From Hand-Held to Body-Worn:
Embodied Experiences of the Design and Use of a Wearable Movement-Based Interaction Concept

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ABSTRACT

This paper argues that movement-based interaction should be designed from a non-technological, people-centered point of view in order to create embodied and engaging interaction experiences. Further, it discusses social and contextual aspects that need to be taken into account when designing for movement-based interaction. The paper presents the design process and user explorations of a wearable movement-based interaction concept that was created in order to explore full-body movement as interaction modality. The starting point was taken in people's own experiences of communication and interaction through bodily movements, inspired by methods and theories used within modern dance. As design guidelines for the prototyped interaction concept we used aspects on movement that were directly derived from field studies of physical expression. The user explorations of the concept show preliminary examples of how people engage in movement-based interaction and how they are affected by the social interaction context.

Author Keywords

Movement quality, movement-based interaction, kinesthetics, wearable artifacts, embodied interaction, social context of use.

ACM Classification Keywords

H.5.2 User Interfaces

INTRODUCTION

Human computer interaction (HCI) has from its beginning mainly regarded desktop environments and work related studies. Due to the rapid development of small, integrated processors, computers can today be embedded into traditional everyday objects. Therefore, computational artifacts come in all kinds of shapes, forms and appearances, physical and concrete as well as invisible and ubiquitous. Today, we use digital objects in various contexts and situations both at work, at home and at leisure time. Consequently, the HCI research has experienced a broadening of its field to even include leisure activities as well as the seamless transition between work and leisure.

To take into account the socio-cultural context in which the use takes place and in which the user acts is no longer a new approach. However, we still need a deeper understanding of how exactly, the user, the context and the artifact affect each other. Hence, there is an increasing interest in exploring new focus areas of computing and interaction, e.g. emotional, embodied, esthetic, physical, pervasive, ubiquitous, tangible, etc.

As part of the new focus areas of computing, we might need to develop novel interactions forms and metaphors for different contexts. This includes considering what kind of physical as well as cognitive interaction we want to design for. Hence, in order to create people-centered conditions for human-computer interaction we need to look for new interaction forms that go beyond button pressing, mouse clicking or touch screens. This paper aims at contributing to the knowledge of such an emerging interaction form, namely movement-based interaction.

MOVEMENT INTERACTION

Human bodily movement is a subtle and expressive means for communication and interaction. As long as mankind has existed, people have used their body language, more or less consciously, as a tool for negotiation, clarification or persuasion. The subtlety and complexity of human movement, and thus the potential of misinterpretations and confusing commands, might be one of the reasons for the previous lack of physical, bodily presence in HCI.

It is often claimed that increased physicality enriches the user experience. But, there is still a need for a greater

understanding and exploration of why this applies [9]. During the last years we have seen an increasing interest in movement-based interaction within HCI. Unfortunately, most of the approaches taken have been technology-driven, meaning that it is the technological abilities that define the applications and interaction designs.

However, within the growing interdisciplinary community of HCI, we can also find approaches to human movement that are not only technology-based, but rather inspired by e.g. anthropology or fashion design [10]. To go beyond the technological aspects of human movement as interaction modality is an important step in striving towards intuitive, engaging, natural and usable applications.

This paper takes another step in the non-technological direction through introducing modern dance as an area that has a strong and deep knowledge of bodily expressiveness and human movement as a communicative device. It is now time to bring this theoretical and methodological knowledge into the fields of HCI and interaction design.

Kinesthetic Movement Interaction (KMI)
In this paper we are looking at what we call Full-Body Interaction or Kinesthetic Movement Interaction (KMI), which means that the whole body could (although not have to) be involved in the interaction. The reference to the term kinesthetic originates in our emphasis on the human kinesthetic sense as an important and necessary part of the ability to sense and experience our own movements.

Full-body KMI differs from movement-based hand-held interfaces e.g. input devices such as the PHANTOM haptic device [14]. With these devices the movement interaction space consists of a predefined physical space. Further, the movement interaction is created using the hand only or another specified part of the body.

Another category of movement-based interfaces that differs slightly from this paper's area of interest is full-body applications such as video games using the EyeToy™ [6], or different versions of the music video game Dance Dance Revolution [5]. In these applications, the user is depending on screen-based visual output in order to get feedback from the system. The screen locks the user to a certain interaction direction focus, i.e. forward, which also delimits the possible variety of movements, e.g. movements including turns. Further, it directs the user's focus towards something outside of her immediate physical surrounding, i.e. away from the body. Although sometimes portable, these systems are often location-based, meaning they cannot be considered as mobile or wearable objects.

Further, applying the framework of expected, sensed and desirable movements suggested by Benford et al [1], one finds that the desirable and expected movements that are required for a successful interaction with a movement-based system such as the EyeToy™, are defined and limited by the system itself [9]. Consequently, the user needs to learn or adopt a specific movement pattern or imitate

predefined movements for obtaining a successful interaction. This does not mean that free or expressive movements are not allowed or even sensed in these systems. They are both sensed and allowed, but they will not be effectual in the meaning of being useful to communicate or interact with the system.

Even though it might be difficult to learn a certain movement pattern or movement command language, these movements engage the whole body in the interaction and thus create a full-body sensible, physical and engaging user experience. However, we would like to see further development of such interfaces where we even design for the rich expressivity that can be found in human movement. But do we have the right tools for doing this? In this paper we have chosen to look for new inspiration within modern dance.

MODERN DANCE AS MOVEMENT INTERACTION
This paper's results originate from a project that aimed at exploring human full-body movement as interaction modality [11]. In order to obtain a people-centered basis that could inform movement-based interaction design, we chose modern and contemporary dance (modern dance for short) as the area in which to search for new inspiration [12].

Modern dance as approach was chosen for several reasons. Firstly, it provides an existing vocabulary for describing movement, as well as its quality and experience that are based in physical experiences and in an experiential body of knowledge [3]. Secondly, modern dance encourages personal style and individual preferences [2]. And thirdly, modern dance is concerned with finding the essence of a movement, and expressing the movement rather than the form [7]. It is what happens between the fixed forms and poses that create the dance, and thus the meaning. Modern dance is therefore about creating and communicating meaning through human movement.

In order to obtain an experiential body of knowledge on human movement, one needs to physically explore human movement oneself. Nearly all people have physical and bodily memories, but not everybody has the vocabulary to express these experiences. However, after having physically experienced a concept, people will also be able to recognize its verbalized description. Since the bodily knowledge is obtained on an intuitive level, verbalization of the own or other's experiences through discussions or readings extends the knowledge from an intuitive to a conscious level [3].

Creating the Meaning of Movement
Below, we present five notions discussed by Blom and Chaplin [3] that describe different aspects of human movement and how they contribute to creating the sense of movement expressions: kinesthetic awareness, phrasing, forming, relating, and abstracting.

Kinesthetic awareness

Developing a kinesthetic awareness implies training to feel differences in movements, to increase the sensibility for the knowledge that is already there within the body, i.e. the body's knowledge of its own movement. This could also be described as bodily knowledge or to trust the bodily memory. Kinesthetic awareness is related to the potential to move and the movement ability, to be able to feel your own limitations and possibilities.

Phrasing

All movement contains rhythms and phrases that provide "the magic ingredient" in any of the performing arts. However, the rhythm is not solely bound to music. It can exist within the movement itself, or reflect an inner pulse of the dancer. Movement phrases will also vary in length and shape, according to their context. Phrasing could be described as a way of grouping movements.

Forming

People create forms or patterns in order to create meaning. The potential of the form lies therefore in its ability to organize pure movements so they make sense to the mover and viewers. It is due to the form that one can distinguish dance from a mere collection of steps. The form in dance has its analogy with form in music. One can for example make use of repetitions or distinctive beginnings and ends.

Relating

We need to develop a sense of self, a moving self, before we can relate to others' movement. We need to learn to know our own movement patterns and preferences of movement quality. Through movement we can then express and feel kinesthetic empathy, how something is experienced through movement. When we work in groups we are given new movement possibilities, as we may do things that are impossible to do alone. Through experiencing other people's movement, we also may gain an increased understanding for that person as well as ourselves.

Abstracting

Abstracting means to deal more and more with the essence of an experience. When abstracting a movement we might eliminate its literate meaning and rather explore and manipulate the movement per se in order to find out what it is about. At higher levels of abstraction we are no longer dealing with the cognitive meaning of the movement. Purely abstract movements differ from the most abstracted ones, as they refer to nothing and are self-sufficient.

Movement Quality and Movement Elements

The quality of a material can be described as the material's physical properties as well as its characteristics. A physical property could be weight, volume, size, etc, while characteristics could be qualities such as color, i.e. something that separates or groups one object in relation to others.

Similarly, in dance, the notion of movement quality is used to describe and separate different movements, their expression as well as feeling. The qualities of a movement can be defined as "the distinctly observable attributes or characteristics produced by dynamics and made manifest in movement" [2]. Hence, as with any other design object, when we talk about human movement as design material, we need to be able to describe which movement qualities we look for.

Time – Space – Force

Time, space and force (also called energy) are three interdependent movement elements that are used to describe and shape the movement quality. The dancer, choreographer and movement theorist Rudolf Laban has rigorously described these movement elements in several books, although using a slightly different vocabulary, i.e. time, space, weight and flow. Laban characterizes the movement elements through describing their opposite extremes: fast-slow for time; near-far for space; weak-strong for weight; and bound-released for flow.

The quality of a movement can be changed through varying the different movement elements. For example, a given movement, reaching out the hand, can be performed fast or slowly, i.e. changing the time. This will affect the force or energy one has to apply in order to perform the movement. It will also affect the size of the movement, and thus the amount of space that the movement takes up. Changing the quality of a movement will not only change how the movement looks from the outside, but also how it feels for the person performing it. Consequently, the movement quality affects both the mover and the observer.

Since human movement are a physical and mechanical matter, we need to consider the size and mechanics of the body parts as well as the influence of physical forces such as gravity. Human beings come in various sizes and shapes with different physical abilities. Hence, different people will be able to perform and experience the same movement very differently. Each individual has therefore certain movement qualities that he or she prefers and that correspond to his or her physical body and bodily training or schooling.

DESIGNING FOR THE PLEASURE OF MOTION

As already mentioned, this paper presents the design process that resulted in a wearable movement-based interaction concept. The aim of the project was to explore human movement as design material and interaction modality.

The design process started with a 15-week long field study that created the basis for our design criteria. During the following implementation phase, the concept was further developed and specified.

Field Study of Movement Explorers

As part of the field study we interviewed and observed nine persons attending an evening course in improvisation and composition based on modern dance [8]. The aim of the study was to obtain self-experienced aspects of human movement that could guide our movement-based interaction design. The course was called Physical Expression and contained exercises that rigorously worked through the previously mentioned notions of kinesthetic awareness, phrasing, forming, relating, and abstracting, as well as movement quality and the time-space-force relationships. Most of the course participants did not have any previous experience of modern dance.

Three in-depth interviews were carried out with each participant before, in the middle and after the dance course. During the course they were also encouraged to reflect upon and formulate their physical experiences through written diaries.

Personal Movement Experiences

One of the most common experiences from the course was that the work had been very fun and self-developing. The participants had been able to perform movements that they thought their bodies were not capable of. They had also overcome their fear of moving and presenting new material, i.e. doing self-revealing activities, in front of others

Through experiencing other people's movement, the participants had gained an increased knowledge of how differently people interpret, phrase and form movements, as well as create meaning through movement. They had also learned to identify their own preferable movement patterns and movement qualities. Hence, they hade increased their kinesthetic awareness.

One of the participants expressed it like this: "It's only the feeling that guides you. And when I feel that the movements suit my body, and when they flow through […] You have this idea, that it's only the little petit girl that can dance so nicely. And that's why it's so cool that it can feel beautiful, even if I think it's far between my fingers and toes." Similarly, the participants described movements that suited their bodies and that they performed without "thinking" as natural movement, or that the movements felt natural. Consequently, one given movement did not feel natural to all participants.

Movement-Based Design Criteria

From the field study we identified several aspects or categories of human movement that were relevant to interaction design. Based on these aspects we deduced the design criteria for the movement qualities of our interaction concept. The categories concerned the physical interaction space, i.e. near the body; what kind of movement to use, i.e. natural; how movement can be initiated, i.e. through impulses; communication, i.e. movement is expressive and impressive; and why movement should be used, i.e.

Movement Aspect	Movement-Based Design Criteria
The personal interaction space	• Three dimensional interaction space • Mobile user-defined interaction space • Tangible interaction near the body • Independency of visual or audio output
Natural movements	• Support free, explorative movements • Support individual preferences
Movement impulses	• Create movement that trigger movement • Use the kinesthetic sense • No specified "correct" or "incorrect" use, no "punishments" are given
Movement as impression and expression	• All kinds of movements make sense in relation to possible input/output • Individually and collaboratively use • Movement dialogue
Movement is fun!	• Movement for the sake of movement

Table 1: Corresponding movement aspects and design criteria

movement is fun! The various aspects and their corresponding design criteria are summarized in Table 1.

We also had a few predefined design criteria for the artifact that was given in order to delimit the possible design space. We wanted to create a small wearable device that was an independent artifact and could be considered as an everyday object, e.g. "something to carry with you when and where ever you wanted", or "a personal movement object".

When designing the movement interaction, our focus was towards involving the body as a whole in the interaction (cf. the notion of KMI presented earlier), i.e. not focusing on specific body parts. On the other hand, we consciously aimed at developing interaction where the hands were not considered as the main tool for input. Consequently, the work resulted in a concept that was not based on button pressing and that was possible to wear on the body, rather than be held in the hands. Further, we wanted to focus on movement as interaction modality and therefore make use of physical movement as the only form of output, and thus excluding graphics or audio displays.

The Prototype BodyBug

The resulting movement-based interaction concept was called BodyBug. It consists of a small box (approximately 4x5x6 cm) running on a plastic covered wire, like a pearl on a thread (see Figure 1). The box contains all mechanical and electronic devices that make the box able to climb up and down, or stay still, on the wire.

At each end of the wire there is a Velcro-strap than can be used to attach BodyBug onto the body parts of your choice. The box has one button that is used to shut the electronics on or off. BodyBug can therefore be worn or used in various and personalized ways, it can be jewelry or a fashion object, a smart dance partner, a personal moving pet, a computer game, or a movement toy comparable to an electronic yo-yo or hula-hoop.

Figure 1: The prototype BodyBug

When BodyBug is worn and switched on, its movement sensor (an accelerometer) senses the wearer's changes in movement. Depending on the input, BodyBug starts to move along the wire for a set time or distance. How BodyBug react to or interpret the user's movements can be reprogrammed, e.g. how sensitive it is, its moving speed, direction or distance.

Because BodyBug is worn and attached to the user's body, it is able to sense a wide range of natural or spontaneous movements that the user perform, e.g. regularly walk, jumping up and down, dance moves, etc. However, in order to make BodyBug move in a certain direction, the user needs to figure out how to move, and this exploration will potentially create new or undefined movements. The aim is to let the user focus on BodyBug's movements instead of her or his own and thus let go of the regularly self-censured movement behavior.

EXPLORING A MOVEMENT-BASED CONCEPT

The BodyBug prototype was implemented as a research prototype aiming at providing us with more knowledge of how kinesthetic movement interaction is experienced when explored. Due to technical difficulties with the prototype, we have not been able to carry out formal experimental user studies. However, we have presented and demonstrated the concept at four different events: a design conference [13]; an Open House day at the technical university; an exhibition at an applied IT research conference; and an Open Session at an international HCI-related conference (see Figure 2). Despite the qualitative and tentative data, these experiences gave us preliminary results of how the use of BodyBug is experienced, as well as indications of how to explore the interaction concept further.

The results presented in this section, are based on qualitative observations of people interacting with BodyBug, informal discussions with the users, and four people's written descriptions of how they experienced the exploration of BodyBug. The texts were collected four to six weeks after the actual try-out and consequently they

Figure 2: Exploration of BodyBug

also reflect the users' memories of the interaction, which might have been further elaborated since the time of exploration. The four try-outs were carried out at the same occasion and with the same condition of the device.

Movement Experiences and Observations

Our main experience from watching several people using BodyBug was how differently people moved. We observed all aspects from big, violent movements taking up large physical spaces, to people standing still just moving one body part. One elderly man held the straps in his hand and danced with the device as if it was a ballroom dance partner. Some people did not move at all as they tried to physically sense what was going on. One person attached the Velcro-straps around his head and said "I don't feel anything."

A typical observation however, was that people engaged their whole bodies in the interaction. Even when the focus was on moving one specific body part, one could see that this activity affected the rest of the body. There was also a difference in whether people had their focus towards the artifact, i.e. the case, and if or how it moved, or if the focus was towards themselves, their body and how they moved.

When describing the movements, both their own and the device's movements, the users referred to a variety of different movement qualities. They used words such as "move more", "graceful", "elegant", "constant, repeated,

jerky movement", "variety and gentleness", "smoothly", or "less fluent".

One user expressed that the interaction made her more aware of spatial aspects and how her movements created an interaction space while interacting. She became aware of her body's spatial existence rather than just her physical body: "In some ways it made me more aware of the space around me: 'my bag' of space if you like, rather than just more aware of the fleshy me."

In some cases it was obvious that people were interacting after the principle the more given input, the more expected output. If they did not experience any feedback, they started to move even more exaggerating. Most often this did not generate any more output, due to how the device was programmed. For others, the movement output seemed to be quite surprising even when they had been told that the case was going to move when they moved.

Those users, who succeeded in finding a suitable movement pattern between BodyBug and themselves, were quite careful in their movements and "listened" to the device with their whole body. One person expressed it as "You try to encourage it by doing specific things. And when I get some feedback on something, I do more of that."

One of the main concerns for all movers was the relationship to other people and other people's possible reaction to their movement behavior. They wondered if they were "good enough" or if they interacted with BodyBug as it was intended. The movers also felt a bit silly or kind of stared at. They became aware of their own movements through their awareness of the spectators: "I was quite engrossed in the bug. But the audience made me more aware and uncomfortable of my own movements as I thought I looked a bit silly."

However, despite the initial feeling of embarrassment, after a short while the users got quite involved with BodyBug, and they forgot about the surroundings. They moved spontaneously and explored the interaction concepts according to their own movement possibilities and conceptions of how BodyBug could be used: "I had to explore to find out [how to make it move] – so it encouraged me to move in new ways."

Interacting with a Moving Device
As BodyBug is a quite small, mobile and anonymous object it tends to kind of disappear in relation to applications consisting of large screens and displays. BodyBug does neither resemble a well-known device and most people are therefore rather blank on what to expect of the interaction. However, when demonstrating the concept, only a few explaining comments are sufficient in order to make people come up with their own understanding of what it is and what it is about. It becomes very obvious that the concept needs to be tried out in order to get an experiential understanding for what it is or can be.

During the try-outs we received comments that BodyBug looked boring and dull, and surely not like something you want to have close to the body. People also expressed their wishes for more feedback from the device, such as lights or sounds. However, despite the anonymous look of the device, people referred to BodyBug as is if it was a living creature, probably due to its ability to move: "I thought of it like a pigeon."

The users described the BodyBug interaction as interesting and encouraging, despite some technical problems: "…something was obviously wrong with it, like a defect clutch in a car. Still though, it was intriguing, somehow challenging. Can I make it go the way I want it to or does it have a mind of its own?" Most people who experienced the prototype were first time users. However, during the same event, several people came back and wanted another try. Some users felt that they had "succeeded" the first time and wanted to see if it could work again. Others felt they wanted "revenge" on the device or at least a second chance, since they had not been so successful in their first try. It was obvious that the concept created an interest in exploring it further: "I already knew quite a lot about BodyBug, but still I caught myself thinking in terms of 'if I do like this, what will happen and why?'"

Further Development and Evaluations
In order to create engaging, intuitive and fun interaction experiences, further development of movement-based interaction concepts should try to increase the focus on varying the different movement related concepts of the interaction, e.g. time, space, force. Using BodyBug as example, this means to elaborate with the speed of the case's movement along the wire, the time it moves, the amount of movement you have to create in order to make it move, etc.

In many devices today, the output aims at focusing the user's attention towards the device by the help of sound or light. This is not the case with BodyBug as it requires another kind of bodily awareness in order to take part of the output, i.e. awareness of its physical movement. The movement output provided might be described as subtle and small. On the other hand, to some extent programming the device differently could change the characteristics of movement input and output.

In the future it would be interesting to study more in detail how people interact with a device such as BodyBug. How do different movement qualities of the output affect the input, i.e. what kind of movements does it create? How does movement-based interaction influence people's experience of their own body and presence in the physical space? In the next section we will discuss some of the social aspects one need to take into account when using movement as design material.

MOVING IN A SOCIAL CONTEXT AND SPACE

When aiming at creating or encouraging movement we need to find motivations for people to move. People in general can have tangible as well as intangible aims and intentions for moving. However, in order to start moving one need something that encourages movement in the first place. Such movement-triggers could be visual or audio cues as well as physical manipulations. A visual cue can be other people's movements and actions, as movement creates meaning. Music and sound are also something that might generate and stimulate movement.

In addition, people need a social excuse or reason to move, i.e. that such movements or movement patterns are socially accepted or encouraged in that specific context. This is also depending on a person's personal style as well as his or her conscious experience or desired impression of him/herself [4]. The social setting therefore defines which movements that are appropriate to use for interaction, and hence, it delimits which movements one feels comfortable doing.

The fears that the BodyBug users' felt in relation to their (lack of) performance and level of movement skills were similar to the comments from the dance course participants prior to the dance classes. One reason for this fear might be that there is a clear visible difference between skilled and less skilled movers and that experienced physical clumsiness often is related to embarrassing situations. However, getting to know your own movement pattern as well as experiencing other people's movement patterns, increase the understanding of and acceptance of your own and other people's movement behaviors. This is why the dance course participants experienced an increased self-confidence in relation to their performance in front of others.

As we saw in the user experiences of BodyBug as well as during the dance course, the kinds of movements one makes are dependent on the social context. Unexpected movements are often more accepted when people understand why other people move as they do. For example when people see a person running in the street they might look oddly on that person. But if they understand that she is running because she wants to catch the bus, no one founds that strange. One of our intentions when designing the concept was to encourage people to do new movements and maybe create new socially accepted movements.

For some years now, skateboarders and their likes have populated, reshaped and contextualized the public space with new movements and physical activities. A growing bodily movement community that makes use of the physical environment in similar ways as skaters but have no other equipment than their bodies, is Le Parkour, also called Free Running. It is described as a sport, an art, a passion, as well as an everyday philosophy. Another contemporary phenomenon that is related to social aspects of movement is Mobile Clubbing, which started as an art project. It is a form of flash mob community where people meet in public places and dance individually to music playing in their private mp3 players.

A few years ago, walking around gesturing and talking out in the air would to most people seem quite weird or lunatic. However, today we are more than used to people talking in their mobile phones using various hands-free devices in all kinds of appropriate and less appropriate places. Technological devices are increasingly introduced to our everyday lives and create new behaviors and movement patterns, which we do not longer question. Consequently, it is most likely only a question of time when we will accept other kinds of movements that seem weird to us today.

Movement as Interaction Modality

The increasing use of theories and approaches such as Labans' theories of movement, contributes to a broader perspective on human movement and movement-based interaction. As previously discussed, time, space and energy are the main building blocks of all human movement. The combinations of those movement elements create the movement quality, which is unique for each individual. Consequently, it exists a huge variety in movement possibilities. When we design for human movement, we therefore need to have in mind, how the movement quality might influence the users' experiences. This includes reflecting on how the movement interaction should be carried out and how the movement should feel, rather than which specific movement the user must do.

When using movements for pure communication, it is important that we have an understanding of the movement, which means that here must exist a relation between what we do and what we would like to express. If this consistency does not exist, we will feel lost or dumb. As previously mentioned, several movement-based interfaces make use of predefined movements, i.e. movement imitation. However, when imitating a movement you need to be able to see and understand what there is to imitate.

Further, the ability to imitate a movement depends on your previous experiences of similar movements, but also your personal physical body and preferences of movement, e.g. movement quality. If the movement is too complex or different from your personal natural or intuitive movement pattern, you will spend too much effort and time on figuring out what to do, i.e. how to give the system the desired input, instead of focusing on the original task or activity.

However, these issues must be considered in respect to each specific application and its context. As usual, one must take into account the system's intended user group, use context and required experience level as well as level of expertise. In some situations we might want to have a rigorously defined movement interaction that requires training, while other times we search for means of input that are intuitive and can quickly be learned and understood.

CONCLUSIONS

In this paper we have presented experiences and reflections from the design process and preliminary user experiences of a wearable movement-based interaction concept. From our work, we conclude that using modern dance as a source of knowledge about human movement as communication and interaction modality has made us able to create a basis for providing embodied interaction experiences. However, the potential for an embodied user experience increases when the movements are defined by the person who is interacting or when the movements are related to how (s)he prefers to move and his or her personal movement quality.

Specific movements are more or less appropriate in certain situations and environments as well as they can be related to specific meanings. Consequently, the social context as well as the physical environment influence people's natural movement pattern and quality of movement. Similarly, people's movements and mere physical presence will affect people's experience of the social environment as well as the experience of the physical space. Design for movement-based interaction should therefore be considered in respect to the social context in which it is intended to occur. Do we want to create a new movement expression in the environment? Do we want the interaction to be highly visible or discrete? Is it possible to scale the amount or quality of movement according to the context?

Similarly, we must have in mind that human movement is not always appropriate as interaction modality. This might be due to aspects such as efficiency and to the social and physical context. When we design for movement-based interaction, it is therefore important to have an idea about why the specific interaction modality is used and what it contributes with. How we design and develop technology influences people's movement patterns and movement habits in a longer perspective. Hence, our development of movement-based interaction artifacts contributes to the social "education" of our bodies.

In order to bring the research on movement-based interaction further, we need more physical experiences and tangible interaction examples. We also need to continue the search for the essence and physical grounding of human movement in relation to technology and computational artifacts. This is preferably done through interdisciplinary research focusing on the users' experiences. One of the biggest challenges however, is to design for movement-based interaction without losing the aspects of individual preferences and differences in movement, i.e. to preserve the spontaneity as well as ambiguity in human movement.

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