

A MATTER OF DESIGN

MAKING SOCIETY THROUGH
SCIENCE AND TECHNOLOGY

PROCEEDINGS OF THE 5TH STS ITALIA CONFERENCE 2014

EDITED BY
CLAUDIO COLETTA
SARA COLOMBO
PAOLO MAGAUDDA
ALVISE MATTOZZI
LAURA LUCIA PAROLIN
LUCIA RAMPINO

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Proceedings of the 5th STS Italia Conference***

*Edited by Claudio Coletta, Sara Colombo, Paolo Magaudda, Alvise
Mattozzi, Laura Lucia Parolin and Lucia Rampino*

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From bits to atoms: sensory displays for digital information

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Traditional media conveying digital data (e.g. screens and displays) should be rethought also paying attention to the user experience. Moreover, sensory channels different from the visual one may be explored by design.

This work analyses how physical objects can display information not only by embedding conventional screen-based interfaces, but by dynamic transformations in their sensory features. As there is a gap in design literature about this topic, this paper investigates the roles and meanings of sensory modalities and media in the transmission of different types of messages. The aim is both to propose a framework for the categorization and analysis of this emerging category of 'dynamic products' and to give some insights on the role sensory modalities and media may assume in different situations. To achieve the goal, a case-study analysis was performed on a sample of dynamic products. Moreover, interviews with users were conducted to verify some of the hypotheses emerged. Results show that dynamic products can communicate messages to users by many different sensory media, which can assume different meanings according to the source of the communication, its aim and the overall context. The work constitutes a starting point in the exploration of an emerging scenario for the digital communication from products to users.

Keywords: *Dynamic products; digital information; senses; aesthetics*

Introduction

The world of ICT has been expanding at impressive speed in the last few years, making new forms of communication emerge and spread.

Computers and digital devices, smart products and systems generate huge amounts of data, which require to be converted into readable messages for users (Barker, 2013). Traditionally, these digital data are translated and displayed by means of digital interfaces (e.g. screens or

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displays), which exploit the alphanumerical and iconic language (Krippendorff and Butter, 1984).

This paper explores the possibility to communicate bits of information to users through an implicit language, based on dynamic changes in the product appearance, as alternative media to digital interfaces. Indeed, nowadays, the product's appearance, intended as the mix of product's sensory features (Desmet, 2012), can assume a dynamic quality: thanks to electronics, informatics and material technologies, the sensory features of products – e.g. shape, temperature, colour, light, smell, sound, etc. – can be controlled and modified in an active and reversible manner during the product life, changing over time. For instance, One (figure 1) is a kettle that informs that water is boiling by showing a coloured texture on its surface.

Therefore, on the one hand, an increasing amount of information is to be conveyed to users, on the other hand it seems that designers can rely on a new language to perform this communication: the one of product dynamic appearance. We believe dynamic sensory features might constitute, within bounds, a new language for the communication of information, replacing interfaces in search of a less complex, but potentially more engaging, kind of communication.



Figure 1: One kettle by Vessel Ideation. A texture appears on the surface when the water boils.

Background: Tangible Interactions and Ambient Displays

During the last decades, many approaches have been developed to find alternative and more tangible ways to interact with the digital world, by bridging virtual data (bits) to tangible artefacts (atoms) (Wiberg and Robles, 2010). The starting point of all these *Tangible Interactions* (Van Campenhout et al., 2013) was the assumption that traditional digital interfaces have a limit: the constraints of the two-dimensional screens, which lack the richness of the sensory and physical experience we have while interacting with the real world (Holman and Vertegaal, 2008).

Some examples of these directions are the works of Ishii and Ullmer (1997) (i.e. *Tangible User Interfaces*) and Van Campenhout et al. (2013) (i.e.

Tangible Interactions). Such experimentations demonstrate that visual screens are not the only way for users to access digital contents.

In the 90's, within HCI, a new research strand called Ambient Displays emerged (Matthews et al., 2004; Pousman and Stasko, 2006; Wisneski et al., 1998). In Ambient Displays *'information is moved off the screen into the physical environment, manifesting itself as subtle changes in form, movement, sound, colour, smell, temperature, or light'* (Wisneski et al., 1998). The focus was on finding more tangible and natural ways to convey information. However, scholars in this field did not pay too much attention to which sensory modality this information should be displayed by, and why it should be displayed that way. Nevertheless, the way information is displayed by the product, the sensory modality involved (sight, hearing, touch or smell) and the media adopted (light, colour, sound, fragrance, etc.) affect both the communication effectiveness and the user experience. Therefore, by taking the Ambient Displays approach as starting point, we intend to explore how information can be effectively displayed in more physical and sensory ways, by the product's dynamic features.

Informing by Dynamic Products

We define *'dynamic products'* objects showing dynamic sensory features that change proactively and in a reversible manner over time, activating one or more user's sensory modalities. Such products can be employed as alternative to the explicit communication performed by conventional interfaces. However, even though there is a growing number of examples of dynamic products (concepts, prototypes and commercial artefacts) designed to communicative purposes, there is still little knowledge on this area, which could support the designer's work.

Aims

This paper presents an analysis performed on a number of samples of dynamic products in order to understand their features and how they can convey digital information by different dynamic sensory media. The aim of the analysis was both to propose a descriptive framework for dynamic products and to generate preliminary insights on the roles senses and media can assume in the information transmission in different situations.

Methodology

The study investigates the area of dynamic products by two research actions. The first one consists of a case-study analysis on a number of samples of dynamic artefacts (Eisenhardt, 1989), aimed to generate a framework to analyse and categorize these products. Moreover, hypotheses on the role of senses are proposed. The second action consists of qualitative interviews with uninformed users, aimed at verifying some of the hypothesis emerged in the previous step.

The specific methodologies followed in the two research actions are described in the respective paragraphs.

Case studies analysis

The first research step consisted of a case-study analysis based on instances of dynamic products.

We collected 48 samples of dynamic products (in form of images and descriptions) among design concepts, prototypes and commercial artefacts, by reviewing journal articles, conference papers, universities' research projects, but also design contests and companies websites. Products were selected according to their novelty factor, meaning that we discarded objects using standardized dynamic signals, such as common warning lights or sound alarms of appliances. Moreover, products had to show a communicative intent, therefore dynamic objects having expressive or aesthetical purposes only were discarded.

By analysing these samples, we generated a descriptive framework for this category of artefacts.

A framework for Dynamic Products

The descriptive framework is based on three criteria, according to which dynamic products can be categorized: the *source* of the message, the *type* of message, and the output *sensory modality* (i.e. the sense which the message is displayed by).

The message source. Within our samples, dynamic products convey messages coming from three main sources:

The product itself: dynamic products inform about their own internal physical state (like temperature, figure 1), their functions, the action they are performing, their energy consumptions, etc.

The environment: dynamic products inform about states of the environment (e.g. the temperature of a room, the level of pollution in the air), which they are indicators of (figure 2)

A human: dynamic products can be used to convey messages coming from a person. For instance, they can be employed in distance communications, to replace the communication based on verbal language and screens (figure 3)



Figure 2 Wearable detect air by Genevieve Mateyko and Pamela Troyer. The jacket detects the pollution level in the air and displays it by light patterns. When the pollution is too high, the jacket vibrates to alert the user.



Figure 3 HugShirt by CuteCircuite. The shirt makes people send hugs over distance, by reproducing the tactile sensation of a hug on the person who wears it.

The message type. Since the messages transmitted by the samples cover a broad range of contents, it was not relevant to categorize them according to the content of the communication. The parameters we identified to categorize the messages concern the *aim* and the *quality* of the message.

According to the *aim*, dynamic products convey messages that can be:

Data-aimed. The message aims to share some data or knowledge with the user (for instance the emotion a person is feeling, figure 4, or the temperature of a room).

Action-aimed. The message intends to exhort the user to take a short-term action (for instance, it encourages the user to drink water, when s/he is dehydrated, figure 5).



Figure 4 *Smart Second Skin dress by Jenny Tillotson. It senses the user's emotions and displays them by spreading different smells in the environment.*



Figure 5 *I-Dration by Cambridge Consultants. The bottle tells the user when s/he needs to drink water, by emitting a flashing blue light.*

According to the *quality*, messages conveyed by dynamic products can be:

One single bit of information, like an on/off message. The product conveys only one gradient of the message by a unique change in the

product sensory features (a colour appearing/disappearing, e.g. ‘the water is boiling’, figure1).

Multiple bits of information related to multiple and variable qualities, or states, of the message source. Dynamic products can transmit gradual variations of an item (e.g. ‘your consumption is low/medium/high’, figure 6, or ‘the temperature is cold/warm/hot’), using different qualities of the medium (e.g. different colours corresponding to different temperatures, or different fragrances corresponding to different emotions, figure 4).



Figure 6 Flower Lamp by Interactive Institute, Swedish ICT. The lamp changes its shape according to the energy consumption in the household.

The output modality. The third criterion of our framework is the user’s sensory modality that receives the message. Dynamic products display messages by transformations in their sensory appearance, which activate one (or more) user’s sense. The possible transformations in the product appearance, grouped by the modality they activate, are summarized and represented by a Sensory Map (figure 7).



Figure 7 The Sensory Map displays the transformations that product sensory features can undergo. The media (changes in light, shape, colour, sound, etc.) are grouped according to the sensory modality they activate.

The resulting descriptive framework is summarized and visualized in figure 8.

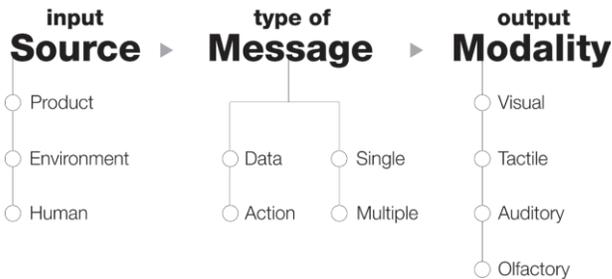


Figure 8 A descriptive framework for dynamic products.

The role of senses

The second step of the case-study analysis intends to investigate if senses assume different roles according to the source and the type of message conveyed. For instance, we analysed the senses used within each source category (product, environment and human), to see if they had different weights. When specific senses appeared more frequently in one source than another, we made hypothesis about the reasons for this discrepancy.

Message Sources vs sensory Modalities

In order to explore the relation between the *senses* and the *sources*, we grouped together the instances related to each sensory modality in the categories of Product, Environment and Human (figure 9). The frequency of the senses within each category is summarized by the graph in figure 10.

	sight	touch	hearing	smell	
product	9 	0	3 	0	12
environment	17 	5 	1 	3 	26
human	6 	6 	0	1 	13

Figure 9 The table puts in relation the source of the message to the sensory modality by which the message is displayed. Pictures of the case studies are reported together with the number of instances.

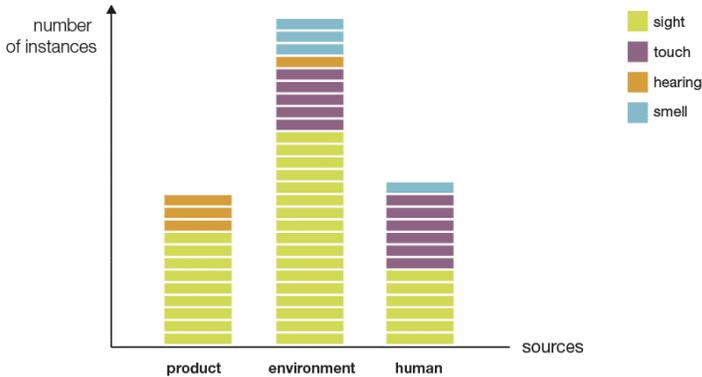


Figure 10 The graph visualizes the frequency of use of the sensory modalities within each source category.

The first finding is that all the sensory modalities are used as channels to communicate information in form of sensations. Even smell, the most overlooked sense in the design of products, has been used to convey information. In the environment category, we can find samples addressing all the four senses, even though with different weights: sound is the less used medium, while sight is the most frequently used sense.

When dynamic products convey information coming from the *product* itself, only sight and hearing are employed. This might be due to the fact that instances in this category are all common products, to which a communicative function is added. These dynamic products are not typological innovations (Rampino, 2011), but products consistent to their category archetypes, to which a layer for the communication is added (e.g. product One in figure 1 is an ordinary product modified to convey information about its function in a poetic way). Thus, the easiest way to achieve the goal is to work on the surface of the artefacts (e.g. by adding lights or thermochromic inks on the surface) and/or to insert a sound.

When the message comes from *humans*, touch gains a great importance, reaching the one of sight. On the contrary, hearing and smell are almost completely absent. This is an interesting finding, whose reason might be that the concept of intimacy which characterizes human communication may be better conveyed by a sensation that recalls the idea of closeness and intimacy (like touch). *'The proximal nature of touch allows for the creation of private displays. This is an important affordance when information is confidential or privileged'* (Jones and Sarter, 2008). Moreover, touch is the

first language we learn and has deep emotional implications (Gallace and Spence, 2010).

Message Aim vs sensory Modalities

The second step of this analysis puts in relation the *aim* of the message (data vs action) to the output modality. The hypothesis that guides this analysis is that the stronger the user is activated by the sensation, the more effective the action-aimed information might be. It means that, to induce the user to act, the medium should be perceived as more intrusive and compelling, also according to the urgency of the required action. Again, the samples were grouped according to the senses and the aim of the message they convey (figure 11) and results are summarized by a graph (figure 12).

	sight	touch	hearing	smell	
	25	7	2	3	
data					(37)
	7	4	2	1	
action					(14)

Figure 11 The table puts in relation the aim of the message to the sensory modality by which the message is displayed. Pictures of the case studies are reported together with the number of instances.

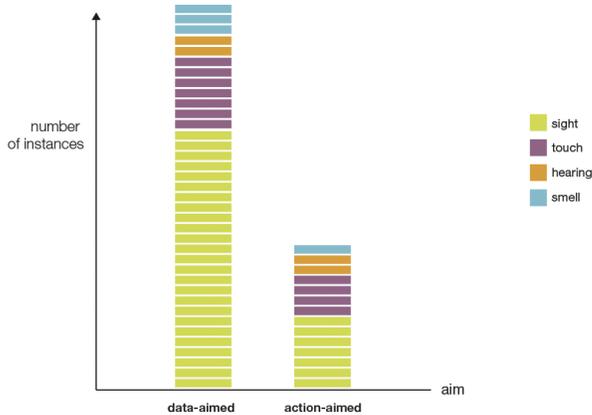


Figure 12 The graph visualizes the frequency of use of the sensory modalities within each message aim category.

The first evident result is that sight is clearly the most used modality in data-aimed messages. In action-aimed messages, results are more equally spread among modalities, and the difference is not significant. By comparing the two categories, no evident results emerge with respect to the role of the different sensory modalities. Indeed, it seems that senses have not different roles in conveying data-aimed rather than action-aimed messages.

However, by analysing the single media instead of the sensory modalities, some elements can be stressed. In touch, vibration is used just in the case of action-aimed messages (e.g. Wearable Detect Air, figure 2) while pressure and temperature are used to convey only data-aimed information. Colour is almost absent in action-aimed information as well. Again, it would be interesting to deepen the analysis of this finding, since it might mean that colour is not as efficient as light or vibration in rapidly grabbing the attention of the user or in exhorting him to take an action.

Message Quality vs sensory Modalities

This last analysis compares the use of senses in conveying single rather than multiple information (figure 13 and 14). The initial hypothesis was that some sensory media (e.g. vibration or pressure) can be intrinsically more suitable to convey single rather than multiple and variable information.

From bits to atoms: sensory displays for digital information

	sight	touch	hearing	smell	
single	10 	8 	2 	1 	22
multiple	22 	3 	2 	3 	29

Figure 13 The table puts in relation the quality of the message to the sensory modality by which the message is displayed. Pictures of the case studies are reported together with the number of instances.

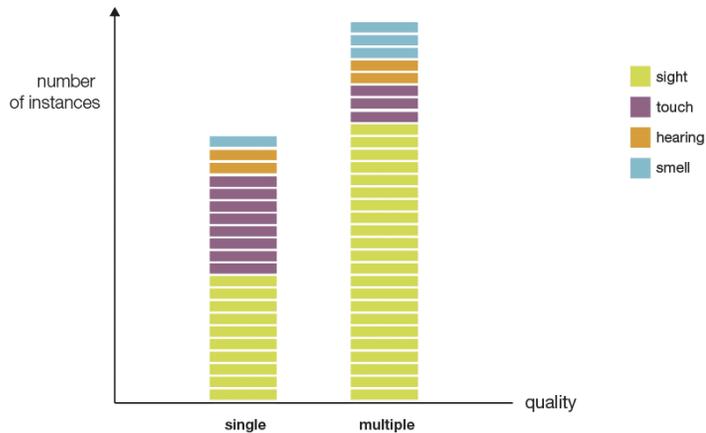


Figure 14 The graph visualizes the frequency of use of the sensory modalities within each message quality category.

Results show that sight is mostly used to display multiple information. Indeed, it is our most precise sense and it allows the user simultaneously receive and compare information. For instance, one can easily compare

different colours or light intensities. Visual media used to convey multiple information comprise light (mainly changing in colour, but also projecting different patterns, or having different intensities, or pulsating at different paces) and colour changes, but also shape transformations. In absolute, colour change is the main medium adopted to convey multiple information.

Touch is employed more to convey single rather than multiple information. This finding might be connected to the fact that touch is perceived with less accuracy than other senses. Especially vibration, even though it can have different intensities, seems to be less suitable to convey different qualities of an event, while it is used much more to convey single information, like simple alerts.

Smell is mainly used to convey multiple rather than single information, adopting different flavours. Interestingly, the analysed dynamic products never use changes in the smell intensity, but only adopted different fragrances.

User interviews: using senses to different aims

In order to confirm or refute some of the insights emerged in the previous analysis, interviews with users were accomplished on a selected number of samples. The overall interviews aimed at investigating many aspects of the interaction with dynamic products. As there are few dynamic products available on the market, for most are in the form of concepts or prototypes, a direct interaction turned out to be unfeasible to set up. For this reason, and since the aim was to perform a preliminary explorative investigation of users' experience, we decided to set up semi-structured qualitative interviews (Drever, 2003) supported by pictures and brief explanations for every product. The results discussed in this paper only concern the relation between the sensory media and the message aims. The intention is to verify if certain sensations might be more effective than others in conveying action-aimed rather than data-aimed information, as the case-study analysis suggested.

Samples selection

For the interviews, 15 dynamic products were selected. As many products adopted similar stimuli to convey the same kind of message, we decided to reduce the number of products to test. We selected the products maintaining the highest variety among the samples, according to the three criteria identified in the first research step. For this reason, within each source category (product, environment and person), we selected products

conveying both exhortative and cognitive messages. Within each sub-category (e.g. products conveying exhortative messages coming from environment) we picked only one product for each different sensory stimulus adopted.

Interviews structure and performance

Five users were involved in the interviews (2 males and 3 females) from an age of 19 to 60. Each user was asked to analyse three products randomly chosen among the selected ones.

The interview consisted of two sections of 5 questions each. The questions were used as a track by the interviewer, and aimed to lead to an open discussion between the interviewer and the user.

The entire interviews were recorded and subsequently transcribed. Memos were written during the interviews, to note additional details. The recordings and memos were analysed following an approach based on Strauss and Corbin's model, already used by previous studies in the field of user experience (Khambete and Athavankar, 2010). The findings were extracted through a coding process aimed at identifying recurrent concepts, which were then clustered into categories based upon similarities.

Results

From the interviews analysis, it came out that specific media have a strong alarming and activating power. In particular, users interpreted vibration, sound and flashing light as conveying urgent information, which required an immediate action:

'I would move away quickly, because I would be afraid. More with vibration than lights, definitely, because it [vibration] is more immediate, you feel it on your body [...]. Would it [the product] have only lights, I would resist longer. Vibration alarms and exhorts; light warns' (User 03 on Wearable DetectAir, figure 2). These results are confirmed by some studies that investigate vibration as a powerful medium for attention allocation (Hattori et al., 1987; Sklar and Sarter, 1999). Light and sound were evaluated differently as well:

'Sound activates more than light, it would make me react' (User 04)

In other cases, when the message wanted to be exhortative in the intention of the designer, but it was conveyed by other stimuli, like a change in colour or visual texture, the information was interpreted as just suggesting or inviting. When talking about Disappearing Pattern Tiles ,

shower tiles whose decoration disappears when the hot shower lasts for too long (Backlund et al., 2007), a user stated:

'I would try to go faster, but the stimulus itself is not asking me to accelerate, the message it conveys do. The change itself does not stimulate me to react [...] It only suggests and warns.'

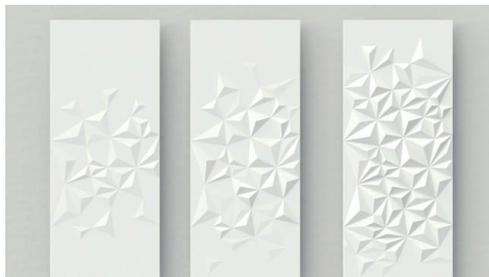


Figure 15 Noi by design-people is a concept for maintaining indoor climate in private homes. The more polluted the air, the denser the surface texture becomes.

In the case of the texture change in Noi (figure 15), a subject affirmed that:

'even though the message is exhorting [because it requires to do something to improve the quality of the air], the sensation is not alarming or exhorting. It is instead suggesting.'

Colour changes were evaluated as appropriate to convey data-aimed information:

'it [colour] suggests and warns. Suggests that it's ready, and warns that it's time to cook. It is a low level of exhortation, because if you don't put the food inside, it will not go crazy. The pot is saying 'if you care, I'm already ready to start' (User 01 on Coral Cooking, figure 16) .



Figure 16 *Coral cooking* by William Spiga and Juliana Martins is a pot whose texture changes from blue to red to display changes in the internal temperature, so that the user knows when it is hot enough to cook.

Also still light was not interpreted as exhorting. Differently, a flashing light was perceived as exhorting and alarming:

'Seeing an object lighting up does not suggest me to do anything. It attracts me, but it is not exhorting' (User 02)

'I would not use a lamp for alarming; an alarm should be direct and unavoidable. However, was the light flashing, it would be effective in alarming' (User 04)

However, if the user is already aware s/he has to perform a very important task, the medium can also be less strong to obtain a hortative effect. In this case, the dynamic product could be just a reminder. For instance, in the case of a pill-box that lights up when it is time to take a pill, a still light was considered enough to exhort the user to take the pill (note that the interviewed user had to take different pills during the day, so he was sensible to the issue):

'the light exhorts, because it is reminding that you have to do something. But it is more a warning, not an alarm. It does not alarm you, it reminds, but by reminding, it also exhorts, because you cannot choose, you know you have to take the pill, it is too important'. (User 04)

The importance of the context

When asking the users to evaluate the effectiveness of the communication performed by dynamic products, they expressed some concerns regarding the choice of certain stimuli, according to the context of use. In some cases, the users evaluated the choice of one sensory modality as wrong, with respect to the product's context of use.

An example is the I-dration bottle: the subject considered a pulsating light difficult to perceive while running, especially outdoor, because the light

would not be visible enough. The user stated that a tactile stimulus, like vibration, would be more effective, because unavoidable.

In conclusion, even though a message is conveyed by the most effective medium, according to its aim, the communication may still fail because of the context. It came out that the interaction with a dynamic product, being based on senses, must always take into consideration the scenario it will take place in.

Dynamic products vs interfaces

Users were also asked if they would prefer to receive the same message through a verbal or numerical language. In none of the cases, they expressed the desire to replace the communication dynamic products performed with a traditional interface. In fact, they stated that the experience with dynamic products was more engaging and pleasant and the message more immediate, evident and discrete. In more than half of the cases, they argued that they would appreciate a more detailed message, by incorporating or associating an interface to the dynamic product. Nevertheless, they would never replace the direct sensation with the interface.

This is a very interesting result, for it highlights that users are minded to lose some details in favour of more immediate sensations, less precise but more surprising; in other words, in favour of the experience the products create.

Discussion

Through the process of collecting and analysing samples, it emerged that all the four sensory modalities (smell, sound, sight and touch) are adopted in the communication from products to users in our samples, often with different roles and meanings according to the situations in which they are employed (different sources or different kinds of messages). However, sight is the most employed sense in each category, no matter what lens we use for the categorization of dynamic products (source or type of message). The only exception is the human category, where visual and tactile media have the same importance. These results confirm the dominance of sight in our sensory perception, even though the presence of many designs exploring different senses is encouraging for the investigation of novel communicative sensory media.

Not only has each sense specific features and roles, but also some media belonging to the same sensory category are used differently according to the source or the type of message. For instance, vibration is used for single and action-aimed messages coming from environment, while pressure is mainly used for data-aimed messages coming from human. How sensory media can be used in different situations and to diverse aims is definitely a fruitful topic to investigate, since, as Schifferstein and Cleiren (2005) put it, *'each modality picks up a different type of information'*, both at the perceptual, cognitive and experience level. This study supports the hypothesis that this statement is valid also for dynamic sensory features.

Another important element to consider when designing dynamic products, which emerged from the interviews, is the *behaviour* of the sensory medium. For instance, if the dynamic medium is the light emitted by a product, it can be both still or pulsating: this difference is not secondary since, from the analysis, it emerged that still light is more frequently used to convey data-aimed messages, while pulsating light is used in action-aimed messages (within the category of person). Moreover, vibration can be used both to convey a sense of urgency and to represent caution, according to its frequency and intensity (Jones and Sarter, 2008).

What emerges from the users' responses is that the message is strongly affected by the sensation it is conveyed by. The level of urgency of the information and its pushing towards action depends on the nature and behaviour of the medium by which the message is transmitted.

Conclusions

Results emerged from the interviews and the case study analysis stressed the importance of analysing the role of each sensory modality and medium in the communication performed by dynamic products. As each sense has its specific features, investigating the potentialities and limits of senses in specific situations is definitely a direction future research should follow. However, it also emerged that the competences of design are not enough for a deep and trustworthy exploration of such issues. Additional competences and approaches, like perceptual psychology, neuroscience and HCI may advance knowledge in this field, also giving designers the bases for a more informed design process. Nevertheless, general experiments carried out so far by these disciplines do not account for an exhaustive overview of the features of different sensory perceptions (how users perceive shape changes, movements, vibration, colours, etc.) especially when they are

dynamic. That means that this area of design would highly benefit from more focused investigations of the sensory perception, also by designing appropriate experiments together with experts from other disciplines.

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