributors to risk assessment, decision-making and problem-solving in the making process. Therefore, emotions seem to guide the progress of the making situation, especially when the material qualities and affordances vary and a successful outcome depends on the embodied knowledge of the maker. This passage is taken from a previous article describing the tactile experiences in Case 2 (Groth et al., 2015, p. 76):

> When throwing clay walls, the only part that touches the clay surface is the tip of the fingers. Through these, the practitioner receives sufficient information on the orientation of the work, the temperature, the resistance of the material and the wetness or softness. These haptic experiences directly provide a feel or a feeling of the working conditions and the possibilities available in working the material. These conditions and affordances may change within seconds, so an update of the conditions at hand is continuously made through the sensory points of the fingertips.

In order to investigate this aspect further, I carried out a renewed analysis of the videos collected during the throwing sessions, this time using the *Interact* video analysis software, which enabled me to fully explore the experience of throwing clay, to pick it apart in its details and see what kind of different aspects and new insights arise from this kind of analysis.

The tactile experiences that were found to be important in knowledge formation during the throwing process involved the density and surface structure of the clay and the positioning of it on the throwing board. Key emotions involved levels of confidence and stress together with high or low spirits Activities that were tagged in the videos were risk assessment, decision-making and problem-solving (Groth, 2015).

I found that during critical incidents, feelings of low spirits and stress were present, together with certain conditions of the clay, in risk assessment, decision making and problem solving during the throwing process. However, I found that these negative emotions were actually helping the process by aiding concentration and focusing on solving the problem at hand. The heightened alertness that the stress and worry about the risky moment in the process involved gave that extra sensitivity and attunement to the material that the successful handling of the critical incident demanded.

Emotions were also frequently aired in the think aloud accounts that facilitated the analysis process. Even claims of fear emerged in the accounts as the process was approaching a risky phase or in sudden critical incidents (Groth, 2015). Emotions as guides in decision-making are familiar from Antonio Damasios' (1994, 1999) work in cognitive science, and he is often connected to the field of embodied cognition. One of Damasios' claims is that *gut feelings* generate emotions that guide us in intuitive decision-making, (Damasio, 1994, p. 169 & 173), and he calls this the "somatic-marker hypothesis" (Damasio, 1994, p. 175). Soma means body in Greek and Damasio links the somatic markers to the theory that emotions are important in risk assessment as they help in our survival (Damasio, 1999, p. 42). This aspect is supported by researchers studying the function of emotions (Keltner & Gross, 1999, p. 472). Mark Johnson (2007) builds on Damasio and elaborates on emotions as the most essential way of making meaning out of our experiences: "emotions are processes of organism-environment interactions. They involve perceptions and assesments of situations in the continual process of transforming those situations." (Johnson, 2007, p. 66-67). As a result of this case study, making in a material can be seen as continuous risk assessment, including

constant decision making and problem solving, and emotions seem to guide the progress of the making situation (Groth et al., 2015, p. 76).

How do design students use embodied knowing in material exploration?

The two students that were studied closely in the third case were using their tactile sense in various situations during their creative process. The tactile aspect of the materials and the use of touch were important on many levels, but especially in the process of deciding which materials to use. The felt experience of materials was also linked to emotions and shared social and ethical values.

Physical touch played an important role in the decision-making process as it confirmed the imagined image of the material. In the interview, one of the students explicitly says that vision provides only half of the perceptive view, and that touch fills in the missing part (Groth & Mäkelä, 2016, p. 17). Touch was seen by both students, as the main means of evaluation when they made choices on what materials to use, or in evaluating the quality of a material.

In addition, the felt experience of physically working the material affected both the students' self-esteem and image of themselves in addition to their relation to the making process. Both students experienced new materials in their exploration process for their designs, and the new material behaviour disrupted their workflow and made them question their identity as makers, similar to the case with the deafblind participants. The students' anxiety was overcome through resorting to familiar patterns of solving material problems known to them from other domains.

In all three cases, the deafblinds, the single practitioner and the design students, we see a pattern of mental discouragement when material conditions become unfavourable and, similarly, how adaption through referring to previous experience overcomes difficulties. In design cognition studies, the concept of scaffolding (Wood et al., 1976; Puntambekar & Hubscher, 2005) is referred to when discussing novices' learning process using their social network as building blocks in learning situations. However, previous bodily experiences are also important in this context, as found by design researcher Biljana Fredriksen (2011). Fredriksen (2011) argues for the embodied knowing that is built up by physical interaction and that is relied on in new material encounters.

The way of creating mental images (Kosslyn, 2005) of materials and mental rotation (Purcel & Gero, 1998) is also familiar from design cognition studies, but the use of the body as informant, or embodied cognition, is seldom elaborated on in this field of design research. However, when confronted with a spatial problem in her two-dimensional design, one of the students built a three-dimensional model in order to be able to see the imagined design from different angles and to measure the intended material over the model. She described this physical exercise as necessary because her imagination was not enough to create the design only in her mind or even on paper through drawing (Groth & Mäkelä, 2016).

As seen in this student's case, her mental rotation of the imagined design was aided through taking the design into the lived experience by the building of a physical prototype, using techniques learned in her previous profession. Both students had acquired sedimented knowledge (Keller & Keller, 1999) during their practice in other domains that emerged in a new domain, and this allowed them to progress in an otherwise stagnated design process.

In design cognition research in general, it has been found that sketching is closely linked to the designer's thinking process (Goel, 1995; Purcell & Gero, 1998; Seitamaa-Hakkarainen & Hakkarainen, 2000). Through drawing, the designer is able to externalize the imagined design (Cross, 2011). Similarly, the craft practitioner's modelling or prototyping directly with her material may be seen as a way of thinking through the interaction of hands and material, body and environment. This was clearly to be seen in the students' way of

working, as well as the deafblind makers' working in clay, in which the option of making a sketch was not available.

One of the deafblind workshop participants even said that she would quite often start her process by picking up the material in her hands, and then by moulding and working it she would find her way to her design idea. Modelling in clay resembles sketching and, as such, may be seen to contribute to thinking through the hands, in a similar manner to how drawing is generally understood, but in three dimensions (Groth et al., 2013). Design researcher Nigel Cross (2011, p. 4) notes:

> In traditional, crafts based societies the conception, or 'designing', of artefacts is not really separate from making them; that is to say, there is usually no prior activity of drawing or modelling before the activity of making the artefact. For example, a potter will make a pot by working directly in clay, and without first making any sketches or drawings of the pot.

Both students also claimed that they found drawing different materials from memory useless when it came to research on material properties. Instead, it was important to obtain a sample of the different materials to be able to investigate and compare the materials physically (Groth & Mäkelä, 2016, in press). Although drawing is indisputably important as a thinking tool for designers, it is difficult to use drawing in the exploration of material choices. Here, physical touch seems to be crucial. A skilled draftsman may be able to reproduce convincing reproductions of a material visually, but to draw materials' physical properties from one's memory is rather challenging. A drawing, even computer aided, gives only a poor sense of weight, density, flexibility, temperature or surface structure.

As the material choice, the mental image of a design and the ability to judge material properties based on previous experiences are all important aspects of design work, the use of touch and related embodied cognition is an issue of great importance in design research as well as in design and craft education. This reflection is supported by psychologist Akter Ahsen (1984) who has investigated mental imagery and came to the conclusion that a mental image is dependent on physical experiences in the meaning making of mental images in relation to the real world (see also Laamanen, 2016, p. 45).

Real world material manipulation has been noted as also being important in the context of education, as sensory-motor interaction with the environment during learning results in more endurable and richer knowledge (Kiefer & Trumpp, 2012, p. 20). As a result of this case study, I would emphasise that design thinking involves embodied cognition as well as making practices, thus it should not focusing on merely the intramental abilities of the designer. Design students benefit from embodied material explorations of multiple kinds in order to more realistically form a mental image of an envisioned design, already in the concepting process.

Emotions were present in all three cases

The word *feeling* as in tactile sensations and *feeling* as in felt emotions merged in the students' descriptions of their sensory and emotional experiences. The way something feels (tactile) seems to affects the way we feel (emotional). The students also used this aspect in their careful selection of materials (Groth & Mäkelä, 2016). We have many shared notions of the feel of materials that are triggered as mental images even when only mentioned in speech (Groth, 2015, p. 12). In the first student's case, emotions are connected to the atmospheres and images that the felt experience of certain material connects to. In the second student's case, it was a more about emotions of discomfort or confusion towards the 'right' or 'wrong' feel of a material, and his project plays with this notion. As with the deafblind subjects (Groth et al., 2013), also in the second case study (Groth, 2015, p. 12), positive or negative emotions were connected to the tactile feel of the material:

> (…) the feel of the material as it is actually touched gives us both the tactile feel and emotion, and thus also the anticipation of what this material has to offer us. For an experienced ceramist, the density of a bit of clay immediately gives an idea of its possible uses, together with an either positive or negative background feeling simultaneously. If the clay is too hard, it is not good because it cannot be easily handled and needs to be soaked. If the clay is too wet, it is also not good and it needs to be dried until workable. A perfectly smooth and dense bit of clay gives a good forecast for any project, and it is therefore experienced with positive emotions.

In general, the tactile feel of materials seems to affect emotions in multiple ways. Impressions of materials carry shared cultural notions, as noted in the case of the design students. As one of the students confirmed her notion of the materials by testing them with her fellow students, we can suppose that designers share general emotion-based notions, not only mental images, but also *mental impressions of tactual experiences* of materials. These findings are similar to those in research by Zuo et al. (2001); they claim that not only physical but also cultural and psychological response and expectations are attached to material properties.

Similarly, Karana, Pedgley & Rognoli (2015) emphasise the experiential perspective and the fact that material interaction occurs through our senses. They describe materials as actors that play roles that the designers have assigned to them (Karana et al., 2015). They also point out that: "Deciding on the role that a material will play in an artefact is one of the creative challenges that designers face" (Karana et al., 2015, p. 17-18). These decisions seem to involve the previous embodied experiences, and emotions, of the designer.

Implications for design education and the concept of design thinking

The field of design has changed drastically in the last two decades and has now increasingly moved also beyond the material realm; thus, design education likewise has to change. The focus is no longer on material manipulation and the relationship between the maker and material as in the field of crafts. The field of craft has also changed, and aspects of communality and sharing have come to the fore. However, as we as human beings continue to be physical, we will always have physical needs, and part of the designer's or craft practitioner's task will still be to improve and develop material objects for physical use.

The present study contributes to the area of design education by highlighting aspects involving embodied cognition in design and to encourage the inclusion of the body as knowledge provider in the study of the way designers think. When the material exploration, prototyping, crafting or production of a design is moved too far away from the design thinking process, there is a risk of the end product lacking in material quality. Ultimately, this will affect the success of the product. In this context, the design student needs to acquire good skills and an embodied knowledge of materials and technical processes simply to be able to construct a design in his or her mind.

Conclusion

The main contribution of this research is the perspective on the making process, here seen from an enhanced haptic point of view. I found that the body and emotions related to physical interaction with material were important informants during designing and making, especially in the many different aspects of decision-making that the designer or craft practitioner goes through.

Sensory experiences are keys to sense-making in material manipulation. What is seen by the eye is confirmed by touch, and through our hands we are able to interact with and test the material, learning by doing and acting; thus we also shape our minds and affect our future actions with similar or new materials. Emotions related to touch experiences become knowledge that the designer relies on. Previous embodied interactions play a key role in

design students' understanding of new material experiences and are relied upon in the choice of materials and techniques during future design processes.

Tactile aspects are important in the evaluation of materials for design, even when forming mental images of tactile experiences. Imaginary material exploration and mental images of physical experiences are based on previous bodily experience of materials, and the body and sensory experiences play a role in the sense-making process. Tactile- and material-based forms of education are therefore key to learning in the field of craft and design as experiential knowledge may only be acquired through situated and embodied interaction with materials. Embodied, emotional and even ethical and social aspects of the materials' properties play a role in the designer's judgement and selection of materials. Some of these notions are shared embodied knowledge that consequently also plays a part in the communication between designer and user.

The practice-led research setting, including the multi-method developed for this study (Groth et al., 2015) was found useful in explicating the personal knowledge and sensory experiences as well as related emotions during the making event. The studio-as-research laboratory and the practitioner-researcher's subjective perspective allowed for a reflection on experiential knowledge that is impossible to uncover in a distant and objective research setting. As emotions were also found to be major contributors to risk assessment, decision-making and problem-solving in the design and making process, it would be interesting to see further research into emotions in the context of making. Video was found especially useful in as it allows for a threefold benefit; in data collection, analysis and dissemination of research results.

The theoretical framework of embodied cognition was found relevant and informative in the analysis of sensory experiences and the making practice; consequently, it can be recommended for further investigations. Design and craft practices are still largely body-based and considerable sense-making activity takes place in embodied material manipulation, thus I propose that embodied cognition be included in the concept of design thinking.

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