Causing Commotion with a Shape-changing Bench
- Experiencing Shape-Changing Interfaces in Use

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ABSTRACT
In this paper we describe results from testing coMotion, a shape-changing bench, in three different contexts: a concert hall foyer, an airport departure hall and a shopping mall. We have gathered insights from more than 120 people, with regard to how users experience and make sense of the bench’s shape changing capability. The paper applies McCarthy and Wright’s six different sense making processes (anticipating, connecting, interpreting, reflecting, appropriating and recounting) as an instrument to analyse people’s experience with shape-changing furniture in the wild. The paper also introduces exploring as a seventh sense making process. Based on this analysis, the paper points to three relevant aspects when designing shape-changing artefacts for the wild, namely: 1) Affordance of shape-changing interfaces, 2) Transitions between background and foreground and 3) Interpreting physically dynamic objects.

Author Keywords
Shape-changing interface; user experience; in situ; design; interactive furniture; sense-making;

ACM Classification Keywords
H.5.2. User Interfaces

INTRODUCTION
Emerging shape-changing technologies pave the way for making seemingly everyday objects become physically dynamic and transform their shape through digitally controlled self-actuation. Shape-changing technologies allow computation to be literally interwoven with the fabric of everyday life. Visions depict how shape-changing interfaces can potentially make their way into for example our bathrooms, as shape-changing water taps [35], our living rooms as dynamic curtains [6], our pockets as shape-shifting mobile phones [14] or even into our streets as dynamic facades [18]. As the above-mentioned examples illustrate, shape-changing interfaces are slowly securing a foothold within the HCI community. However, despite the increasing amount of research in shape-changing interfaces, the focus is still primarily on their potentials and technical challenges, rather than on how people experience these types of interfaces [30]. We argue (in line with e.g. [30]) that this exploration must go hand in hand with the study of how humans can make use and make sense out of such dynamic objects and environments in everyday life.

Although researchers have begun seeking to understand how people experience shape-changing interfaces, this has primarily so far been done in the lab (e.g.[13,15]). The challenge of testing shape-changing interfaces in a lab setting is that people know that they are participating in some kind of experiment. While they might not be prepared to encounter a shape-changing interface, they are prepared to encounter something new. As a way to gather insights into how people actually experience the, as of yet, uncommon experience of shape-changing interfaces, we suggest taking them out of the lab and into the “wild”. Testing in the “wild” is not a new approach [3], but as advocated by Rogers et al. [32] among many others, it offers a way to understand complexities of how users behave, understand and appropriate technologies on their own terms and in complex contexts and situations. User testing in the wild is generally conducted by introducing users to a piece of design and then letting them try out the design for a period of time [3]. However, we have deployed coMotion, a shape-changing bench, in the wild without instructing people about its functionality or purpose, while observing how people experienced the shape-changing ability of the bench, as they sat down to rest while shopping, waited for a plane or relaxed with a drink during a concert intermission. To get further insights into their experiences, people were approached and interviewed as they left the bench.

In this paper, we present related work on shape-changing interfaces and experience design. We present coMotion, a shape-changing bench, which has been designed to explore how people experience an encounter with a piece of shape-changing furniture and how shape-change can affect social behavior in-situ. We discuss insights gained from three user studies of coMotion ‘in the wild’ with regard to McCarthy...
and Wright’s [24] framework for making sense of the experience of living with technology. We also present an additional category, namely exploring, to McCarthy and Wright’s framework advocating the importance of embodied, exploratory actions in sense making. Furthermore, we discuss three topics of relevance when implementing shape-changing interfaces in the wild: affordance of shape-changing interfaces, their transition from background to foreground and user interpretation.

RELATED WORK

During recent years numerous shape-changing interfaces have been explored within both the science and art communities. Examples of shape-changing interfaces can be found in mobile phones [14], toys [19], and home appliances [35]. While most shape-changing interfaces are implemented at a scale relating to the hand or other isolated body parts, rather than the whole body, there are examples of larger shape-changing installations, such as Muscle Space [28], Textile Mirror [7] and ExoBuilding [33]. There exist a few examples of shape-change being implemented on a body-scale, allowing for a tactile as well as visual effect of the change. Examples include: Hebing’s [11] interactive bench that changes its physical form based on the actions of the person sitting on it and Chalayan’s [4] shape shifting garments.

Over the past decade, there has been a growing recognition that as interactive technology becomes an integral part of our everyday lives and environments we need to understand how users experience technology [2,20,24]. The developments of shape-changing interfaces have spurred a growing concern for the agendas and conceptualizations that guide their design, but they have yet to be studied more systematically from an experience perspective. We address these concerns from an experience-oriented perspective by acknowledging the complexity of experiences, as they are merging feelings, thoughts and actions. Koskinen and Battarbee [2], identify three broad approaches to apply and interpret user-experiences in HCI: First, the ‘measuring approach’ to develop and test how technology emotionally affects the user; Second, the ‘empathic approach’ to design products that are connected to an individual’s needs, dreams and motivations; Third, the ‘pragmatic approach’ addresses user-experience as the basis of linking action and interaction to meaning. In this manner, the ‘pragmatic approach’ accounts for the situated unity of action, emotion and thought [ibid] and it emphasizes a focus on lived, everyday life experiences [24]. One example of this approach is McCarthy and Wright’s work [ibid] on making sense of experience, which is further explored later in this paper. Based on the coMotion bench user studies we point towards unleashed potentials for people’s sense making process through bodily action and engagement with shape-changing interfaces.

THE COMOTION BENCH

The coMotion bench (see Figure 1) is a shape-changing bench. CoMotion was designed as a probe to understand how people will experience shape-changing interfaces in their daily life, rather than as an outstanding, innovative design or as a future product. With the coMotion bench, we also sought to explore whether an unexpected shape-change in an everyday object could spark encounters between strangers. The bench was chosen as a medium for the experiment, as it is a typical artefact in public spaces, where strangers co-locate for periods of time, while rarely engaging with one another. While an unexpected event that make strangers talk with each other can be generated in many ways, for example by sound or street artists, the bench allowed us to explore how physical shape-change and the effects of bodily manipulation, can influence and potentially trigger social encounters in public spaces. The following sections provide a description of the design, and the methodological research approach.

The design

The coMotion bench has a simple rectangular form with neither back nor armrest and can comfortably accommodate six people. The bench is 2,5 meters long, 55 cm high and 40 cm wide. The height and angle of the bench seat can be altered by eight linear actuators (four pairs), which are hidden beneath the grey and black upholstery. The height of each actuator is controlled through instructions sent from the coMotion’s main control board to control boards connected to each actuator. The main control board is equipped with an AVR ATMEGA 32 micro-controller and each motor control board uses an AVR ATMEGA 8 for controlling the communication and one actuator. The height-changing commands is sent to the main board either by a wireless remote control or is automatically generated by the main board based on input from six seat-sensors integrated in the surface of the bench that detect how people sit on it. The shape of the bench can be altered in three sections, making it possible to angle the seat, and altering the appearance of the bench, from a flat seating surface to an angled one. The bench moves at a slow pace, which makes the movement almost imperceptible at first, in the three contexts, as the sound of the actuators could not be heard. Further technical descriptions can be found in [20] and a visual experience of the coMotion bench and our experiments can be found in the supplementary video material to this paper.
The form, material and color of the bench were designed to allow the bench to blend in, rather than stand out, in the three different environments where it was deployed. The digital properties of the bench was hidden, and there was only a few clues about the bench’s shape-changing capabilities, such as the power-cord coming out of the bench, and the somewhat unconventional upholstery materials used (spandex and elastic). Consequently, people were not assisted in making sense of the functionality and how to control it, but had to interpret the form and movement of the bench themselves.

The methodological research approach

The coMotion bench was tested “in the wild”, as it provided a possibility for people to experience the shape-change of the bench in their daily life. Deploying the coMotion bench in the “wild” enabled us to investigate some of the challenges facing users of ubiquitous computing systems when technology becomes invisible and disappears into the woodwork.

We deployed the coMotion bench in three different locations; a concert hall foyer, an airport departure hall and a shopping mall. We selected these contexts as each of these locations has different atmospheres and people from different walks of life. However, the locations still hold similar characteristics as public spaces that have a high flow of people [ibid]. We advocate that testing in different contexts secure a foothold, when analyzing people’s experience of a new type of interfaces from a more general point of view. The key figures of our tests is illustrated in Table 1.

<table>
<thead>
<tr>
<th>Location</th>
<th>Days</th>
<th>Seated minutes</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concert hall foyer</td>
<td>2</td>
<td>125</td>
<td>47</td>
</tr>
<tr>
<td>Airport departure hall</td>
<td>2</td>
<td>80</td>
<td>54</td>
</tr>
<tr>
<td>Shopping mall</td>
<td>1</td>
<td>60</td>
<td>28</td>
</tr>
<tr>
<td>In total</td>
<td>5</td>
<td>265</td>
<td>129</td>
</tr>
</tbody>
</table>

Table 1. Data from the three test locations.

The three tests were divided into two phases; an explorative phase using the Wizard of Oz (WoO) method (i.e. using a wireless remote control to alter the bench’s physical shape), conducted in the concert hall and the airport departure hall. The insights gained in the first two tests were used to inform the second phase (i.e. test three) where the coMotion bench was programmed with ‘behavioral patterns’ (i.e. to take on diverse physical expressions) depending on how people sat and used the bench in the first two tests. The programmed behavior of the bench was tested in the shopping mall (a description of the programmed behavior can be found in [20]). All three tests were video recorded from a distance. Users were not aware that they were participating in a test until they left the bench, where a researcher who conducted a short semi-structured interview approached them. As a consequence, the interviews also served to ‘de-brief’ people with a negative experience of the bench. Indeed, working with ‘unaware users’ put emphasis on the ethical aspect of our research. Each interview took on average five minutes and the questions focused on people’s experience through investigating how people made sense of the bench, before, during and after their engagement with it. The interviews were voice recorded. During the tests there were two-three researchers present ensuring that multiple persons or groups could be interviewed when they left the bench simultaneously. A few people were missed due to getting lost in the crowd and a few of the interviews were rather brief as people were not interested in participating. The video recorded observations were eventually compared to the interviews and analyzed using the framework by McCarthy and Wright [24]. A seventh perspective was added to the framework as a result of this investigation.

MAKING SENSE OF THE EXPERIENCE

Few have provided frameworks, seeking to describe how users make sense of artifacts and experiences. However, Krippendorff [22] has presented a framework describing making sense, as a cognitively constructed relationship, where features of an object and features of its context (real or imagined) are selectively connected into a coherent unity. McCarthy and Wright [24] have presented a framework seeking to describe experience as well as how we make sense of an experience. The framework consists of four intertwined threads of experience: the sensual, the emotional, the compositional, and the spatio-temporal thread, alongside six different sense making processes; anticipating, connecting, interpreting, reflecting, appropriating and recounting. The six processes do not occur as a linear sequence of thought and action, but are intertwined and do not occur in a predefined sequence.

We have found McCarthy and Wright’s framework a useful tool for directing attention during the analysis, as well as for articulating the different aspects of people’s experience with coMotion, and to some extent it resonates well with the observations made throughout our study. We saw for example several instances where people’s anticipation influenced the way they connected with the bench. Thus in the following, we present our analysis according to the six processes outlined by McCarthy and Wright [ibid]. The framework provides a structure for describing the different aspects of people’s sense making processes, but also presents the challenge of disentangling the intertwined sense making processes and separating them into categories. Based on our experiments we propose an additional category, exploring, to the six sense making processes described by McCarthy and Wright. During the trial periods it was striking how people engaged in actively exploring the bench, physically and tactically, by looking down under it, trying to squeeze it, trying to lift up the textile, moving around on it etc. Paradoxically this sensorial rich part of the experience does not seem to be covered...
Anticipating: Is it a bench or not?

McCarthy and Wright [24] indicate the need to extend the sense making of an experience beyond its starting point. Given that users do not arrive unprejudiced to an experience, but bring all sorts of expectations, prior experiences, and sense making strategies with them.

The majority of people seating themselves on the coMotion bench were not anticipating an experience, but just a place to meet, to wait, or simply to rest one’s feet. Indeed, the design of the bench seeks to encourage users in anticipating an ordinary bench. However, while the design of the coMotion bench attempts to adhere to the familiar ‘format’ of a bench, with regard to seating height and the length, it still differs from the look-and-feel of the average public bench in terms of the materials, as spandex and elastic is used, rather than the familiar hardwearing materials, such as wood, metal and concrete.

The behavior of the bench also aims to support people’s initial impression of it simply being an ordinary bench. The bench waits 30 seconds before it begins to alter its shape, allowing people to get seated, comfortable and thereby hopefully dispelling any doubts caused by the divergences from the prototypical bench in public spaces. Despite the attempts to design the coMotion bench in a way where it would blend into the different surroundings it was tested in, the design still caused people to be unsure about what to anticipate. The sense of uncertainty as to what to expect and whether it was a bench or not, was apparent in people’s recounts of their experiences, such as "In the beginning I was unsure whether one could sit on it or not" - [female, 50’s] and “I went off right away when it began to move. I thought, oh... this is not for seating” - [male, 60’s]. Another remarked “I thought, what is that for a monstrosity? And then I saw that it was plugged in, and then I thought, why was that? Could it do something or what?” - [female 70’s].

The uncertainty could also be observed in peoples’ actions. People often touched or poked the bench before sitting down, as if to test whether their assumption of it being a place to sit held true. In the shopping mall, the presence of other people on the bench in its static state, tended to attract more people to the bench. As if the fact that someone else was sitting on the bench helped with categorizing the structure as a bench, rather than something, which might be a bench, but that also might be something else.

Connecting: when sensation becomes emotional

Wright et al. [37] describe connecting, as the first sensuous impact of a situation, occurring as a pre-linguistic response, before we even begin giving meaning to the sensation. As such, connecting represents our immediate impression of for example a bench, and how this engenders a quick emotional response. We emphasize how connecting posits the unity of senses into an overall atmospheric experience situated in the contextual setting.

Due to the temporal aspect of the coMotion bench, two different experiences of connecting are created: one before

Figure 2. Making sense of the experience.

sufficiently by McCarthy and Wright’s framework. Despite that the framework is based heavily on pragmatist philosophy, which emphasises that knowledge is participative, felt and sensed [25], McCarthy and Wright somehow understate this in their six processes, placing the emphasis on the mental reasoning about the experience. Figure 2 presents a visual account of the sense making processes, and their interconnectedness, as we interpreted them in the context of the coMotion bench.
Session: Shape-Changing Interfaces

Initially, the thought that the bench would begin to move seemed inconceivable. However, if the occupants remained seated on the bench, then the initial sense of disbelief was dispelled, as the source of the sensation gradually became evident with the increasing inclination of the seat. A couple in their 30’s described the experience as: “we thought it was defiantly entertaining” - [male 30’s], “you were pretty annoyed when it just happened” - [female 30’s], “but, that was because I didn’t know what was happening” - [male 30’s]. The man continues: “We didn’t talk about it right away, I just had to comprehend what was going on ... is it the room or me? I thought that something was wrong here. The funny thing was I had a thought, isn’t something happening, and then I thought, nothing is happening we are just sitting on a bench. I actuarially thought that it was funny that even though the room seemed to change, then I thought it must be my head that something is wrong with, until it became obvious that it just was the bench that was moving” - [male, 30’s]. Other people similarly attributed the experienced sensation to themselves, a woman in her twenties said “initially I thought, I must be going crazy” - [female, 20’s]. However, the majority of people eventually attributed the sensation as being caused by the bench. Others did not remain seated long enough to rectify their initial interpretation of the sensation, as they left the bench rapidly, still believing the sensation to be attributed to something being wrong with themselves. A woman in the shopping mall left the bench in a hurry immediately after the bench began moving. The interviewing researcher caught up with her to ask her about her experience with the shape changing bench, which caused some confusion as she answered: “Was it the bench that moved? I have just had a virus causing balance disorder, and I thought it was flattering, I wanted to go home straight away” - [female, 60’s].

People who sought to interpret the sensation proposed a varied spectrum of interpretations based on the shape-change of the bench. Many of the occupants interpreted the movements as a warning notifying them that they were not allowed to sit there. A woman noted, “I thought I wasn’t allowed to sit on it” - [woman, 60’s], while another got up and looked at the bench after it moved, saying that “I had to see what it was for a thing, I had to see if I had sat down too hard and something was broken... Then I decided that the guard, which was passing by would scold me if I wasn’t allowed to sit here, but he just passed by, and then I thought it was okay to sit her” - [male, 70’s]. Others interpreted the movements as someone playing a trick on them: “at first I thought it was hidden camera, or some kind of joke, or something else (laughing)” - [male, 30’s].

We observed how people’s interpretations were often formed socially in a group, through discussing and recounting individual interpretations to the group.

and one after the shape change. Initially, as people seated themselves on the bench their senses were not subject to any unexpected experience, as they simply ‘connected’ with the common sensation of sitting down on any given bench. However, when the bench suddenly began to alter its shape, thus impacting on the occupant’s senses in an (for most people) unexpected way, it immediately gave rise to a range of experiences, ranging from fright, to confusion, surprise, dizziness, and amusement.

The recorded video-material from the three test-sites provides direct and unfiltered reactions to the unexpected occurrence of the bench beginning to alter its shape. Through the video analysis it became evident the bench’s shape-change was a bodily and often quite emotional experience People changed facial expressions, looked around, froze, stood up, walked away or even became afraid. A person said: “I think it was confusing. I sat quite comfortable, but when it moved, it was like an underlying feeling of unease suffused my body. I was scared that somebody would come up from behind” - [male, 50’s].

Connecting addresses how the user’s processes the bench experience from background awareness into focal attention. However, the shape change did not always cause the bench to be in focus. What was experienced as coMotion changed shape seems to be influenced by people’s bibliography as well as their momentarily emotional state when sitting down. To give an example a man in the airport said: “I just realized that I forgot my wallet and when the bench then moved, I felt unwell, like everything fell apart” - [male, 60’s]. Hence, his stressful mind seemed to influence his experience of the bench. In this situation, the bench’s movement amplified the embodied state he was in, rather than alter it to become something different.

People’s immediate reactions to the bench’s movements differed in the three contexts. People in the concert hall smiled and laughed more, and reacted more relaxed towards the intrusion of the unexpected movements. However, in the other two contexts, the sudden movement caused more people to feel a sense of alarm and to become uncomfortable. The deployments in the three contexts indicate that even our immediate response to sensations, including the unexpected ones, can be affected by the context in which it is experienced.

Interpreting: what just happened?
McCarthy and Wright [24] describe interpreting as giving meaning to an unfolding experience, discerning what has happened and what is likely to happen, as well as determining the possibilities for action.

Interpreting the immediate sensation, caused by the bench altering its shape, was not a straightforward task for the occupants of the bench, as the initial sensation was often met with a sense of disbelief. Occupants on the bench often attributed the initial sensation, as something being wrong with themselves, rather than attributing it to the bench.
Exploring: making sense through action

When surveying the sense making strategies and processes that people employed when attempting to make sense of the coMotion bench, a number of instances of peoples’ actions and experiences did not seem to fit into the six sense making processes proposed by McCarthy and Wright [24]. What we term exploring, refers to the process of making sense through bodily action and engagement. This involves sensing the material and the physical resistance of the object, moving around it, and by trying to bodily approach it in different ways, e.g. lying on the bench, sitting on it, standing beside it. Exploring also holds a social aspect to it, as the physical exploration primarily happened when people were in pairs or groups. However, the exploration in some cases went outside the predefined groups. For a short while, two groups could for example, explore the bench together. An example of this is in the music hall where two pairs (two girl friends in their 20’s and a couple in their 50’s), together stated to joke and laugh about the bench after it had started to move. After a while four all people got up from the bench to look at it, before eventually sitting down on it again. The exploration also became social in the sense that people tried to physically explore it with others, to see how it would change when there is more than one person on it, when sitting close and far apart etc.

The abovementioned actions cannot be categorized as either interpreting or reflecting, but instead as trying to make sense through exploration and by sensing it.

Reflecting: What is the meaning of this?

McCarthy and Wright [24] describe reflecting as a sense making process, which can happen either in an experience or as reflection on an experience after it has run its course. Reflecting hence deals with the judgments made about an experience as it unfolds and whether a person can make sense of it. Reflection also deals with how a person feels about the situation and what value is placed on the experience. Reflecting often takes the form of a dialogue, either with oneself or with others.

Peoples’ reflections on their experience with the coMotion bench, was generally wrought with confusion, curiosity, amusement, or even annoyance. The three locations seemed to influence how people felt about the situation. In the concert hall people had prepared themselves for entertainment, which seemed to affect their experience of the bench, reflected in statements such as: “At one point we stood up; it was as if the ride was over” - [couple, 40’s]. Whereas the reflections in the airport seemed more influenced by the heighten sense of alertness, for example caused by entering through the security check and the stress of travelling.

The reflections recounted in the interviews, were mainly focused on reflecting upon why the bench acted in such an unordinary way. A dialogue between two friends was observed: as one of the two friends arrived back to the bench from a visit to the toilet, the other said “I really don’t know what’s happening, all of a sudden it just stood up (…) It is really a very odd chair” (she looks frustrated). An airport security guard passes by the bench, and one of the men asks “Do you know what this is?” to which the guard answers “No, I have never seen it before” and moves on. The girl replies back to the guard “It is moving, you know”. When approached by the researches, one of the women immediately asked: “What is the meaning of this? (…) We have just been sitting and discussing what it was that we were sitting on. And we agreed that it must be a work of art. We really want to know what the meaning of it is” - [female, 20’s & 30’s]. Although many of the occupants on the bench reflected upon their interpretation of the bench behaviour, and it’s seemingly unwillingness to have people seated on it. Few sought to provide an explanation for the bench’s odd behaviour. One reflected upon this as: “...the idea could be that it was a clever way to say that you can rest here for a few minutes, but then you have to move on” - [male, 40s]. Others pointed to that “it could be a preparation for going flying. You know elderly people who have to sit in a plane for a long time, might benefit from a bit of exercise to get the blood circulation started” - [female, 30’s]. Some users also reflected upon the social situation created by the bench. One user pointed to wishing he had been seated the other way round on the bench, as he thought that, as the bench moved, he was sitting a little too close to the other occupants on the bench.

Although the bench had been designed to spark social encounters between strangers, only a few of the interviewed occupants reflected upon this. When asked about what the bench was designed for, one answered that: “It could also just be furniture designed for exploring encounters between people” - [male, 40s]. However, although people tended not to reflect upon the ability of the bench to foster social encounters, this often happened. The alteration in shape did often spark encounters between strangers as they sought to make sense of the experience. The encounter was generally initiated as means to seek confirmation that the bench, rather unexpectedly, was moving. This was done either simply by a movement of the head, flicker of the eyes, a smile, or a comment spoken out to the other occupants on the bench. As one of the men explained in the interview: “[…] the other man said to me; I think it is moving” - [male 60’s]. Another person said: “Indeed, we talked about what was happening; it was not that we talked about anything else than the bench, but we talked with all the others while sitting there” - [male, 50’s].

Appropriating: How does it become mine?

McCarthy and Wright [24] describe appropriating as making an experience our own, by relating it to both previous and future experiences and thereby giving the experience a more personal meaning to us.

Users appropriated the movements, the design and the unexpected occurrence of technology to their prior experiences. Especially in the deployment in the airport.
context, users related the coMotion bench to their previous experiences. In the airport the design caused people to relate it to different aspects of transportation, “the elastics refer to the seatbelt, something about being fastened down” - [female, 30’s], she further remarked that “The first thing I think of is that I am going flying. And the bench kind of refer to spreading our wings and taking off”. Another person also related it to the context “It has an aviation feel about it…” - [male, 40s]. In the concert hall a woman noted that that the bench reminds her of an experience being at a toilet in Japan that unexpectedly flushed upwards with water, played music and had a vibrating seat, which caused her to stand up to get a good look at what was happening - [female 60+]. For others it was rather the movement that sparked their memory, “it reminds me of a massage chair” - [female, 20’s] or the effect of the movement, which made them relate the coMotion experience to other experiences: “I started thinking about that I visited my neighbour last night, and he was suddenly saying that he felt dizzy... he is only 40-45 years old, and then he suddenly fell down. And then I thought, am I experiencing the same?” - [female, 60s].

Recounting: guess what I just experienced

McCarthy and Wright [24] describe recounting as being essentially dialogical, as the experience is recounted to ourselves and others. Recounting the experience enable us to savor the experience again, discover new possibilities and new meanings. As the experience is recounted it can be altered depending on the situation and the moment-to-moment response from others. When recounting an experience to others, we draw out their responses, which might in turn alter our own assessment of an experience.

The information used to recount the users’ experience with the coMotion bench in the previous sections, is based both on what is observable in the video, as well at people’s recounts of how they experienced the bench altering its shape underneath them. Therefore it is important to note that the majority of the quotes used in the sections above are derived from people recounting their experience. What has been recounted to the interviewer may thus not always be what was interpreted or reflected upon in the experience, but may be altered by new meanings and interpretations formed as the experience was recounted. Consequently, it is difficult to separate the “sense made” in the other sense making processes, from insights users gained during recounting their experiences. However, what seemed clear was that the questions asked during the interviews, led the users to a deeper reflection about the preceding experience.

What was interesting to note was that when users were presented with the opportunity to recount their experience to people, who had not yet experienced the unexpected movements of the bench, they often chose not to recount it. These instances often occurred when people had experienced the bench changing shape on their own, while waiting for friends or relatives. Users in this type of situation generally attempted to keep it quiet, seeing it as an opportunity for a good joke, where they were in on the prank while the others were not.

DISCUSSION

The coMotion bench exemplifies how shape-changing technologies can, in their static state, weave themselves almost imperceptible into the fabric of everyday life. However, people’s interaction with the coMotion bench illustrates that the occurrence of movement is drastically and unexpected. The bench’s transition from static to a dynamic object is not smooth, despite the slowness of the movement. The surprise, or even chock, caused by the transforming action of the bench becomes amplified when physically felt or experienced, rather than seen at a distance.

The deployment of the coMotion bench into everyday life settings illustrates that shape-changing technologies embedded in everyday life poses a number of challenges for the user, especially when the shape-changing capabilities are hidden. As the hidden shape-changing capabilities are revealed, objects that formerly were part of the background awareness, can suddenly force themselves into the foreground of peoples attention. Our work raises the question of, if we are to embed shape-changing capabilities imperceptibility into objects, then how do we deal with, for example: 1) changing affordances in shape-changing interfaces, 2) their transition from background to foreground and 3) user interpretation of shape-changing interfaces? We will now discuss perspectives that emerged from our early investigation of the abovementioned three topics. Hopefully this work will help to initiate a debate and provide questions for future work on shape-changing interfaces.

Affordance of shape-changing interfaces

Affordance has, since Gibson [9] coined the term and Norman [25] introduced it to the HCI community, been widely used by for example computer scientists, designers and psychologists. Gibson [9] defines affordance as the actionable properties between the world and an actor. Norman in turn described affordances as the “perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used” - [27, p.8].

The notion of affordances [9,25], and more specifically the potential for dynamic affordances has been widely mentioned within shape-changing research (e.g. [5,23,30]). Affordance, and especially dynamic affordances, has been used to boast about the potentials shape change hold, such as: “learn to adapt to their different conditions of use and respond with just-in-time affordances” - [5, p.3433], and “in the case of shape-shifting materials these affordances exist over time, but not statically” - [24, p.38]. However, despite the numerous references to affordances within shape-changing research, few use it to analyze their designs’ or reflect on the users’ ability to understand dynamic affordances. Shape-changing interfaces
appropriate affordances in two ways; static and dynamic. Static refer to the static physical properties indicating an artifact’s action possibilities and shape changing capabilities. Dynamic refer to the physical shape change indicating altered action possibilities or information embedded in the kinetic change itself.

In its static state, the coMotion bench affords ‘sitting’, and other uses of an everyday sturdy bench, such as ‘laying down on top of it’ or ‘placing a heavy bag on it’, all of which action that we observed performed on the bench. CoMotion deliberately does not provide the users with perceptual information about its shape-changing capabilities. Possible affordances that the bench can demonstrate through changing its shape are at this stage (and in Gaver’s terminology [8]) hidden. As the bench begins to alter its shape, a user’s original interpretation (i.e. based on the actions afforded by the static shape) is challenged. The bench no longer has a horizontal seating surface and the height of the bench no longer matches the length of the occupants’ legs. If the bench initially had this non-horizontal form, it would not have afforded ‘sitting’. However, the majority of people remained seated after the transformation from the horizontal to the ‘cracked up’ or non-horizontal state, despite the uncomfortable seating position. At this point however, few people sat down on the bench, and those who did, either knew people sitting on the bench, or had observed the shape-change at distance.

The shape-changing capability of coMotion hence challenge the idea that the desired, relevant actions should be readily perceivable in a design [26]. In some cases it is in the discrepancy between the perceptual information provided to the user, and the actual capabilities, wherein the quality of the design lie, as it can be a source of engagement, curiosity and appropriation. However, as also pointed out by Jung et al. [16], if it is not the intention to surprise users, then designers should provide predictable cues, such as structural appearance or sound, which allow users to naturally foresee upcoming events. Having said this, designers must be mindful of, as seen in the case of coMotion that although some indicators (material and cord) provided the user with indicators of the bench’s shape-changing possibilities, this was often not enough information for people to comprehend the capabilities of the bench. Furthermore, if movement had been used to indicate that the bench could change shape, then people might not have considered it to be a bench in the first place.

Consequently, providing cues of shape changing capabilities is not straightforward, especially when dealing with shape-changing furniture, as the change will often be felt, rather than seen. It raises the question of whether we need to define a new visual language to communicate shape-changing capabilities within consumer products, and common spaces to make people aware of such capabilities and their functions? How can we employ the notion of affordances to emphasize desired affordances and re-emphasize undesired ones [8]?

Transitions between background and foreground

The coMotion bench challenges the paradigm of the invisible computer and allows for exploring the experiential aspects of the ubiquitous vision in peoples’ everyday lives. Building upon Weiser and Brown’s notion of Calm Technology; “a calming technology may be one that easily moves from center to periphery and back” - [37, p.2], we address some ethical issues on the sense making of shape changing interfaces disturbing the calming effect.

Indeed, when people approach coMotion they are unaware that they are about to interact with a technology-augmented bench. Upon sitting down, the bench is generally positioned in peoples’ background awareness as they are “only sitting on a common bench”. However, when coMotion begins to move it immediately shift into people’s focal attention. Instead of designing for calm transitions between background awareness and foreground attention, we accentuate the transitions, which promptly lead to strong emotional responses. From the field tests we observed how people tried to make sense out of a confusing situation, and how the experience influenced body posture, as it for example caused users to imitating each other’s posture (both consciously and non-consciously) as a way to cope with the unknown.

Within the interaction design community, researchers have presented different perspectives on dealing with the transitions between background and foreground attention. With few exceptions (e.g. [32]), there seems to be a general tendency towards designing for calming effects. We elaborate upon Kinch and Hoejlund [21] who describe how the concept of ‘embodied habituation’ helps designers to gradually and through repetitive actions accentuate the users background awareness to accomplish a given task. This is fruitful when for example designing for a stressful situation [ibid]. We acknowledge that the consequences of hiding the shape-changing capabilities in the coMotion bench, is an obstruction of the embodied habituation process. However, we will in the following turn towards some neglected potentials and experiential qualities of shifting peoples’ collective mindset within a fraction of a second.

Derived from soundscape research, Augoyard and Torgue [1] propose a range of ‘sonic effects’ to articulate how to design for sonic experiences, which changes over time. To address peoples’ unexpected experience of sitting on the coMotion bench, we point towards their proposed ‘cut-out effect’ that “punctuates movement from one ambiance to another” - [1, p29]. The ‘cut-out effect’ is best explained through an anecdote of a broken glass; “Suspected for a moment, the murmurs of the hall resume. The timbre and rhythm change. People come back to tell their stories. We can feel the warmth of the place rising again. A consensus has been found again, as if the cards had been re-dealt” - [1, p.158]. The quote points towards how collective shifts in
awareness are incorporated in everyday life, thus we emphasize that transitions from background to foreground attention not only exist as calming, habituation processes [21], but may also be disrupted, leading to dis-habituation. Habituation and dis-habituation are both natural processes, which are mutually dependent on each other. When we design for dis-habituation, we propose that manipulating people’s collective awareness scaffolds new types of experiences, which exists in the realm of the shifting from background to foreground awareness. Designing for intersubjective and atmospheric experiences can foster social encounters, as illustrated by the coMotion bench [20]. However, social encounters are shaped differently according to the interaction modality, thus sound and visuals have other socializing effects [30], than the haptic modality investigated in this paper. The haptic sensation is one reason why people initially point towards the shape-change as something happening within them (i.e. a bodily experience). Consequently, the dis-habituation is reserved for those who are physically affected by the shape change.

**Interpreting physically dynamic objects**

Classic psychology experiments, for example by Heider and Simmel [12] and Scholl and Tremoulet [34], have illustrated how people tend to attribute motivations, intentions, and goals to individual rigid objects, based solely on the pattern of their movements. These studies show how proficient people are in detecting movements and deriving meanings from them.

The application of anthropomorphic or zoomorphic movement patterns has been used to design product movement patterns, and has had some success in getting people to interpret the intentions of the product movement (e.g. [15,16,17]). However, the movements of the coMotion bench did not lean on anthropomorphic or zoomorphic movement patterns, as has been a common approach when designing shape-changing interfaces. Rather than seeking to portray emotion or postures through form change and movements, the bench’s shape change relied on the haptic effect on its occupants, caused by the altered angle of the seats. Consequently, people’s interpretations focused on why the bench moved, such as: “I thought I wasn’t allowed to sit on it”, or “…to say that you can rest here for a few minutes, but then you have to move on”, rather than the character of the movement itself. This might be due to the lack of anthropomorphization of the movements, or that users’ interpretation of the shape-change used in coMotion often relied more on interpreting the haptic sensation, rather than on visual information. Although users’ reflections on the bench indicated that they did not personify the bench, as is often the case with shape-changing interfaces, they still often patted the bench or stroked it when it moved.

A parameter, which other studies of motion (e.g. [15,16,17]) have not taken into account, is the influence of context on people’s interpretation of the shape change. The coMotion study indicated that people’s interpretation was not only affected by the movement itself, but was affected by the context, the seated people’s present activity and their emotional state. We wish to stress the importance of considering how the test-context influences the interpretation of a shape-changing artefact, and that a lab where (any) technology is tested is not a neutral place, but influences how people respond and interpret shape change.

**CONCLUSION**

In order to fully exploit the potential of shape-changing interfaces, we need to study how they are experienced and adopted by people in real life and “in the wild”. The presented study reports on lessons learnt from 129 people’s encounter with a shape-changing bench in three different contexts. One lesson indicates that the coMotion bench promotes strong emotional responses, both positive and negative, which advocates the importance to ‘debrief’ people after their first encounter with coMotion. Another lesson indicates that designers of future shape-changing interfaces must be aware of both the mental and bodily effects shape-change may have on people.

The paper applies and develops McCarthy and Wright’s framework for Making Sense of Experience to analyse and discuss people’s experiences with the shape-changing bench. The authors found that the six sense making processes, as described by McCarthy and Wright worked well for this purpose. However, to complement the existing framework, this paper also introduced exploring as a seventh sense making process. Applying the seven processes, points to for example that aspects of affordances are critical to consider when designing shape-changing interfaces. Therefore, there might have to be developed a new visual language to assist people to comprehend and effectively use shape-changing artefacts. We illustrate how the context is highly influential upon how people interpret the meaning of shape-changing objects. With this work, we are only beginning to understand how shape-changing interfaces are experienced out there “in the wild” and we encourage the CHI community to help us further explore the issues outlined and discussed in this paper.

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