Tactility Trialing: Exploring Materials to Inform Tactile Experience Design

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Abstract. Although materials of tangible interaction designs largely determine their user experience, material choices are often steered by practical motives. This paper presents 'tactility trialing', an approach to explore tactile experiences of materials to inform the design of tangible artifacts. Through experience formulation, material selection, artifact creation and short user studies, designers and design-researchers are enabled to make informed decisions on the materials to be used in order to evoke the intended experience. The approach is illustrated through two case studies of student work. Tactility trialing helped them in getting acquainted with tactile material qualities in practice, and with the applicability of material characteristics such as resilience and hardness in design.

Keywords: Tangible interaction, materials, iterative design, interaction design, user study, user experience design, tactile experience.

1 Introduction

Our experience of (interactive) products is largely influenced by our perception. While these perceptions incorporate all of our sensory modalities, the visual and auditory modalities are often mainly exploited in Human-Computer Interaction (HCI). However, particularly in the area of tangible interaction [1], which explores physical manipulation of tangible artifacts, the tactile modality plays an important role.
The shape and material of (interactive) tangible artifacts largely determine the initial user experience. Careful selection of materials should thus be an integral part of the process of designing for (tangible) interaction [2]. However, choice of materials in tangible interaction design and research seems mostly steered by practical motives or to create a certain look, rather than by considering the resulting 'tactile experience' when the design is manipulated. This differs from approaches used in product design, which usually consider sensorial aspects of materials throughout the design process [3]. The work presented in this paper aims to explore the value of, and increase understanding of material qualities in tangible interaction design and research.
Different materials may evoke different tactile experiences, depending not only on the material itself but also on the way it is used and shaped into the artifact. Therefore,

iterative exploration of material and artifact is deemed relevant to result in desired tactile experiences. In this paper, we propose an iterative approach, entitled *tactility trialing,* for hands-on exploration of tactile experiences. This approach consists of five phases (*experience formulation*, *material selection*, *artifact creation*, *user study* and *design translation*), which alter making and thinking, and is intended to enable designers and researchers to make informed decisions on the materials to be used in order to evoke the intended experience. In this paper we describe the tactility trialing approach and discuss each of the phases by illustrating them through two case studies.

2 Related Work on Materials and Interaction

The field of HCI has, in the past decades, gradually shifted its focus from 'usability' to 'user experience'; focusing beyond functionality and productivity towards enhanced (emotional) experiences resulting from interaction with products and systems [4, 5]. In line with this development, research approaches involving design practice (e.g. 'research-through-design' [6]) are increasingly being applied. Such approaches advocate involving users throughout the process and engaging in hands-on making to gain a rich understanding of the topics at hand [7]. The proposed tactility trialing approach embraces the approach of research-through-design and suggests an implementation specified to exploring materials to inform tactile experience design.

In the field of tangible interaction, a number of related studies explore people's tactile experiences. Some studies apply methods suitable to *inspire design*. The material probe [8], for example, can be used to elicit participants' stories about and experiences of materials, in order to inspire tangible interaction design. Landau et al. [9] explored tactile experiences of various materials to inform interior designs of vehicles, by having people create mood boards using pre-selected materials. Kaye and Brown [10] explored people's tactile experiences of abstract vibrating objects with various material covers to gain insight in design opportunities to enhance haptic feedback.

Other studies use methods to *evaluate designs* leveraging the tactile modality. The sensual evaluation instrument [11] for example, uses various abstract objects to enable self-report of emotions through the tactile modality. Obrist et al. [12] studied verbalizations of tactile experiences of vibrating objects using specific interview techniques. Choi and Jun [13] studied the tactile experience of surface roughness by collecting and clustering pairs of antonymous adjectives. Inspired by this approach, Kierkels and van den Hoven [14] explored tactile experiences of physical artifacts of varying hardness, by having children manipulate these artifacts without seeing them.

We contribute to this body of work by proposing an approach that is not tailored toward a specific phase of the design process, but which can be applied throughout the process to iteratively explore material qualities to inform tactile experience design.

3 Overview of the Tactility Trialing Approach

Tactility trialing was developed as a collaborative effort between a tangible interaction researcher and a materials and design expert (two of the authors), and used in an

under-graduate course for interaction design students. This course has been taught 7 times at the Eindhoven University of Technology in the Netherlands, with approximately 14 to 24 students participating during each edition.

Tactility trialing aims to support designers and design-researchers in exploring appropriate materials for their (interactive) tangible artifacts, and consists of the five phases illustrated in Fig. 1. In the tactility trialing approach, the intended experience is summarized in an experience word such as 'persuasive' or 'engaging' (phase 1: *experience formulation*), and various materials are collected that may evoke this experience (phase 2: *material selection*). Promising (combinations of) materials are shaped into comparable artifacts (phase 3: *artifact creation*), which are experienced by participants (phase 4: *user study*). These findings are then translated into a (interactive) product or system design (phase 5: *design translation*). The tactility trialing approach is iterative; it may start from any phase and can be repeated multiple times to optimize the outcomes. Hence our description should not be seen as a step-by-step plan, but as flexible guidance for tactile experience explorations throughout the design process. In the following sections we illustrate each phase through two case studies from our under-graduate course, each executed by a pair of students. Note that these cases are included to exemplify possible ways to execute tactility trialing, rather than to present specific materials that are most appropriate for particular user experiences. After presenting the two case studies, we discuss generalized lessons learned for each phase.

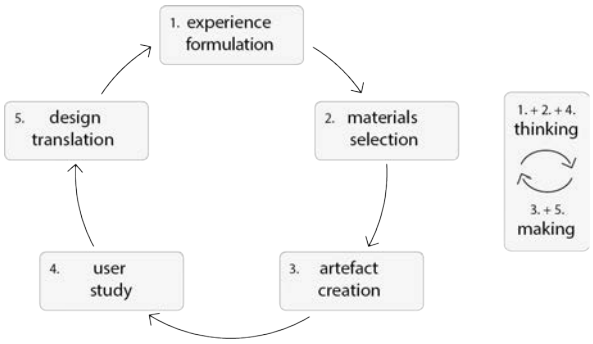

Fig.1. Visualization of the Tactility Trialing approach.

4 Phase 1 'Experience Formulation'

The phase 'experience formulation' aims to specify the intended experience. This is done by selecting a key experience word, such as provocative, engaging, comfortable or intriguing. This word is detailed through an elaborate description of the intended experience, usually involving a number of adjectives and antonyms, to provide a clear grasp on what the intended experience means to the designer or researcher.

Case 'Gentle Pockets'. The first case is entitled 'gentle pockets' and started from the experience word 'gentle'. This was further detailed by formulating its antonym as 'harsh', and by listing words the students associated with gentle, including soft, warm, squishy and smooth, and their antonyms (stingy, cold, rough and bumpy).

Case 'Bothersome Phone Covers'. The students conducting the second case, entitled 'bothersome phone covers', started off with the experience word 'bothersome' and, after discussion, specified 'soothing' as its antonym.

Lessons Learned. While formulating the intended experience seems a short part of the overall process, we experienced it to be an important aspect of tactile experience design because it includes taking decisions on focus and prioritizing. Making the intended experience concrete by elaborately discussing it in the design team (students in our case) turned out useful in later stages when evaluating to which extent selected materials or artifacts could evoke the intended experience. In our experience, the discussions about the experience formulation helped to broaden the vocabulary of the designers (students) in the expression of an experience.

5 Phase 2 'Material Selection'

After specifying the intended experience, materials are collected that might evoke this experience (see Fig. 2). These materials can be sought anywhere: the first selection is intended to be as broad as possible, to widely explore material qualities. The collected materials, preferably cut into samples with a comparable shape, are discussed in groups to come to a selection of materials that likely evoke the intended experience.

Case 'Gentle Pockets'. Starting from the word 'gentle', a large range of materials was selected, including metal, foam, felt and moss (see Fig. 2b and Fig. 2c). Through discussions, the students realized they had collected materials with both refined and coarse textures. To select materials, they placed the collected materials on a matrix, with 'gentle' versus 'harsh' on one axis and 'refined' versus 'coarse' on the other axis, see Fig. 2c. The discussion the students had while creating this matrix helped them in deciding they would continue exploring eight materials with varying textures, which they hypothesized as feeling gentle or harsh: steel wool, flat tin foil, feather-fabric, wood veneer, stingy fabric, wrinkled tin foil, tufted carpet and velvet fabric.

Case 'Bothersome Phone Covers'. In the 'bothersome phone covers' case, the students sought materials that could feel 'bothersome', but also those which felt 'soothing' and might thus have the opposite effect, see Fig. 2a. When touching and manipulating the materials, rough textures and hard materials seemed more bothersome, while smooth textures and soft and flexible materials provided a more soothing experience. The students therefore decided to further explore smooth and textured versions of both hard and soft materials, namely wood, polypropylene plastic, foam and fabric.

Lessons Learned. While there may be various ways to approach material selection, we experienced that discussions on generalized material properties (e.g. refined versus coarse texture, soft versus hard surface) were often fruitful. This made student design teams aware of the relevant variables in material selection, of the materials aspects that may result in the desired experience and it provided handles to select new (combinations of) materials that may be even more successful than the initial selection. Furthermore, exploring the materials gave insight in the effects of the way mate-

rials are handled on the tactile experience. For example touching a material with one finger results in a different experience compared to holding it with the entire hand.

Fig. 2. The material selection phase. (a) raw materials collected in the 'bothersome phone covers' case; (b) students discussing collected materials in the 'gentle pockets' case; (c) a matrix created to feed the discussion in the 'gentle pockets' case; and (d) an example of material qualities labeled and described in a third case study, not detailed in this paper.

6 Phase 3 'Artifact Creation'

Whereas material selection is usually done intuitively, through association and discussion, the next phase of 'artifact creation' aims to result in artifacts with various material qualities, which can be experienced and compared by users. To enable a fair comparison, the materials or material combinations need to be shaped as similar as possible and differ mainly in material qualities. In other words, a set of physical artifacts with similar shapes but varying (combinations of) materials or material surfaces needs to be created. To gain insights relevant to the tangible product or interface that is to be designed, these artifacts should be shaped such that they afford manipulation similar to the way users would manipulate the intended design. For example, if the intention is to design a steering wheel, one may explore the tactile experience when firmly grabbing a cylinder shaped artifact crafted out of or covered with various materials. However, when designing wearables, artifacts may be created that can be worn (e.g. around the wrist), of which the surfaces that touch the skin vary in material qualities.

Case 'Gentle Pockets'. When discussing the materials in the 'gentle pockets' case (see Fig. 2c), the students realized that when assessing how gentle a material was experienced, they were invited to stroke the materials with a flat hand rather than to squeeze or grasp them. They therefore created a beam with a rounded edge inside a box (see Fig. 4b), on which they mounted the selected materials (see Fig. 3a). This would encourage user study participants to stroke the materials with the whole hand.

Case 'Bothersome Phone Covers'. In the 'bothersome phone covers' case, the students decided to compare rough and smooth textures of soft and hard materials. They created four pairs of two artifacts, each pair constructed of one of the four selected materials and each pair consisting of one artifact with a rough texture and one with a smooth texture (see Fig. 3b). Since the students reasoned that the textures were best experienced when touching the materials with the fingertips, the artifacts were shaped as flat squares that could be laid on a table. After conducting a user study with these

artifacts (described in section 7), the students realized that their selection of materials had been too broad. They therefore decided to run a second iteration in which they explored seven different textures of a single material: hard plastic, see Fig. 3c.

Lessons Learned. As seen in Fig. 3., created artifacts sometimes clearly resemble a certain product category (e.g. shoesoles), while in other cases the artifacts are more abstract (as in both cases detailed above). This stems from the fact that some design-processes start with a rather concrete application in mind, while others have a more exploratory nature and cover a wider range of possible experiences. From our experience, in the first type of processes the artifact creation phase serves an important role in determining the details of the design. In the latter, more exploratory processes, this phase serves as inspiration for the direction of the final design, similar to the way material explorations conducted in related work inspired design (e.g. [6,10,13]). Tactility trialing may thus be applied for a range from concrete to exploratory design goals and in various phases of the design process.

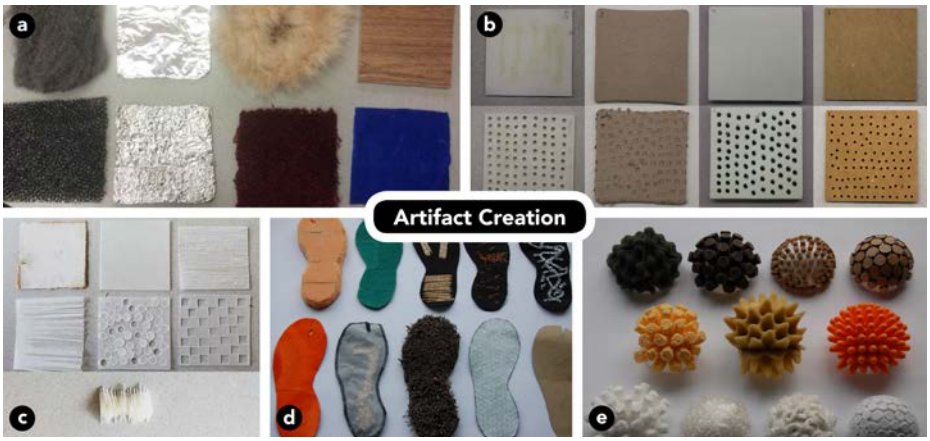

Fig. 3. The artifact creation phase. (a) 8 artifacts in the 'gentle pockets' case that can be stroked; (b) 8 artifacts created in the first and (c) 7 in the second iteration of the 'bothersome phone covers' case; and examples from other cases of (d) shoe soles, and of (e) materials that can be pressed, not detailed in this paper.

7 Phase 4 'User Study'

To gain insight in the tactile experiences evoked by the material qualities of the created artifacts, they are to be explored in a user study. As detailed in related work (e.g. [9–12, 14]), various methods can be suitable for evaluating tactile experiences. To ensure minimal influence of factors other than tactile qualities, one approach [14] is to have participants manipulate the artifacts without seeing them (e.g. in a 'black-box', see Fig. 4). However, since experiences of tangible artifacts in everyday life are not limited to the tactile modality, one may argue that this approach is not always appro-

priate. The most suitable user study approach thus depends on the aims of the study and the stage of the design-research process in which tactility trialing is applied.
In our course, the aim is to design an artifact that evokes the intended experience (defined in the experience formulation phase). Inspired by [14] we asked our students use a 'black-box' in their user studies to rule out influences of pre-conceptions about their experience resulting from visual appearance. To ensure user studies that were manageable in the short time available, while still leading to relevant insights, students were advised to use Likert scale ratings (also applied in [10, 13, 14]) of adjective and antonym pairs to evaluate the experiences evoked by the created artifacts. These adjective and antonym pairs were either formulated beforehand by the students (based on [14]), or generated by user study participants while touching the artifacts (based on [10]). While the latter approach may result in a more authentic formulation of participants' experiences, the first alternative involves fewer steps and is thus quicker to execute. Both approaches can easily be extended by adding elements such as interviews, (video) observation or 'thinking aloud'. In both presented case studies, all participants were fellow students who did not participate in the same course.

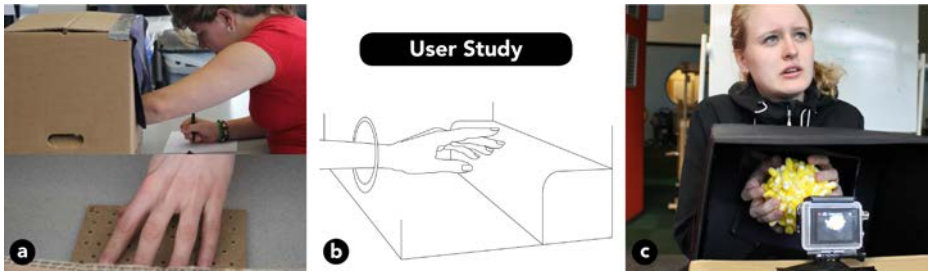

Fig. 4. The user study phase. (a) A participant touching and rating an artifact in the 'bothersome phone covers' case; (b) curved surface in a black-box to encourage stroking in the 'gentle pockets' case; and (c) a video-observation user study, not detailed in this paper.

Case 'Gentle Pockets'. The students conducting the 'gentle pockets' case had selected eight materials that may evoke a gentle or harsh experience, see Fig. 3a. The tactile experience of these materials was explored in a user study, in which ten participants stroked each material individually in a black box (see Fig. 4b). First, each participant touched each material separately, while thinking aloud and naming any word that came to mind (inspired by [10]). After all participants did this, the mentioned words were clustered into five categories of adjectives relating to gentle (pleasant, warm, refined, soft and friendly) and their antonyms related to harsh (unpleasant, cold, coarse, hard and unfriendly). Subsequently, the same participants again touched each material in the black box and ranked them on each of the five adjectives mentioned above, on a scale of 1 to 7 (e.g. 1 meaning extremely pleasant and 7 meaning extremely unpleasant). The average results of this ranking exercise (all 5 adjectives combined) are found in Fig. 5. As shown in Fig. 5, materials 3 and 7 were, on average, rated most gentle. When touching these materials, participants thinking aloud mentioned "lovable", "I want to lay down on this" and "makes me think of pastel colors". Materials 1 and 5 were rated as most harsh, and received comments such as "annoying", "makes me pull away" and "thorny".

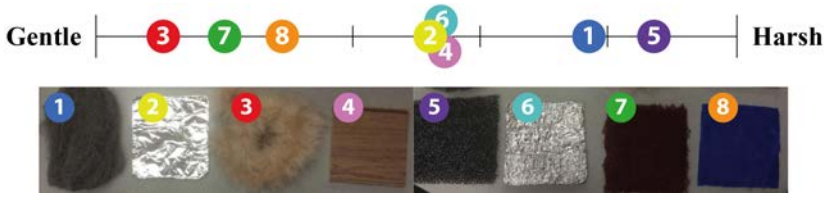

Fig. 5. The average results of 10 participants' ratings on 5 adjectives (pleasant, warm, refined, soft and friendly) of each of the 8 artifacts created in the 'gentle pockets' case. Materials: steel wool (1), flat tin foil (2), feather-fabric (3), wood veneer (4), stingy fabric (5), wrinkled tin foil (6), tufted carpet (7) and velvet fabric (8).

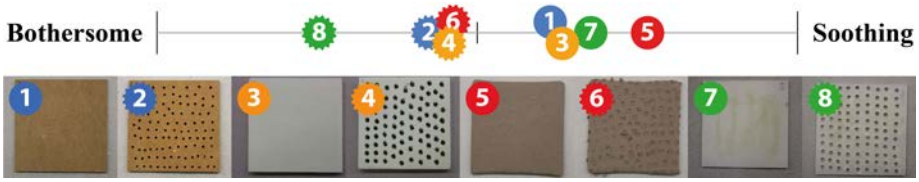

Fig. 6. The average results of 16 participants' ratings on 10 synonyms of 'bothersome' of each artifact created in the first iteration of the 'bothersome phone covers' case. Materials: wood (1 and 2), foam (3 and 4), fabric (5 and 6) and polypropylene plastic (7 and 8).

Fig. 7. The average results of 6 participants' ordering from most bothersome to most soothing, of 7 artifacts created in the 'bothersome phone covers' case 2nd iteration. Materials: polypropylene plastic finished in different textures.

Case 'Bothersome Phone Covers'. The students conducting the 'bothersome phone covers' case were interested in exploring the tactile experience of four selected materials, each with a smooth and a rough texture (see Fig. 3b). A user study was conducted in which sixteen participants touched and stroked the artifacts, which laid down in a black box, see Fig. 4a. The participants rated each artifact on the following ten adjectives (and their antonyms) which the students associated with bothersome: rough, irritating, painful, sharp, synthetic, unknown, annoying, awkward, dirty and strange. A 1 to 5 scale was used in which 1 for example meant very rough and 5 meant very smooth. Fig. 6 shows the average results of this rating exercise.

As evident from Fig. 6, all textured materials were experienced as more bothersome compared to the smooth materials. It thus seems that texture has more influence on how bothersome an artifact is experienced compared to the materials it is made of. Textured material 8 (hard plastic) was experienced as most bothersome. While this finding is interesting, the students conducting this case expected that exploring various types of textures might provide more detailed insights in possibilities to evoke

bothersome tactile experiences. Therefore they conducted a short second user study with 7 artifacts made of hard plastic, each with a different texture (see Fig. 3c). Six participants were handed the 7 artifacts (no black-box was used), and were asked to order them from most bothersome to most soothing. The average results of this ordering exercise are shown in Fig. 7. This graph reveals that materials 7 (triangles of hard plastic glued together) and 3 (hard plastic with sharp ridges created through sawing) were experienced as most bothersome.

Lessons Learned. In our course, students carry out short user studies using a 'black-box', and apply one of two variations [10, 14] of Likert scale evaluations. In our experience, this approach quickly leads to relevant insights and is easy to repeat when realizing a mistake or misassumption has been made (e.g. in the 'bothersome phone covers' case where a second user study with different artifacts was run). Using a black-box ensures that participants reflect on their actual tactile *experience*, without being influenced by the artifact's visual appearance (as also elaborated in [14]). This teaches students that evaluations could focus on one single element of a design. However, depending on the phase of the design process and the sophistication of the artifacts created, other types of user evaluation methods may also be suitable, such as those detailed in related work [9, 11, 12].

8 Phase 5 'Design Translation'

Having explored the created artifacts with users, the gained insights can now be translated to the design of physical products or interfaces. Depending on the phase of the design process in which tactility trialing is applied, the exact product to be designed may be known, or only the targeted tactile experience may be determined. In the latter situation, the design translation phase includes idea generation of applications that may benefit from the developed tactile experience, and the conducting of the entire tactility trialing serves as inspiration for this. We can imagine this to be suitable for designs that ask for an enriched experience, or in cases where an interaction experience is defined while the (interactive) product is in its concept-phase.
The design translation phase in our under-graduate course was rather limited and had to be conducted in a short period of time. The resulting designs are therefore often conceptual and not fully thought-out yet; in some cases they are abstract objects, to be pictured as a future interaction design. We discuss the designs resulting from the two cases here, in order to share the translation between user study and design.

Case 'Gentle Pockets'. The students conducting the 'gentle pockets' case concluded from their user study, in which participants among other things indicated that "they wanted to lay down on the material", that a gentle experience is an intimate, private experience. With this observation in mind, the students decided to design trouser back-pockets with the more gently experienced materials inside, see Fig. 8b. This way, people can have a private, gentle experience by stroking the material.

Case 'Bothersome Phone Covers'. The students conducting the 'bothersome phone covers' case concluded from two iterations of user study, that triangles of hard plastic

glued together and hard plastic with sharp ridges were experienced as bothersome by participants. When translating this finding into a design, the students thought about an application domain in which they would like to discourage people to use their devices. They choose to design two smartphone covers (see Fig. 8a) that feel bothersome, such that people would be less eager to pick up their phone in social settings. Their first design used triangles of plastic leading to a rather bulky cover, which makes more of an object for debate, rather than a usable product. The second design, which uses the ridges texture, makes a more practical cover.

Fig. 8. The design translation phase. (a) Two 'bothersome phone covers'; (b) trouser pockets that evoke a private gentle experience in the 'gentle pockets' case; and (c) an interactive 'persuasive' armrest designed in a fourth case, not detailed in this paper.

Lessons Learned. When carrying out the phases of tactility trialing, design-researchers (students in our case) often come to realize that there is no single best material (-combination) to serve the intended experience. As a result, the translation between user study results and design is not always straightforward and may involve further exploration of materials or combining materials that were tested separately. The design translation phase thus requires design-researchers to interpret the insights gained throughout the process, giving them handles to inspire design.

9 DISCUSSION

This paper proposes 'tactility trialing', an iterative approach for exploring material qualities and translating these to the design of (interactive) tangible artifacts. The approach is developed as part of an under-graduate course aimed at making interaction design students familiar with conducting short user studies to gain insights in the experiences triggered by their designs. Matching this educational aim, the presented case studies illustrate a rather specific way to apply this approach. However, having run this course seven times with around 10 pairs of students in each edition, we have realized that the approach is more generally applicable and can be seen as an umbrella-approach with many variation possibilities.

Most importantly, we realized that the approach is applicable in various stages of the design process; it may serve as early inspiration, can help explore alternative material qualities after the concept phase or can be used to more systematically explore suitable materials in a later stage of development. When used in different phases of the

design process, different user study approaches may be applied. For example, in a later stage, a user study in which participants would use the design for a few days might provide insights in the everyday experience of using the design. Appropriate evaluation techniques in such a case may be contextual observations, interviews techniques (e.g. [12]), logging of usage or experience sampling [15].
The process of carrying out tactility trialing often leads to the insight that there is no single best material to evoke the intended experience. Additionally, the process regularly leads to a clearer image of what exactly the intended experience is. For example, in the 'gentle pockets' case, the user study revealed that a gentle experience is often intimate. Tactility trialing is thus not simply a method to help select (combinations of) materials. Rather, it is an approach that helps to gain better insights in the effect of material qualities on the user experience of one's design, thereby informing choices of shape, material, interaction and intended experience.
After translating insights gained through tactility trialing into a design, the design process is likely not finished. In many cases follow-up iterations can optimize the user experience. Such follow-up iterations may make use of tactility trialing as well. For example, the students conducting the 'bothersome phone covers' case decided in the design translation phase to develop phone covers that would discourage people to use their phone in social settings. With this new goal in mind, a new experience formulation could be specified (e.g. involving words such as discouraging and confronting) and a new material selection may be conducted (e.g. multiple variations on the sharp triangles and ridges that revealed to be promising after the user study), leading to new artifact creation (e.g. phone covers of various materials). A user study with these artifacts likely leads to new, more specified insights for a (re-)design translation. Tactility trialing may thus offer an iterative approach to tactile experience design.

10 Conclusions

This paper presents an iterative approach for hands-on exploration of material qualities and resulting tactile experiences through short user studies with abstract artifacts of various materials and forms. This approach - *tactility trialing* - aims to inform tangible interaction design and supports designers and researchers in making informed decisions about the materials to use in order to evoke intended user experiences.
We presented two case studies from an under-graduate course in which interaction design students used the five phases of tactility trialing (*experience formulation*, *material selection*, *artifact creation*, *user study* and *design translation*) in the beginning of the design process. The variety of explorations, design-goals and eventual designs resulting from this course made us realize that tactility trialing could valuably be applied in various stages of the design process. By presenting tactility trialing, we contribute to the research area of tangible interaction, an umbrella approach that can be 'filled in' with various creative idea generation methods, different artifact creation (or interactive prototyping) approaches and diverse user study techniques.

Acknowledgements. We thank all participating students, in particular Lizette van Gameren and Rachel Loop who conducted the 'Gentle Pockets' case and Carola Brus

and Oscar van Beek who conducted the ‘Bothersome Phone Covers’ case. Furthermore we thank all participants of the conducted user studies for their time.

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