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How does it feel? Exploring touch on different levels of product experience

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Technological innovations pave the way for alternative interaction paradigms, which allow for more intuitive and pleasurable user experiences. Such new interaction types are particularly called for when considering that people are facing an ever-increasing information flow that in the end oftentimes hamper satisfying experiences with technology. Connecting knowledge from the fields of interaction design, product design, and psychology, we present a theoretical framework that explains how different modalities can be used in interaction with products. We will focus on the tactile modality in particular and present two case studies that show how designers can design for this modality in a direct (functional) and in an abstract (symbolic) manner, respectively.

Keywords: modalities; interaction design; tactile feedback; user experience

1. Introduction

Navigation devices, tablets, and mobile phones are examples of products used in a wide variety of situations, which are often taxing and demanding. For example, in busy traffic, social gatherings, and unfamiliar places we visit for the first time, information flow is high, and one may find that paying attention to everything that is imposed on our senses is exhausting. In such taxing situations, functional interactions with electronic devices can be cumbersome, tricky, and sometimes even dangerous (e.g. navigating traffic while entering a new destination on one's navigation device). Likewise, figuring out whether incoming messages or social media updates on one's phone are *important* or *interesting* may be disruptive or inappropriate during social gatherings. These examples show how technology and related interactions are integrated throughout our everyday activities and that attention that we pay to technology may take place in the periphery of awareness (e.g. being engaged in conversation while registering one's phone vibrating). Recently, the concept of peripheral interaction was explored by Bakker (2013) to study how interactive technology can be designed to form a seamless and meaningful part of people's everyday routines.

The examples above also show that both functional interaction types (aimed at successful completion of a specific activity) and symbolic–reflective interaction types (in which users give personal meanings to product actions) may prove cumbersome in demanding settings. In part,

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these problems relate to the fact that most devices still have to be operated using traditional interfaces requiring textual input and tiny, impractical buttons. Furthermore, they usually rely on vision only when it comes to reception of product output (e.g. a digital map with arrows pointing the way).

Of course, in today's market, electronic products increasingly allow and also ask for 'new' types of interactions, involving multimodal input such as voice recognition and gesturing. Think, for example, of the range of wearable devices such as smart watches that is now entering the market. The smaller size of such devices, compared to tablets and smartphones, limits the space that is available for the interface and hence, voice and gesture control have been explored as alternatives for interacting with such devices.

In product design research, new interaction types have been explored mainly in the field of 'tangible interaction', an umbrella term for design approaches seeking to materialise digital data flow and to bring back meaningful, hands-on product interactions. The premise of this approach is that interactions make much more intuitive sense and are more pleasant when people can rely on bodily dynamics instead of exhaustive cognitive and serial information processing (see e.g. Djajadiningrat, Overbeeke, and Wensveen 2000; Djajadiningrat et al. 2004). Already in 1997, the tangible media group of Prof Hiroshi Ishii proposed the concept of the tangible user interface as opposed to the mostly used graphical user interfaces (Ishii and Ullmer 1997). More recently, in their work on peripheral interaction, Bakker, van den Hoven, and Eggen (2015) explored in several design case studies how physical interaction that takes place in the periphery of attention can support computing technology to seamlessly integrate in people's everyday routines.

In sum, both in today's market and in the fields of product and interaction design research, products drawing on new types of interactions are gaining momentum. Multiple modalities have been explored whereby the tactile modality seems promising in particular. In design research, several studies have explored how materials and textures can elicit various aesthetic responses (aesthetics/visceral level; Norman 2004; Sonneveld 2007), an emphasis likewise apparent in marketing and consumer research (e.g. mobile phone covers widely available in different materials and textures). In their work on multisensory design, Spence and Gallace (2011) emphasise the important role that touch plays in our everyday evaluations of products, stressing how touch can play an important role on different levels of experience (i.e. on the emotional level but also with respect to meanings that people attribute to different materials). Lederman and Klatzky (2009) give a useful tutorial on the sense of touch that gives insight into fundamental scientific research on human haptics. Although these and other insights on the sense of touch indeed offer valuable guides for designing and evaluating the effectiveness of haptic interfaces, only a few studies in applied research have explored how tactual output may facilitate behavioural goals (functional–behavioural level) and communicate abstract meanings (symbolic–reflective level; see Figure 1 and the next section for a more elaborate discussion of the levels hinted at). For example, several design researchers have studied the relative effects of visual and tactile characteristics of products and materials on the perceived experience of warmth (Fenko, Schifferstein, and Hekkert 2010; Wastiels et al. 2012). However, results of these studies were not consistent with respect to the relative importance of different product characteristics. Hence, to date, research has not satisfactorily addressed the question how touch can be applied on different levels of product experience in order to achieve different types of goals people have and that designers design for. At the same time, findings from related disciplines that might help designers in this effort, often fail to provide information on how these findings might be implemented in design. Moreover, papers presenting these findings are often considered too abstract or inaccessible for designers.

Hence, the question becomes: how can we exploit opportunities inspired by emergent new technologies, and research into sensorial experience and user behaviour to design not only pleasurable (visceral level), but also meaningful (symbolic level) and intuitive, action-oriented

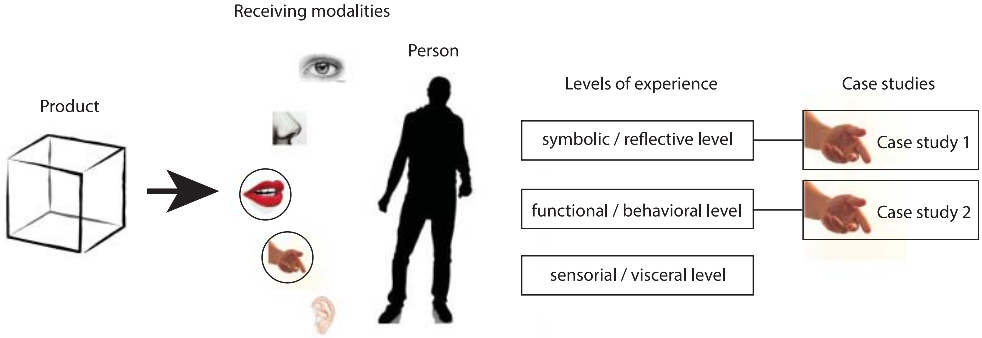

Figure 1. People can experience products through different modalities. This can have an effect at three levels of product experience. The case studies presented in this paper study tactile output at two different levels of experience.
Note: The tactile modality is represented by the image of a hand but this by no means indicates that tactile input could only be experienced by people's hands.

(functional–behavioural level) types of feedback in products? Answering this general research question is a prerequisite for applying tactile parameters in design for tangible interaction. That is, before applying (for instance) product volume or weight in order to implicitly and non-demandingly provide feedback to users, it is of utmost importance to have insights into the meanings connoted by such product factors (the rationale for case study 1). Subsequently, such insights can fuel design projects, which *are* specifically aimed at tangible interaction in a specific context (e.g. case study 2).

Figure 1 portrays the building blocks of our enterprise by showing that people can experience products through different modalities on three different levels. It also shows how the design cases that we will present in this paper relate to these different levels. The two case studies explore the potential of integrating tactile feedback in product design on the functional–behavioural and the symbolic–reflective level. Before presenting the details of these studies, first we will present an overview of the notions involved.

2. Modalities in interaction: three levels

In our introduction, we have outlined how technological developments and the increasing demands for attention that we face in interacting with products and information call for new interaction paradigms. Figure 1 outlines how, instead of solely relying on vision and perception of textual or numerical data, touch can be considered when conceptualising human–product interactions at different levels of product experience. We use three levels that largely correspond to the three levels of design that Norman (2004) uses in his book on emotional design and which are also part of Jordan's (2000) pleasure framework.

The visceral level deals with immediate (non-reflective) sensations inspired by physical product characteristics such as the soft, pleasant feel of linen, or the reassuring sound of a vacuum cleaner. This level corresponds to Jordan's (2002) physical pleasure, conceptualised as direct (i.e. without mediation of cognitive processes) pleasure derived from the sensory organs. Hence, this level deals with one's primary affective reactions to intrinsic product features. Following recent conceptualisations of product aesthetics relating aesthetic experiences to the pleasure attained from sensory perception (i.e. sensuous delight; Hekkert 2006), it is thus at this level that aesthetic experience takes shape. With respect to multimodal product experience, designers at this level face the challenge of not only creating an overall eye-pleasing visual appearance, but thus also of assuring that input received by the other senses brings aesthetic pleasure. In his framework on product emotion, Desmet (2008) shows how frustration of aesthetic concerns gives rise to positive (i.e. delight or satisfaction) or negative (i.e. disgust) emotions.

The functional–behavioural level, coined ‘psychological pleasure’ in Jordan’s (2000) framework captures intuitive pleasure during product use and is closely related to perceived control and mastery, the extent to which a user feels in control and can do what he/she wants to do. For instance, the smooth and easy handling of a navigation device may be said to inspire intuitive and pleasant experiences on a functional level. Reversely, an overly complex user interface may be said to harm user experience on this level, and thus to lower psychological pleasure. Furthermore, in demanding and complex situations, which confront people with a high cognitive load for a prolonged period of time, capturing attention in case of unexpected events may prove difficult. For instance, in the context of an automated cockpit system, Sklar and Sarter (1999) compared the effectiveness of visual and tactile cues and found that different types of tactile cues were more efficient while they did not interfere with the complex visual tasks at hand. Similar results were found by de Korte et al. (2012) who tested effects of tactile feedback and visual feedback on lifting of the hand or fingers from a mouse in a computer task and compared these to a situation with no feedback. In their study, all types of feedback proved efficient. However, continuous tactile feedback scored higher on comfort and acceptability of the signal because it matched with the required action. Both Sklar and Sarter (1999) and de Korte et al. (2012) conclude that introduction of non-obtrusive feedback, and tactile feedback in particular, is a promising avenue towards better support of human–machine interaction in information-rich domains.

The notions discussed here closely align to the concept of flow (Csikszentmihalyi 1990), a state of absorption with the (product-related) activity at hand. Overly complex or cumbersome interfaces may prevent flow experiences (e.g. a navigation device with difficult-to-read visual maps or pointers preventing flow while driving), and give rise to negative (i.e. irritation or frustration) or positive (satisfaction or contentment) instrumental emotions (Desmet 2008). As hinted at, it is at this level that designers should ensure that task performance progresses smoothly and that users can manage data input (and complexity thereof) in different types of situations. In case study 2, we will present an example of how designers can resort to tactile output in order to facilitate task performance and reduce cognitive load.

Finally, the symbolic–reflective level (ideological pleasure in Jordan’s framework) deals with attributions of symbolic meaning and people’s resulting tendency to perceive products as embodying values, personality, and hence as a means for self-expression. For instance, dependent on design attributes such as product weight, material texture, and visual appearance, a product may strike one as playful or serious (van Rompay, Hekkert, and Muller 2005). Likewise, dependent on sound characteristics, auditory signals may be perceived as signalling danger, calm, or excitement.

As another example, consider the design case of a mobile phone increasing in volume as calls, messages, and other types of data accumulate during the day. Fabian Hemmert and his colleagues of the T-Mobile design research lab (Hemmert et al. 2010) experimented with these and other tactile forms of feedback for mobile phones. From the feedback that the shape-changing phone in Figure 2 provides, it should be clear to users (both visually and tactually) whether or not attention is required.

Although in this case the design of the phone was not based on research assessing user impressions of mobile phones varying in volume, note that the coupling between size and urgency makes intuitive sense as ‘size’ is throughout daily language use associated with importance and urgency as indicated by common expressions such as ‘tomorrow is a big day’, and ‘a looming big issue’ (Lakoff and Johnson 1980).

Interestingly, research in cognitive linguistics (i.e. the embodied cognition framework) shows that people often ‘use’ concrete, sensory experiences in order to communicate about more

Figure 2. Shape-changing phone developed by the T-Mobile design research lab.
Source: Hemmert et al. (2010).

abstract domains (i.e. embodied metaphors; Lakoff and Johnson 1980, 1999). Thus, in addition to size (‘Tomorrow is a big day’), weight may be used to talk about importance or value (i.e. ‘a weighty issue’ or ‘an issue not to be taken lightheartedly’). Such couplings are embodied so far from childhood on – we learn through our embodied interactions in and with the environment that objects of great size or weight are generally more important or valuable. Similarly, the coupling between warmth and intimacy apparent in language use (e.g. a warm smile) can be traced to embodied interactions in which experiencing intimacy and feeling bodily warmth (e.g. a young child secure in his mother’s arms) are part of the same interaction.

Translated to the domain of design and social behaviour, Ackerman, Nocera, and Bargh (2010) showed that texture-wise rough objects such as a hard, as opposed to a soft-cushioned, chair rendered social interactions more difficult, amongst others transpiring in a lowered willingness to seek compromise in a negotiation task. Such couplings are rooted in object interactions in which we find that objects such as marbles move less speedily or smoothly on rough surfaces. Similarly, in interacting with objects of different material substance, we find that some materials yield to bodily force or pressure (e.g. textiles, wood), whereas others do not (glass, iron, etc.). Because of this embodied grounding, we intuitively understand the meaning of common linguistic phrases such as ‘a soft personality’.

3. Two case studies on tactile experience

Having discussed the three levels of product experience, we will now turn to the case of tactile feedback to illustrate how to design for this modality in particular. In our introduction and in the previous section, we have sketched the opportunities that the tactile modality provides for designing interactions at different levels of product experience. Also, we have suggested how designing for experience can be fuelled by insights from the behavioural sciences.

Hence, we will present two case studies, the first one addressing the potential of sensations of weight on the symbolic level, the second study focusing on tactile sensations in relation to the functional–behavioural level. (As mentioned earlier, the relationship between touch and the visceral level is more widely discussed in design research and applied in design practice.)

3.1. *Case study I: exploring the meaning of weight in a cell phone*

3.1.1. *Background*

Inspired by the embodied cognition framework discussed in the previous section, Ackerman, Nocera, and Bargh (2010) tested influences of weight on social evaluations. To this end, passers-by evaluated a job candidate by reviewing resumes on either light or heavy clipboards. Findings showed that candidates 'presented' on heavy clipboards were perceived as displaying more 'serious' interest in the position. In a similar line of reasoning, Jostmann, Lakens, and Schubert (2009) showed that holding a heavy clipboard increased judgements of importance and value (e.g. the importance of fair decision-making and judgements of monetary value). These findings clearly show that the relationship between weight and value is not a mere linguistic curiosity but is fundamental to cognition in general, and as such, weight may implicitly inform decision-making with respect to product design as well.

3.1.2. *Design case*

Translated to the design context, these findings on the weight–value relationship nicely concur with scepticism people may feel when holding lightweight (technologically advanced) gadgets or devices. For although downsizing and accompanying decreases in product weight are obviously warranted with respect to mobility considerations, they may also inspire impressions of flimsiness in the case of excessively lightweight products. In order to test this relationship in the design context, an experimental study was conducted in which mobile phone weight was varied (van Rompay et al. 2014) and users were asked to take part in a small product evaluation study centred on 'look-and-feel' impressions of early prototypes. The prototypes (see Figure 3) for this study were modelled in Rhinoceros 4.0 and subsequently printed in 3D by Shapeways (a 3D-printing marketplace). Based on Apple's iPhone4 (the most common phone model at the time of this study, weighing in at 137 g), two weight variants were created (see Figure 3): a relatively heavyweight variant (180 g) and an excessively lightweight variant (60 g).

Participants were 96 respondents (50 males, 45 females, 1 participant did not reveal gender; mean age: 34.0 years). They were recruited at the town centre and neighbouring companies at a large Dutch city. Upon agreement, participants were handed one of the phone variants (identical on all other aspects such as material texture, colour, etc.), and asked to indicate whether they agreed with the statements 'This phone is casual,' 'This phone is cheap,' and 'This phone is worth paying a premium price for.' Additionally, they were asked to provide an estimation of the expected price in store (open-ended question). Hence, two value measures were incorporated

Figure 3. Mobile phone prototypes: lightweight (left panel) and heavyweight (right panel) variants.

to assess the weight–value relationship. Although no real-life interactions such as messaging and calling were available, participants were clearly instructed to pick up the phones in order to assess their 'look and feel' and to get a sense of their retail value.

Participants' responses indicated that the weighty variant was perceived as significantly more valuable compared to the lightweight variant. The effect of product weight on price expectations was also significant, showing that the weighty variant triggered a higher price expectation (i.e. a price of 289 euros) compared to the lightweight variant (221 euros).

Although this study focused on static designs and assessed relatively straightforward value perceptions, these findings do suggest that mobile phone weight can be used to provide feedback on importance, similar to how dynamic increases in size may inform users on data storage. Thus, variations in weight sensations (e.g. effectuated by varying the phone's weight distribution; see Hemmert et al. (2010) for technological feasibility) could indicate to the user whether important phone calls, notifications, or other data types came in during the day. Hence, in addition to volume signifying the total amount of data stored on the phone, weight could be specifically used to communicate in an intuitive manner about the importance of specific data types. Taking into account that users can tag or designate favourite contacts in terms of importance, such types of feedback could instantly tell users whether attention or actions are required without demanding types of information processing such as scrolling down lists of messages, notifications, and the like.

Again note that material selection may not only be considered at the visceral level (i.e. is a heavy feel experienced as pleasant?) or at the functional–behavioural level (i.e. does a heavy feel facilitate product interactions and task performance?), but thus also at the symbolic–reflective level. As technology-enabled means for dynamic variations of material properties such as sensations of product warmth and weight increase, such considerations could, in our opinion, pave the way for more intuitive and less demanding product interactions and experiences. In sum, although not focused on tangible interaction in a demanding context, findings resulting from studies such as this are required in order to provide for interactions in which intuitive meaning portrayal is all-important.

In the next case study, we will present a design project addressing the design of a tactile navigation system. Emphasis was here on the functional–behavioural level.

3.2. *Case study II: design of a tactile navigation system*

3.2.1. *Background*

As argued throughout this manuscript, the choice to provide information or feedback through an alternative modality can increase product safety in tasking situations and render interactions with products more intuitive and pleasurable. When discussing facets of product experience grounded in task-related interactions with products, we are concerned with the functional–behavioural level. For instance, by spreading information across multiple modalities and by bringing feedback closer to the body (i.e. by ensuring more instantaneous feedback) designers can facilitate task performance and reduce cognitive load arising from situations in which feedback *does* require cognitive interpretation. It is therefore not surprising that several designers and researchers have undertaken efforts to design new and safer solutions (exploring alternative modalities) for navigation tasks (see e.g. Wang and O'Friel 2007). Spence and Ho (2008) explored effects of using multisensory warning signals for car drivers. In their study, participants initiated their braking responses significantly more rapidly when they were presented with a combination of auditory and tactile warning signals than when they were presented with either unimodal auditory or unimodal vibrotactile warning signals. This indicates that besides using the right modality for feedback, spreading feedback across modalities may be beneficial in some situations.

Zooming in on the context of navigation, cyclists might particularly benefit from a product that improves safety by *not* providing additional information through vision (since the visual sense is already needed to focus on the main task at hand). Therefore, the case study that we will present here was aimed at designing a bicycle navigation product that uses unimodal tactile output. Our main interest was in exploring if people would understand and how they would experience the tactile feedback given by such a product.

3.2.2. *Design case*

For the design of our tactile bicycle navigation product, we decided on the option of a bracelet because it can provide instantaneous, tactile feedback (see Figure 4 for a render image of its envisioned appearance). To transfer navigation directions and commands into tactile feedback, it was decided to directly translate these commands into corresponding movements that people using the bracelet would be able to feel. In our final design, the commands are transferred onto the human skin by a small moving chain. The chain can move in two different directions: back and forth. To be able to indicate different commands, at least four directions must be possible. The bracelet should therefore contain two chains, placed at an angle of 90°.

A test with 18 participants (13 males and 5 females, mean age: 25 years) was conducted with a functional prototype and a number of graphical representations of the original design. We used both graphical representations and a prototype because the functional prototype did not look exactly like the design envisioned for this product. The prototype was made of two elastic bands that were attached to a piece of 3D printed ABS that included the tracks for one chain. The functional prototype we used for the test therefore provided two navigation commands only: ‘go left’ and ‘go right’.

The test was carried out in a lab setting, where the participant and the interviewer were seated at a table where additionally the materials required for the test were displayed (prototype, graphical representations of the final design and questionnaires). The test was videotaped to allow for

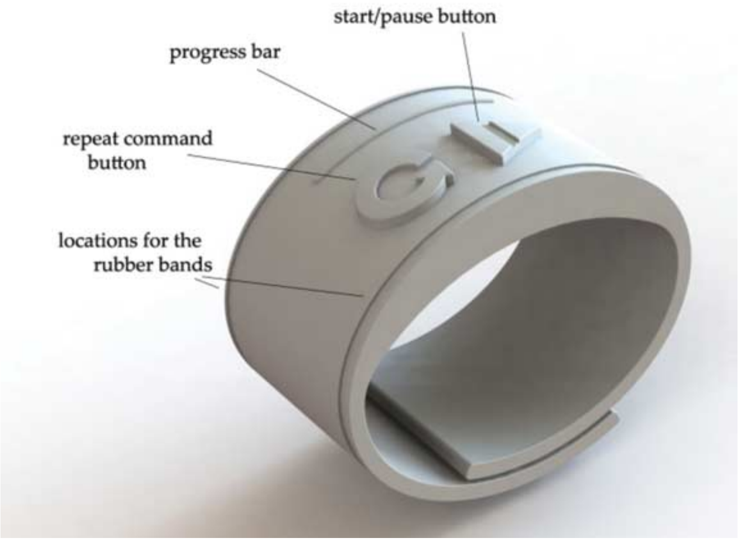

Figure 4. The envisioned design for the tactile bicycle navigation bracelet.

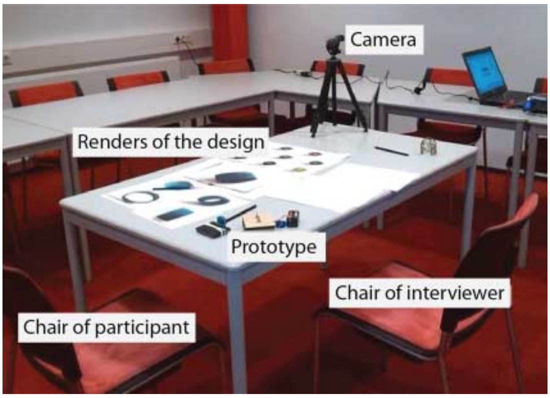

Figure 5. Set-up used to test the bicycle navigation bracelet.

reviewing (see Figure 5 for our test set-up). The goals for our test were twofold; first, our test aimed to determine whether people could feel and understand the tactile information presented. Second, we aimed to test whether people felt comfortable receiving the tactile signals and could see themselves using such a product.

The procedure was as follows: The prototype was placed around the participant's wrist and he or she was asked to provide feedback on comfort and fit. Subsequently, participants were asked to indicate what they thought the different signals meant, imagining that they were using the product (i.e. feeling the signals) while navigating. Signals were repeated if participants requested multiple (tactile) exposures. When participants where sufficiently accustomed and attuned to the signals, they were asked to draw a short route on paper, following the signals provided by the bracelet. Next, the prototype was removed and the graphical representations of the final design were shown. Participants were asked to answer 15 questions about the navigation bracelet that ranged from questions about how well the participant could understand the signals the navigation device provided (e.g. 'the signals that the bracelet provides were easy to understand') to how the participant would feel if he or she would wear such a device in everyday life (e.g. 'Wearing this bracelet would make me feel insecure'). All responses were given on 7-point scales with end points 'do not agree at all' and 'agree completely'. At the end of the questionnaire session, participants were given the opportunity to write down comments and suggestions. Mean responses to all questions were analysed as were the routes drawn by the participants and their comments and suggestions.

Our results showed that it was quite difficult for our participants to feel and interpret the commands in the right way. Most of the participants needed some practice before being able to understand the commands transmitted. In the navigation task (on paper), most of the participants made several mistakes, suggesting that the tactile commands were not sufficiently clear in terms of spatial distribution. Hence, in forthcoming redesigns, it might be wise to give the commands for 'left' and 'right' at different (more spatially distributed) sensitive spots on the skin. Another suggestion for improvement of the commands is to use 'moving steps' (a free translation of a participant's comment on the questionnaire). If, for instance, the user needs to go left, the bracelet could provide the commands in three, slightly pushing 'steps' (i.e. pushing up on the skin) from right to left.

As for experienced pleasure, most of our participants responded positively to the questions that inquired about the experience they had while using the bracelet. People clearly saw the benefits for a tactile bicycle navigation product (mentioning the improved safety) and most of the participants would like to be seen with such a bracelet.

This design case gives some insight into the process (and the difficulties) in designing for other modalities than the visual. When first presented with the prototype, most of our participants were able to directly transfer the tactile information to commands. However, while performing a 'real-life' navigation task, participants had a hard time interpreting the signals because they could not always distinguish in what direction the chain was moving on their skin. Nevertheless, most of our participants saw the potential of such a device, which indicates that there are indeed opportunities for tactile feedback at a functional level, warranting further explorations on how to implement tactile feedback in navigation devices.

4. Discussion

In this paper, we have discussed two design cases illustrating the different levels at which the tactile modality can be used with different aims (i.e. case 1: symbolic–reflective level concerned with the transfer of symbolic meaning; case 2: functional–behavioural level concerned with task performance in a high demanding situation). What these cases do not show is how sensorial properties of a product that were designed to have an effect on, for example, the functional–behavioural level, may also affect one of the other levels of user experience. Designers need to be aware of this. For instance, the tactile commands in case study 2 may not only facilitate task performance (functional–behavioural level), they may also be perceived as (un)pleasant (visceral level) or as, for instance, *timid* or *aggressive* (symbolic level).

Admittedly, the design cases presented require follow-up studies to further assess the relevance and usability of the findings presented in the design context. For instance, findings on the physical–social warmth relationship could be relevant for designers as (with respect to design of gadgets and social media applications) dynamic variations in material warmth could indicate towards users whether favourite users, family and friends called or checked in via social media during the day. That is, based on the discussed coupling between material and social warmth, users should have an easy time making an intuitive connection between these two domains. In this scenario, a 'cold' feel, as opposed to a 'warm' feel, could signal the absence of personal messages and vice versa. Naturally, it would be up to users themselves to designate 'cold' and 'hot' contacts (although note that frequency and duration of calls could serve as input in an 'automatic' mode).

Moreover, the same line of reasoning that we have illustrated in our design cases might be applied to the other senses. For instance, sound is widely used to convey danger, and sound characteristics such as pitch and tempo are easily interpreted by users. For example, a high-pitch, fast-paced series of bleeps will be interpreted as signalling danger. Especially when hands-on interaction is troublesome (e.g. while driving) and extraneous sounds are limited (e.g. in indoor environments), sound may be an excellent candidate for both functional–behavioural prompts (as is widely used in navigation devices already; e.g. to warn a user of speeding cameras on route) *and* symbolic meaning portrayal.

With respect to the latter, Lageat, Czellar, and Laurent (2003) had people rate different flip-top lighter sounds. Results revealed (at least for a large segment of consumers) a relationship between value perceptions and sounds characterised as 'matte', 'even', and 'low-pitch'. Ludden and Schifferstein (2007) explored the combined effects of auditory and visual attributes of dust busters and orange juicers and found (at least for some cases) that sounds matching the product's perceived symbolic expression based on their visual appearance resulted in higher recognition of the intended expression. In sum, these combined findings and observations suggest that, similar to material feedback, sound can be applied on all three levels. That is, sound can be experienced as pleasant or annoying (visceral level), may hinder or facilitate task performance (functional–behavioural level), and connote specific meanings (e.g. danger, value, excitement).

Arguably, some of the senses are less suitable to transfer more abstract information. This might be particularly true for olfaction. On the other hand, olfaction might be a logical choice in cases where subtlety of information transferred is needed. In his article on the use of scent in human–computer interaction, Kaye (2004) mentions that 'scent is an excellent medium for ambient or calm display'. One could, for example, imagine a product–service system aimed at helping people to reduce their stress level by emitting a lavender scent (i.e. a low-arousal, calming scent) at times when stress levels are too high for a prolonged period of time. In this case, distinguishing among the three different levels is less straightforward; the physiological (calming) reaction may be placed at the sensorial–visceral level, while associations with nature (lavender) arise at the reflective–meaning level. Finally, more relaxed and controlled user activities (resulting from exposure to the calming scent) 'occur' at the behavioural level. Due to a greater range of possible interpretations and preferences across people with respect to scent, designing more specific feedback using this modality might be more difficult. In addition, scent as feedback might not be appropriate for rapidly changing information.

Another issue that deserves attention relates to the focus of our paper on different types of sensory output received from the product (rather than users providing different types of sensory input). Apart from voice recognition, recent developments have paved the way for alternative types of user input (e.g. gesture and multitouch input). Also within the field of tangible design, focus is generally on the user and ways in which they can provide tangible input (e.g. by manipulating marbles representing voice mail messages on an answering machine or tunes on an MP3 player (e.g. further described by Dow, Ju, and Mackay, 2013)). This is not to say, however, that non-visual information cannot be incorporated at both the input and output sides.

For instance, the hug shirt developed by Rosella (2004), and her colleagues at CuteCircuit embed sensors and actuators which feel and recreate the strength of touch, skin warmth, and heartbeat rate such that partners interacting at a large distance can actually feel each other and thus not only receive tactile output but at the same time provide tactile input.

Concluding, this paper showed how designers can consider alternative modes of output on different levels of product experience, paying special attention to the many possibilities that the tactile modality can play in interaction. It was our aim to show how recent findings from the behavioural sciences present insights which, in our opinion, are highly relevant to the product design context and the field of interaction design. The case studies have contributed to this by demonstrating that indeed designers can design for different levels of experience (manipulating tactile attributes to create a certain symbolic meaning and using tactile information as commands on a functional level). Since a large body of work in behavioural sciences is more focused on experiences that take place at the reflective level of experience, designers may especially benefit from drawing on this domain when designing for that level of experience. However, we hope that this paper will inspire both designers to learn from behavioural sciences (and use insights from this domain in research through design studies) as well as behavioural scientists to connect their work to the product design and interaction design contexts. A very effective way to achieve this could be sought in setting up multidisciplinary design projects in which at least these two disciplines are represented.

Disclosure statement

No potential conflict of interest was reported by the authors.

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