On intuitive use, physicality and tangible user interfaces

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Abstract: 'Intuitive to use' is so often assigned to tangible user interfaces (TUIs) and physical interaction, for example, in conference lectures, informal communication and in scientific publications, that it seems obvious that physicality evokes intuitive use. However, on closer inspection the topic becomes less obvious. It appears that the use of the term *intuitive* are diverse and a common definition is still missing; this is true in general for the field HCI but it is particularly true for the fields physicality and tangible interaction. This paper provides a definition of intuitive use and reviews formerly separated ideas on physicality, and tangible user interfaces and intuitive use that were partly included in past publications. We also investigate further aspects which enable or facilitate intuitive use, namely image schemas and familiarity. As interaction has an impact on the overall product experience, we also discuss whether intuitive use influences the users' aesthetic judgements of such products.

Keywords: aesthetics; dynamic world model; familiarity; image schemas; intuitive use; physicality; TUIs; tangible user interfaces.

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Biographical notes: Johann H. Israel, Jörn Hurtienne, Anna E. Pohlmeyer, Carsten Mohs, Martin C. Kindsmüller and Anja Naumann are the Members of the interdisciplinary IUUI research group (Intuitive Use of User Interfaces), a team of psychologists, computer scientists, engineers and designers which has made it its business to explore intuitive use as a well-defined scientific concept. Originally founded at the Center of Human–Machine-Systems of the Technische Universität Berlin, the research group now includes members from various institutions, universities and companies. IUUI has contributed to various national and international conferences such as the *ACM Conference on Human Factors in Computing Systems (CHI), the HCI International Conference, the ACM Conference on Tangible and Embedded Interaction (TEI)* and *the German Usability Professionals Conference (UPA).*

1 Introduction

The possibility to create systems which are intuitive to use is among the most frequently mentioned advantages of physical and tangible user interfaces (TUIs) and contributes vastly to their popularity (cf. Hornecker and Buur, 2006). But what exactly is meant by 'intuitive use'? Being intuitive is regularly attributed to a physical or tangible interface in terms of a static system property. It is often named along with other attributes such as direct (cf. Ishii, 2008), easy-to-learn and natural (Fjeld et al., 1999; Kato et al., 2000), fast, simple and effective (Ichida et al., 2004), easy-to-use, self-explanatory (Diaz and Rudomin, 2004), 'present at hand' (Hornecker, 2007), etc. When looking at the context of intuitive use in TUI-related publications, some factors can be derived which are (although often not explicitly) claimed to contribute to intuitive use. These are the material (Beckhaus et al., 2008; Gillet et al., 2005; Hornecker, 2002) and spatial representation of the interface (Sharlin et al., 2004), the possibilities of physical access (Gillet et al., 2005; Hornecker, 2002; Kato et al., 2000; Lee et al., 2005; Ullmer et al., 2005), the clear representation in respect to human perception (e.g. contrast, shape, texture, colour, shading, etc. cf. Gillet et al., 2005; Wensveen et al., 2004) and the embeddedness in the user's working and interaction space (Dourish, 2001; Hornecker, 2002).

Few authors of physicality and TUI-related works explain their concept of intuitive use. A comprehensive framework for designing intuitive interaction was introduced by Wensveen et al. (2004). They identified six characteristics in which user actions and the manipulation of digital information should be unified, namely time, location, direction, dynamics, modality and expression. Sharlin et al. (2004) emphasise that successful spatial mappings between the physical object and the digital information or function that it embodies contribute to intuitive use. “Successful TUIs incorporate intuitive spatial mappings to the application task, and exploit spatial abilities and mappings known innately and learned early in life before those learned later” (p.339). Billinghurst et al. (2005) draw upon the physical control, one-to-one mappings and distributed space multiplexed access, which they find are the reasons that TUIs are ‘extremely intuitive to use’ (p.17). Hornecker (2007) suggests that intuitiveness is relative to a user’s domain knowledge and might have varying intensities.

Because there is no widely accepted definition of the intuitive use of user interfaces (IUUI) in the HCI community, for example, such as the definition of usability (cf. ISO 9241-11, 2006), the inconsistent usage of the term is not surprising. This makes it not only difficult to investigate and to evaluate intuitive use, but also to develop design guidelines and strategies.

Our research addresses this deficit by providing a definition of intuitive use which aims at establishing a common understanding and consistent application, particularly, in the context of TUI and physicality. The elements of our definition, namely mental efficiency, prior knowledge and subconscious applications are discussed in detail in Sections 2–4. We then discuss physicality, images schemas and familiarity as aspects which enable or facilitate intuitive use (Sections 5–7). In the final passages of this paper, we investigate how intuitive use influences the aesthetic perception of interactive products (Section 8). We also address some controversies about intuitive use which reflect the current discussion in our research group. We acknowledge that intuitive use is not always appropriate, that it might even hinder the emergence of novel interfaces and that highly specialised interfaces, for example, for experts, which are not intuitive at first, are in the long run often more efficient and can be the better solution for a given scenario (cf. Hornecker and Buur, 2006).

2 Defining IUUI

The frequent and inconsistent use of the term ‘intuitive’ for characterising a product, and/or the use of a product, shows the need for a theoretical definition of intuitive use. So far, few definitions of IUUI have been published, which mainly draw upon prior knowledge, its subconscious application or on familiarity (cf. Blackler et al., 2003; Naumann et al., 2007; Raskin, 1994). In this paper, we refer to our definition of ‘intuitive use’ which is the first result of the interdisciplinary work of the IUUI research group on the concept of ‘intuitive use’:

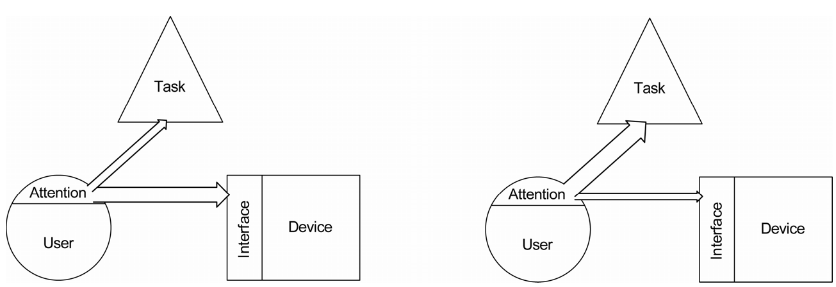
> “A technical system is intuitively usable if the user’s subconscious application of knowledge leads to effective interaction” (Mohs et al., 2006).

The basis of our definition is the assumption that only human information processes can be labelled as intuitive. 'Intuitive' is not an attribute of an object. It rather describes a relation between a person and an artefact, if at all, then this relation can be labelled 'intuitive' (Mohs et al., 2007c). Terms like 'intuitive interface' or 'intuitive device', which have often been used to describe and promote products in recent years, should thus be avoided. 'Intuitive use' can only be used in the context of task, user, environment and technical system. More precisely, intuitive use can only be attributed to the human–machine interaction in a certain context for the achievement of objectives, but not to a technical system *per se*. We also emphasise that interaction must be *effective*, which means that users must achieve specified goals with satisfactory 'accuracy and completeness' (cf. ISO 9241-11, 2006, p.5).

Regarding the efficiency, that is the 'resources expended' by the users in order to achieve specified goals (ISO 9241-11, 2006, p.5), the main effect of intuitive use in terms of our definition is *mental* efficiency. It is achieved by the subconscious processing of user interface elements, which in general means less cognitive workload. Thus, more cognitive resources will be available for solving the working task at hand (the 'overall problem', see below), instead of wasting time and mental effort on figuring out how a piece of technology works. The user's attentional resources are mainly allocated to the working task at hand and not to the technical system (Figure 1).

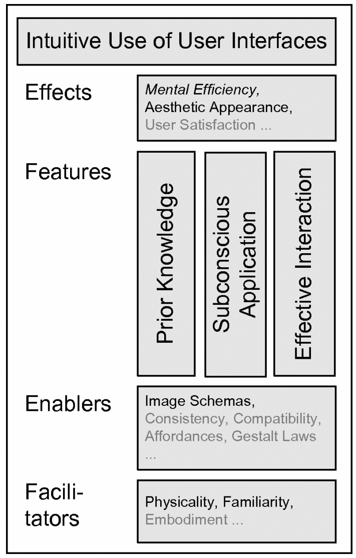
We intentionally do not set motor efficiency as a criterion for intuitive use, but subconscious processing and effective interaction. Even, if we assume that intuitive use is perceived as fast by the user herself or himself, it is first and foremost mentally efficient if the actual interaction requires few cognitive resources. The extensive use of tangible interface items for solving a certain task might, for example, raise high motor effort and take longer than solving the same task by means of fast point and click operations in a GUI, but the TUI solution might still be more mentally efficient because it might be easier to process and direct less attention to the control of the interface than the GUI variant. This means in turn that even if TUIs are slower to use than GUIs in certain contexts, they can still be the better solution if intuitive use is required.

Figure 1 User's attention allocation through non-intuitive use (left) and intuitive use (right) of an user interface



Source: Mohs et al. (2007a).

Figure 2 Effects, features, enablers and facilitators for IUUI

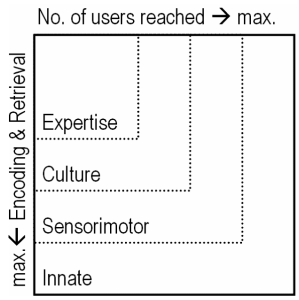


In order to get a grip on the aspects of intuitive use, we classified them into effects, features, enablers and facilitators (Figure 2):

- The main *effect* of intuitive use is *mental efficiency*, as discussed above. But also other, secondary effects, such as *aesthetic appearance* (Section 8) and *user satisfaction* (cf. ISO 9241-11, 2006) can evolve from intuitive use.
- The core *features* of intuitive use according to our definition are the user's subconscious application of prior knowledge which leads to effective interaction (Sections 2– 4).
- We describe *enablers* as those principles, the primary effect of which – when applied to user interfaces – are to support intuitive use. In turn, if they are broken or missing, an intuitive use will most likely not be possible. Particular enablers of intuitive use in tangible interfaces are image schemas which are described in Section 6. Other enablers, for example, self-descriptiveness and conformity with users' expectations are discussed in the ISO 9241 part 10 (2006).
- The *facilitators* are characterised as those principles, which – if present in the user interface – contribute considerably towards intuitive use, but – if absent – would not break it. As major facilitators, we discuss *physicality* and *familiarity* in Sections 5 and 7. Other facilitators of intuitive use such as embodiment have been discussed, for example, by Hummels et al. (1997) and Dourish (2001).

This list is not intended to be complete, the transitions between the categories are smooth and various aspects might not entirely fit into this classification. Altogether, we are aware that the research on intuitive use has by far not reached the depth and robustness as, for example, the research on the usability construct. This paper is intended as a further building block towards establishing a theoretical foundation of intuitive use in the context of tangible interaction.

Figure 3 Continuum of knowledge in intuitive use



Source: Hurtienne and Blessing (2007).

3 Prior knowledge

Users can interact with a technical system effectively and intuitively when applying their *previous knowledge* to a certain situation with minimal cognitive effort. This previous knowledge may originate from different sources. These knowledge sources can be classified along a continuum from *innate* knowledge, knowledge from embodied interaction with the physical world (*sensorimotor*, e.g. affordances (Gibson, 1979); image schemas (Johnson, 1987)), and *culture* to professional areas of *expertise* (Figure 3). Further, we get towards the top level of the continuum, the higher is the degree of specialisation of knowledge and the smaller is the potential number of users possessing this knowledge. Still, on each level of the knowledge continuum we may find 'intuitive use' according to the above definition – as long as prior knowledge is *subconsciously* applied by users.

The application of knowledge may be subconscious from the beginning (as with reflexes) or may have become subconscious due to frequent exposure and reaction to stimuli in the environment. As learning theory suggests (cf. Bower and Hilgard, 1980), knowledge from the lower levels of the continuum are more likely to be applied subconsciously than knowledge from the upper levels. If the subconscious application of knowledge is a precondition for intuitive use, it will be more common to see intuitive interaction involving knowledge at the lower levels of the continuum.

In our understanding, intuitive use, in the first instance, refers only to operations as parts of more complex actions. Here, intuitive use can be measured in a straightforward way, for example, by means of dual task studies. It should be noted that according to our definition an operation is meant to be intuitive if the demands of cognitive resources are minimal even if it causes a higher investment of other dimensions, for example, time or motor activity.

4 Subconscious application

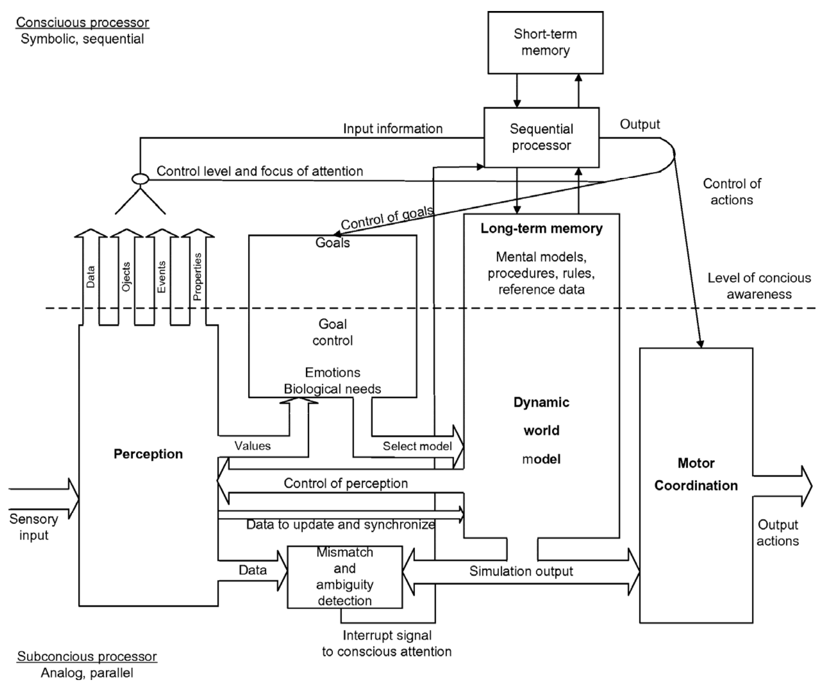
Because our sensory equipment is too slow to monitor fast object manipulations in the physical environment, we simulate the behaviour of objects and also our own motor actions internally. Rasmussen (1986) describes this in the concept of the subconscious internal dynamic world model (Figure 4), which has an important role "as part of a complex loop of interactions in conjunction with the perception and goal systems.

The world model (…) forms the basis of a high-capacity, efficient feed-forward control of physical actions" (p.77). The simulation allows parallel, fast and efficient skill-based manipulations which require few attention resources and does not need to be controlled consciously. The simulation is continuous and becomes conscious only if there is a contradiction between inner simulation and outer perception (interrupt). In this case, human needs to apply rules and knowledge in order to solve the contradiction in a comparatively slow sequential manner.

According to our definition, a prerequisite of intuitive use is that it occurs subconsciously. Thus, in order to achieve and maintain intuitive use, the interface should be designed so that no conscious processes for solving the interaction problem should be necessary. In respect to Rasmussen's model, subconscious processing mainly depends on:

- *Perception*: automatic recognition of the intrinsic and extrinsic properties (invariants, cf. Gibson, 1979) of the interactive object, their functional properties (affordances) and current state.
- *Simulation*: automatic prediction of the behaviour of interactive objects and their response to user's manipulation.
- *No interrupts*: both perceived object's behaviour and user's own motor behaviour should match with the simulation.
- *Motor coordination*: automatic execution of the simulated motor behaviour in the real world by acting, manipulating objects and moving oneself.

Figure 4 Map of human data-processing functions, employing the subconscious dynamic world model as an important part in the interaction with the perception, motor and goal system



Source: Rasmussen (1986).

Because physical manipulation of objects is frequently repeated and encoded beginning in childhood, and detailed, deeply engrained prior knowledge is available to the user, it is usually processed below the level of conscious awareness, in the analogue, fast and parallel subconscious processor (Rasmussen, 1986). Furthermore, because humans have evolved to have highly optimised sensorimotor skills for manipulating physical objects, those manipulations are usually processed below conscious level. In consistence with Rasmussen's model, empirical data supports the claim that users perform more efficiently and more effectively with both specialised and physically represented interactive objects instead of general purpose or graphically represented interactive objects (cf. Couture et al., 2008; Fitzmaurice and Buxton, 1997; Huang, 2004; Krause et al., 2007).

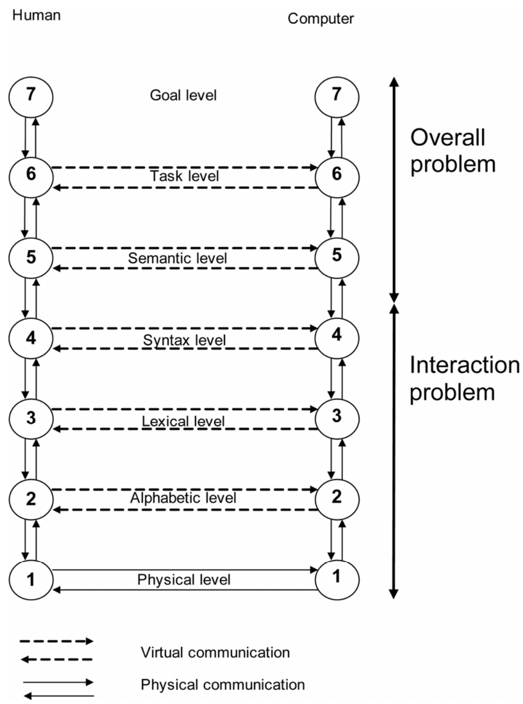
Rasmussen's model also emphasises different kinds of processing behaviour. Whereas the conscious processor operates on symbols (e.g. icons, commands) and can work only on one task at a time, signals are processed in parallel, subconsciously and faster (cf. Swendson, 1991) in the subconscious processor. Thus, if intuitive use is the design goal it should be most advantageous to use physical user interface elements rather than graphical or language-based user interface elements (cf. Swendson, 1991).

5 Physicality

Powerful applications of physical interface elements are not new. Steering a car, for instance, involves mapping the turning direction of the steering wheel to the turning direction of the car. TUIs went beyond such physical-to-physical mappings by mapping physical user interface elements to digital representations of physical things. A famous example of this is urban planning workbench (Urp) by Underkoffler and Ishii (1999). Urp uses scaled physical models of architectural buildings to configure and control simulations of shadow, light reflection, wind flow, etc.

In fact, tangible interfaces are unique in providing physical access to digital information. In their review of TUI applications, Ullmer et al. (2005) stated that "the most popular application of tangible interfaces has been using physical objects to model various kinds of physical systems" (p.82). As tangible interfaces are embedded in the user's physical environment, they are inherently meaningful also in social interaction (e.g. point to, hand over, put forward, hide, etc.) Nevertheless, their functionality and computational power are usually very limited (cf. Blackwell et al., 2007). In order to find ways for implementing complex functionality by means of tangible interfaces and to frame the scope of the discussion, we might first look at semiotic models of human–computer interaction (cf. Buxton, 1983; Foley and van Dam, 1982; Nielsen, 1986). Semiotic interaction models (Figure 5) separate aims and tasks of the user (the 'overall problem', Streitz, 1986) from concrete physical manipulations and interaction syntax in the real systems (the 'interaction problem', Streitz, 1986). From the perspective of our definition, the aim of designing for intuitive use is to create interfaces that induce less workload on the lower levels, are ready-to-hand and transparent to the user (cf. Winograd and Flores, 1986), thus freeing resources for the solution of the overall problem.

Figure 5 The virtual protocol model for computer–human interaction, employing physical communication (energy exchange) as the basis of all higher levels of interaction



Source: Nielsen (1986) and Streitz (1986).

Surveying tangible interfaces reveals that most of them rely on one-to-one mappings which (to a certain degree) bypass the syntax level and forward spatial and material manipulations at the physical level directly to digital functions. The syntax is usually implicitly given by the physical coding of the interface (cf. Blackwell, 2003; Montemayor, 2003), action and object are merged into a single interaction token (Nielsen, 1993) and affordances and constraints are encoded physically (Ullmer et al., 2005). One can argue that mapping as much functionality as possible directly to the physical realm, for example, by introducing more objects and providing more physical degrees of freedom, amplifies intuitive use because less cognitive processing of syntax is required. This is certainly the case for a broad range of existing tangible interfaces.

On the other hand, syntax is a powerful means to construct meaning. The richer the syntax of an interaction language, the more meaningful interaction tokens can be generated and the fewer objects are needed to evoke complex functions. We agree with Blackwell (2003) that "(…) advantages [of TUIs] must be sought at the syntactic, or semantic levels" (p.394) and see the difficulties to encode syntax in tangible interfaces as a major reason for their limited applicability to productive applications. Attempts to encode complex syntax entirely mechanically have frequently led to 'physical clutter' (Ullmer et al., 2005). Thus, the design challenge as we see it, is to depart at least partly from encoding syntax within mechanical constraints and to search for other methods which are subconsciously de- and encodeable by the user. Here, we suggest *image schemas* as a dedicated approach.

6 Image schemas and their metaphorical extensions

Although, the physical representation of digital objects facilitates their manipulation, the danger is that tangible interaction gets stuck in only manipulating physical objects. Hornecker and Buur "warn of stopping at simple, direct mappings" and "feel that too many tangible interfaces aim for direct one-to-one mappings, remaining literal and missing out opportunities" (Hornecker and Buur, 2006, p.440). What opportunities could they mean?

New fields of technology application involves the interaction with abstract data, for example, managing financial data in enterprise resource planning systems, updating a profile on a dating website or caring for the health of a virtual pet. Although, the content manipulated with technology is getting more abstract, user interface elements remain primarily spatial in nature. How can the spatial coordinates of tangible input tokens be mapped onto abstract data?

Recent developments in the cognitive sciences point to ways by which abstract domains of thinking can be represented at the user interface. One particular theory is image schema theory. Image schemas are abstract and analogue representations of knowledge that are formed by basic recurrent experiences (Johnson, 1987). However, they are not only grounded in visual knowledge but pertain to all modalities of sensorimotor experience. Examples from a number of about 40 image schemas are *up–down, left–right, front–back, container, blockage, compulsion, centre–periphery, warm–cold* and *smooth–rough*. The up–down image schema, for instance, is metaphorically extended to abstract concepts like status, quality and quantity. For instance, repeated experience of the correlation between verticality and quantity (e.g. experiencing the level of liquids rising or falling with the amount of liquid in a container) builds the association *more is up – less is down*. This correlation is then generalised to more abstract entities like finances or age. This can be seen in expressions like 'My income *rose* last year', 'Rents are going *up*' or 'He is *under*age'. About 250 such metaphorical extensions of image schemas have been collected from a wide range of publications, including Lakoff and Johnson (1980, 1999), Baldauf (1997) and Kövecses (2005).

The use of image schemas for representing abstract concepts is one promise for TUI design (Hurtienne and Israel, 2007). Image schemas 'built into' TUIs can trigger the 'prewired' connections to abstract target domains in the users' minds.

The claims of image schema theory were validated in a GUI context. Results indicated that user interfaces congruent with the metaphorical extensions of image schemas are judged to be more suitable by users than incongruent user interfaces. What is more, they enabled users to make faster decisions with greater accuracy (Hurtienne, 2009; Hurtienne and Blessing, 2007). These studies also show that current user interface design guides, like population stereotypes (Loveless, 1962) or the proximity-compatibility principle (Wickens and Carswell, 1995), are productively extended by image schema theory.

If image schemas are representations of knowledge, are they also useful in practice? A set of more than 40 image schemas was used as a metalanguage in a user-centred redesign of a business application (Hurtienne et al., 2008a,b). We found that image schemas are readily identified from the context of use, that is, from task sequences, the users' language and the user interface of the current system. Image schemas were also used to specify user interface requirements. Image schemas easily bridged the gap between the requirements phase and the phase of producing design solutions. They narrowed down the possible design space but still provided flexibility in producing concrete design solutions. We designed two prototypes, one graphical and one TUI that differed in their appearance and interaction, but were based on the same image schematic requirements.

Both solutions were evaluated by users. They found that both prototypes had higher pragmatic and hedonic qualities compared to the current software solution. The TUI was rated higher in hedonic quality than the graphical user interface, but both interfaces did not differ significantly in pragmatic quality. These first results showed that image schemas have practical value in a user interface design process and also for designing TUIs. Clearly, more research is needed in this direction.

To summarise, image schemas, together with their metaphorical extensions, are assumed to function as basic building blocks of thought. They are used for communication in various ways – in gesture, in language and in graphics. They are shared by many people, used automatically (i.e. below consciousness) and therefore have the potential to enhance the design for intuitive use. Image schemas allow to make a connection between the features of the interaction and the *meaning* of the interface. Designing with image schemas will lead to interactive systems that match the preexisting knowledge of users, that is, automatically applied to the interaction, thereby freeing cognitive resources for solving the overall problem. UIs that disregard image–schematic thinking or violate its metaphorical extensions put a stop to automatic processing and hence require more cognitive effort to solve the interaction problem. Preliminary evidence shows that goals influence the mental activation of image schemas. Thus, they are ultimately tied to the task being solved (see above).

Secondly, image schemas are, especially, interesting for the design of TUIs. Because of the rich sensorimotor experiences conveyed with physical UIs, they immediately and directly connect themselves to the sensorimotor basis that image schemas are originally derived from. They also provide a metalanguage on which several design phases can be based.

Thirdly, metaphorical extensions of image schemas (like *more is up*) bind thinking about abstract concepts to more concrete, physical experiences. This opens up a way in which TUIs can overcome over-literal, physical-to-physical mappings that have been addressed as one of the major problems of tangible interaction.

Although, image schemas are very promising for TUI design in theory, we are only at the beginning of understanding their practical value empirically. Questions that need to be addressed are how specific image schemas are triggered, whether the proposed set of image schemas (and their metaphorical extensions) is valid, and how reliable the effects are.

7 Intuitive use through adapted familiarity of physical objects

Intuitive use is characterised by subconscious application of prior knowledge. What kind of knowledge is applicable subconsciously? Paramount examples are skills of perceiving and using objects which have become familiar through repeated use. To find objects which are familiar to a wide range of possible users, it seems to be a good strategy to look for simple physical objects which are in day-to-day use by almost everyone. But physicality alone is not enough to evoke intuitive use.

Assuming you find physical objects which are familiar to almost everyone and employ them in a TUI, you might follow Raskin (1994, p.18) who stated that "(…) a user interface feature is 'intuitive' insofar as it resembles or is identical to something the user has already learned". Regarding tangible interfaces, we agree that the application of physical objects as devices for input or even output in a hybrid interface containing virtual and physical objects could facilitate the transfer of their familiarity into the new context. But this is not the whole story. Familiar interface features may *stay* familiar if they are applied in different surroundings, because they are the same interface features. So far Raskin would be right when he states "In short, 'intuitive' in this context is an almost exact synonym of 'familiar'" (Raskin, 1994, p.18). A new interface is hardly completely familiar in all its attributes. But, nevertheless, it can be still intuitively usable because 'intuitive use' is the transfer of existing skills with familiar objects to a new context of use with the adaptation of these skills to the new setting. Also, this transfer can be done subconsciously with minimal cognitive effort, maintaining the preconditions for intuitive use (Section 2).

With respect to the innovative strength of interfaces which are intuitive to use, Raskin (1994, p.18) is rather sceptical: "(…) if superior, it [the interface] cannot be the same [as other interfaces], so it must be different (typically the greater the improvement, the greater the difference). Therefore, it cannot be intuitive, that is, familiar". We believe that Raskin's view is too restricted here – even according to his own words as he presents a far better definition in the very same paper: "(…) intuitive equals uses readily transferred, existing skills" (Raskin, 1994, p.18). According to this definition, we can say that an innovative interface for an application or device does not have to be the same as the old one, it does not even have to make use of the same skills. It is only necessary to use existing skills, and these might be transferred from a very different domain or from very different objects, as long as users can bridge the gap between source and target domain. Whether users can bridge this gap is highly dependent on the interface design. Can a user intuitively grasp the required skills by instantly discovering the source domain (where these skills were developed) just by looking at or quickly exploring the interface?

The unlock function of the Apple iPhone might serve as an example. One unlocks the iPhone by sliding a button from left to right. This method of unlocking is new; nobody can be familiar with it. On the other hand, everybody has the skills required to perform that operation. These skills might have been developed by using sliding controllers in toasters, car air-conditioning or equalisers in hi-fi systems. Thus, the interface has to tell the user which skills to use. In the case of the iPhone this is done by a short animation that appears when you switch the device on for the first time. Since, the overall appearance of the interface supports the interpretation of the button as a sliding controller this one-time animation is enough for the user who has seen it. However, without this one-time animation the overall appearance of the interface seems not to be enough.

Unlike standard user interfaces, TUIs – as a result of their physical constraints – are less arbitrary in the skills they ask for, and therefore, they are promising candidates for bridging gaps between source and target domains. Using a physical object as a user interface triggers prior experiences with similar objects in potentially rather different domains. The extent to which a physical object, as an interface can trigger skills that were developed in a different domain, is directly related to their *prototypicality* (sensu Rosch, 1973). If designers want to trigger skills that were developed in a different domain they should look at the *prototypical* ways of how this physical object is handled in the original domain. There is no need to look at each and every interaction skill and sometimes not even at the *defining* ones, as can be seen in the iPhone example above: a defining feature of a sliding controller (cf. toasters, car air-conditioning systems or equalisers in hi-fi systems) is the possibility to gradually adjust a physical value. This feature is omitted in the iPhone.

What this example also shows is that intuitive use can be achieved by simply teaching the user once how to operate the interface (e.g. showing an animation of the sliding controller). As the example suggests, this can be accomplished while the user is completely unaware of how the interface design is bridging the gap between source and target domain of the usage pattern.

8 The interplay of aesthetics, physicality and intuitive use

So far, our discussion was centred on mental efficiency as the primary effect of intuitive use. In the final part of this paper, we would like to demonstrate that the effects of intuitive use go beyond 'productive' aspects of interaction. Following Djajadiningrat (2000) who call for a shift from focusing on the beauty of the mere appearance to focusing on the beauty that lies in interaction, we argue that intuitive use also affects the aesthetic judgement of the user.

Aesthetics has often been referred to as the pleasure derived from visual appreciation (Creusen and Schoormans, 2005). However, restricting aesthetics to the visual sense underestimates its impact. We adapt the definition of aesthetics as proposed by Hekkert and Leder (2008): '[aesthetics is] the pleasure attained from sensory perception' (p.260). This sensory gratification is not limited to the visual sense; rather it implies all senses (e.g. tactile and auditory). Hence, it takes a much richer variety of experiential components into account. This highlights one of the values of tangible interfaces. By adding the third spatial dimension, numerous *formal* properties of a product (e.g. form, material, weight, temperature, sound and smell) can enhance and stimulate the user's experience through multiple modalities.

However, it should be noted that following the above-mentioned definition, aesthetics are an *outcome* rather than an *input*. In other words, aesthetics are not a system feature; it is the resulting judgement of a user/perceiver. On the other hand, certain design solutions of *formal* system properties such as visual organisation and symmetry are more likely to lead to an aesthetic appreciation than others. Many of these solutions (e.g. Gestalt laws or, as outlined later, familiar features) are shared both by design for intuitive use and design for aesthetics. For example, Reber et al. (2004) argued that symmetry preference might be partly derived from the ease of processing. Apparently, there are strong interconnections between the unhindered flow and ease of cognitive processing, emphasised as the prominent feature of intuitive use, and aesthetic processing. Theses interconnections and the ties of aesthetics to subconscious processes and previous knowledge shall be explored in the following.

Regarding the flow of aesthetic processing, Leder et al. (2004) proposed a model in the context of modern art. The aesthetic experience is conceptualised in an information-processing stage model with the phases of subconscious (e.g. perception and implicit memory integration) and conscious information-processing (e.g. classification, interpretation, understanding and evaluation). The authors suggested two types of evaluation output: an *aesthetic emotion* (emotional reaction) and an *aesthetic judgement* (dependent on whether an artwork was successfully classified and understood or not).

Norman's (2004) model of emotional design also identifies subconscious levels (visceral, behavioural) and a conscious level (reflective). Implications with respect to intuitive use are that recognition of innate perceptual preferences (e.g. Gestalt psychology) and familiar patterns in a design during the subconscious stages can form the basis of a positive aesthetic evaluation. On the other hand, hindered cognitive fluency disturbs the process and thus prevents a positive evaluation.

Another relation can be found between aesthetic judgement and familiarity. In accordance with the so-called 'mere-exposure-effect', first studied by Zajonc (1968), people like familiar things. Repeated exposure to an object or a certain look (also with regard to interpersonal attractiveness) promotes an increasingly favourable evaluation. However, despite the necessity of a certain degree of familiarity, it is not a sufficient condition for something to be classified as aesthetically appealing.

Hekkert et al. (2003) highlight the importance of a carefully designed balance between typicality and novelty. The proposed dual-process can be summarised by the MAYA-principle 'most advanced, yet acceptable': typicality and novelty as joint predictors of aesthetic preference. This brings us back to the concept of an aesthetic experience mentioned above. Intuitive use, which relies on previous knowledge, might be the precondition for a positive output with respect to interactive systems. However, an overall positive aesthetic judgement is only formed if the user is additionally stimulated by the object of evaluation (e.g. through novel, original, innovative features). The appropriate balance is a function of the context. While novelty might outweigh the importance of familiarity in contemporary art, typicality might be more relevant in time-sensitive situations where cognitive resources are limited. This is often the case with interactive systems.

In sum, design for intuitive use and design for aesthetics share a number of underlying constructs and processes. As a result, interactive systems that are intuitive to use have better chances of receiving a positive aesthetic judgement. However, the reverse logic is still actively debated in the HCI community: while some argue for a relationship of 'what is beautiful is usable' (Tractinsky et al., 2000), numerous examples of ill designed systems exist that are beautiful to look at. Something can be aesthetically appealing to one sense (e.g. visual). However, this does not necessarily imply overall 'goodness'. This, in turn, is dependent on both, beauty and usability (Hassenzahl, 2004).

Physicality offers additional channels for an aesthetic experience to unfold. In particular, as Overbeeke et al. (2003) stated "products have become 'intelligent', and intelligence has no form" (p.9), we believe that giving products back their physical form would facilitate the design for intuitive use. As a result, this could decrease the cognitive burden that might otherwise be involved in a designed system that is overly cognitive, alias 'intelligent'. The reliance on the previous experience of manipulating tools in a physical, straightforward manner could be seen as a form of 'Retro-(Interaction)-Design' and thereby perhaps the best qualification for intuitive use. However, the design of multimodal systems also bears the potential of drawbacks and can necessitate additional integration efforts. It has to carefully consider an entire orchestration of sensual perceptions, which should be mutually consistent (Hekkert, 2006).

9 Conclusions

This paper started with the question whether the physical representation of tangible interfaces may contribute to or even evoke IUUI. After having defined IUUI as the subconscious application of prior knowledge, we found parallels between physical interaction and intuitive use in various domains. To summarise, the key issues are:

- Interacting with physical objects involves primarily subconscious processes because it is easy to *simulate* internally, the affordances of physical objects are often highly apparent and many physical manipulation skills are highly learned and automated by the user.
- The deep *familiarity* with physical objects may help to evoke knowledge from source to target domains with minimal cognitive effort.
- *Metaphorical extensions* of image schemas can be employed for the design of intuitive use of abstract data which keep the information-processing below the conscious threshold due to their subconscious origins.
- Formal product properties can subconsciously trigger recognition of familiar system characteristics, which is generally appreciated by the user and forms the basis of a positive aesthetic judgement; physical interaction amplifies the possibilities for *aesthetics* in terms of sensory gratification.

We have touched on the interplay of physicality and intuitive use, and considered at more length physicality and its mapping to digital even abstract data, but we have not covered the hybrid character of tangible interfaces or the apparent physicality/virtuality seam. It remains an important research question which interface functionalities should be allocated to physical and which to digital elements in order to evoke intuitive use (see Hurtienne et al., 2008a, for a first attempt towards this issue). The possible benefits of tangible interfaces beyond intuitive use have also not been covered. Because our definition focuses on the interaction problem, the question whether physicality has the power to render the overall task intuitive to use remains for further discussions. Though, we have not discussed means for measuring intuitive use in the context of physicality and tangible interfaces, general purpose methods are currently under development (Blackler and Hurtienne, 2007; Mohs et al., 2007b).

We hope we could contribute to the formation of a concept of intuitive use of TUIs. We hope to see the term ‘intuitive use’ being used more confidently in the future and call for further investigations on its aspects, opening up new research possibilities and challenges. Finally, we hope that a clear definition of ‘intuitive use’ will also help the physicality community to explain that tangible interaction is more than just intuitive and that the concepts of physicality and tangible interaction go far beyond the creation of ‘easy-to-use’, simple and direct, but limited interfaces.

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