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DESIGNING FOR RICH INTERACTION: INTEGRATING FORM, INTERACTION, AND FUNCTION

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[Here I report on research that was performed as part of my PhD research. I limit myself to the main outline and findings, for a complete report I refer the reader to my PhD thesis (Frens, 2006)]

INTRODUCTION

State-of-the-art interactive products differ from traditional non-interactive products. During the rise of interactive products information-for-use gradually became more and more abstract. For example, a person can directly perceive from the form of a drinking glass what it is for, and how it can be used. The information-for-use is a natural consequence of form and use, it is directly available. In contrast, a person needs to read and interpret the labels on the controls of a digital camera to understand what he can do with it. In this case the information-for-use is much more abstract. There is a difference in how people's skills are addressed. Overbeeke et al. (1999) identify three types of humans skills that are relevant in this context: perceptual-motor, emotional, and cognitive skills. Where the earlier products address all of people's skills, the new electronic interactive products mainly address people's cognitive skills. The focus of interaction with products shifted from an action-based paradigm to a cognition-based paradigm.

I see two reasons for this shift. First, in electronic products the functional components do not determine the controls. Second, the design of form and interaction are explicitly separated. This has far-reaching consequences. If the controls of a product are not determined by the functional parts then they can be chosen by the designer of the product. Or in other words electronics give designers freedom, not only because electronics are small but also because a designer is free to choose how to control them. The controls are coupled to electronic hardware through programming. With the advent of electronics the 'real' interface was born and interaction-style was now 'designable'. This fact made it possible to design the form of electronic products separate from the interaction.

An interactive product can be seen as having three properties: form, interaction, and function, see figure 1. In traditional non-interactive products these three properties are related. For form invites to interact and in this interaction functionality is reached. However, when we regard the state-of-the-art interactive products it is striking to see that form is richly varied but that interaction is standardized. In fact, design for interaction is heavily influenced by design principles that are borrowed from the human computer interaction (HCI) community (Cooper, 1999). For products to offer information-for-use inspired by function and interaction they need to be opened up for

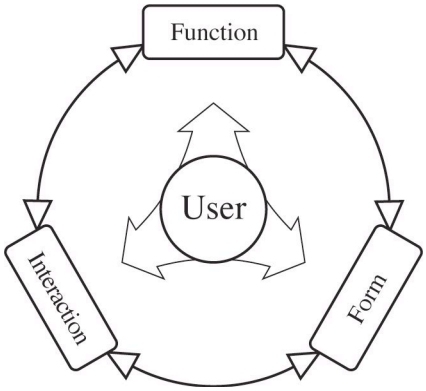

Figure 1, three properties of interactive products

all skills of man. To accomplish this, I feel that the design process of interactive electronic products needs to be adapted. I propose an integral design process for interactive products, inspired by the traditional design process; a design process where form, interaction, and function are explored and designed concurrently in order to integrate them in dedicated interactive products; a design process where information-for-use is inspired by function, and where the skills of man are central to interaction. But before going deeper into this I first explain my research approach.

APPROACH

The aim of this document is to explore new interaction paradigms for interactive consumer products. I choose to do this in a typically designerly manner, by designing interactive products, by conducting research through design.

Research through design

Research through design is similar to Archers' 'research through practice' (Archer, 1995). Archer recognizes research through practice as a form of action research which he defines as '*Action Research: Systematic investigation through practical action calculated to devise or test new information, ideas, forms or procedures and to produce communicable knowledge*' (Archer, 1995, p. 6). He warns that since action research is situation-specific it is '*difficult and dangerous to generalize from Action Research findings*' (Archer, 1995, p. 12). What is important in this statement is the word: 'situation-specific'. For me this implies two things. First, the skills of the designer play an important role, it is through the designerly skills that the problem area unfolds. Second, the knowledge gained through a research through practice project is applicable to a specific situation. Or as Hummels states, it leads '*to conditional laws instead of general laws*' (Hummels, 2000, p. 1.27). In the case of design it is applicable to a specific class of products and its design process. Archer states that a practitioner should position himself in opinion and theory concerning the domain in which the knowledge from his research is applicable. How such knowledge is generalizable in a specific domain is demonstrated for example by Wensveen (2005) who designed and researched an affective alarm clock. He set design specifications for products that are to recognize human emotions. Moreover he adds to existing theory on how to recognize emotions. His framework for coupling action to information-for-use taps in nicely with learning and conditioning theory from psychology. The generalizability is thus supported by other sciences.

When conducting research through design products are designed to explore implications of theory in context. The resulting products are subjected to experimentation in real life situations to understand the complex relationship of man with designed reality. Thus knowledge on products and knowledge on the process of designing these products is generated.

Setup of this document: four questions and answers

This document is organized around four questions. First, what will be the basis for this alternative interaction paradigm? Second, what is the solution domain of this new interaction paradigm? Third, how does such a new interaction paradigm compare to the old one? Fourth, how can this new paradigm be characterized? Here these questions are answered in a designerly manner, doing research through design. The first question is answered by taking position in theory. The second question is answered by designing. The third question is answered through

experimentation. Finally, the fourth question is answered in a reflection on the answers on the first three questions.

QUESTION ONE: ON WHAT WILL THIS NEW INTERACTION PARADIGM BE BASED?

To answer the first question I position myself in theory (Archer, 1995). Two areas of research form the background for the new interaction paradigm that is explored in this research: the area of tangible interaction (e.g., Ishii and Ullmer, 1997; Ullmer, 2002) and the theory of direct perception (Gibson, 1986). Tangible interaction is one of the few HCI interaction-styles that concerns itself with the physical. It involves the use of physical objects to interact with computer systems, offers function-specific interfaces, and involves more human skills than only the cognitive, it offers opportunities for embodied interaction (Dourish, 2004). The theory of direct perception (particularly the notion of affordances) provides deeper insight into how information-for-use can be given.

Rich interaction

Inspired by tangible interaction and the concept of affordances I propose a term: 'rich interaction'. Rich interaction is a new interaction paradigm for interactive consumer products. Tangible interaction inspires the use of 'action-driven' interaction, while the concept of affordances inspires and steers the usage of information-for-use. Respecting and starting from people's skills rich interaction aims for aesthetic interaction through the unity of form, interaction, and function. In more detail this means:

Starting from people's skills: Information-for-use relates directly to all human skills (i.e., perceptual-motor, emotional, and cognitive skills) instead of abstractly to cognitive skills alone.

Aiming at aesthetic interaction: Several researchers in the area of design related research pursue something that they have dubbed 'aesthetic interaction', e.g. Djajadiningrat et al. (2000), Overbeeke et al. (2000), Hummels (2000), Graves-Petersen et al. (2004), Forlizzi and Batterbee (2004). Opinions differ on what aesthetic interaction is. For now I propose to use the working definition: 'aesthetic interaction is the aesthetic experience that only can be had while interacting'.

Integrating form, interaction, and function: An interactive product can be seen as having three properties; form, interaction and function (strictly speaking interaction is not a property of a product but a relationship between product and man). In traditional artifacts these properties are strongly and meaningfully related. A hammer for example invites a user to hammer. The form invites to interact, one can grab the shaft to swing the hammer. In this interaction with the hammer its functionality is reached; hammering nails into pieces of wood. The form of the hammer not only invites to hammer, it also expresses the function of the hammer. The relations between form, interaction, and function carry information-for-use.

In state-of-the-art interactive products there is no technical reason for these meaningful relations to exist. As a result they are eased. A product can have any form, buttons are added to interact, and functionality is delivered in unified software platforms. However, in line with Wensveen et al. (2002), who state that form is not arbitrary, I argue for the restoration of these meaningful relations. Rich interaction is about inviting one to interact through form and behavior thus reaching functionality. It is about expressing functionality in form. I aim to

restore the unity of form, interaction, and function. The designerly skills of product designers are essential in accomplishing this.

Though product designers are trained in such integration in traditional products I believe that interactive products offer more aspects that need integration. I distinguish six aspects that can be explored in a design process, see figure 2.

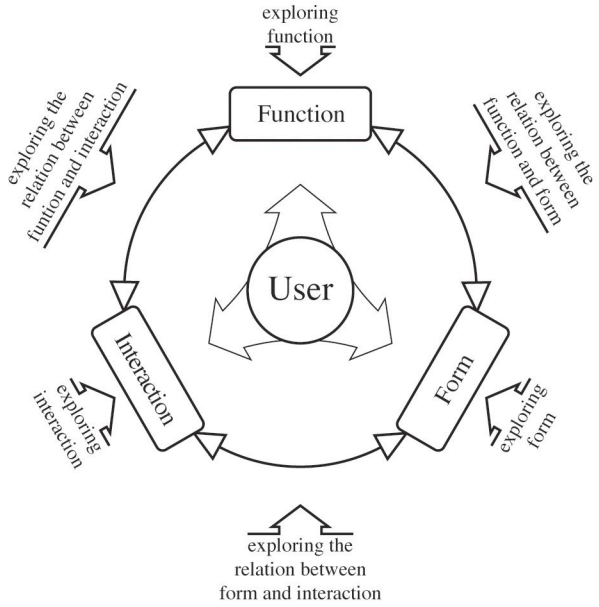

Figure 2, framework for exploration

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QUESTION TWO: WHAT IS THE SOLUTION DOMAIN OF THIS NEW INTERACTION PARADIGM?

Exploring and demonstrating rich interaction by designing

Previously, I explained what rich interaction is in words. But I believe that what is meant by rich interaction is best demonstrated and explored with product designs. In 'doing design' the knowledge that is implicit in design skills is made explicit. Through the process of designing actual product concepts rich interaction is physically defined. Theory on tangible interaction and affordances is applied to the new concept in a designerly manner. The resulting product concepts are physical hypotheses on rich interaction that can be tested in experiments.

Five digital camera concepts were designed, see figure 3. The design explorations were done in an experiential manner while using the framework for exploration that was introduced previously. A combination of sketching, foam-core modeling and cardboard modeling technique were applied while user-actions (as part of interaction) were used as a starting point for the designs. Step-by-step combinations of form, interaction, and function were researched, put into form and tested, thereby exploring all six fields and evaluating their solution domains.

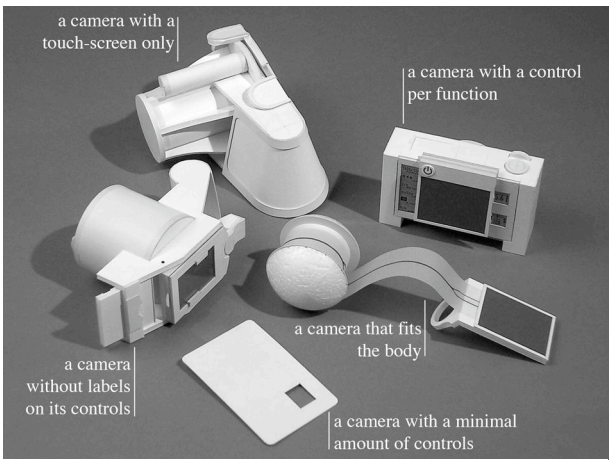

Figure 3, five digital camera concepts

Mode-relevant action-possibilities and mode-of-use reflected in physical state

While designing the five concept-cameras I found that two typical characteristics kept resurfacing as a result of the integration of form, interaction, and function. First, mode-relevant action-possibilities. Second mode-of-use reflected in physical state.

Mode-relevant action-possibilities (MR APs)

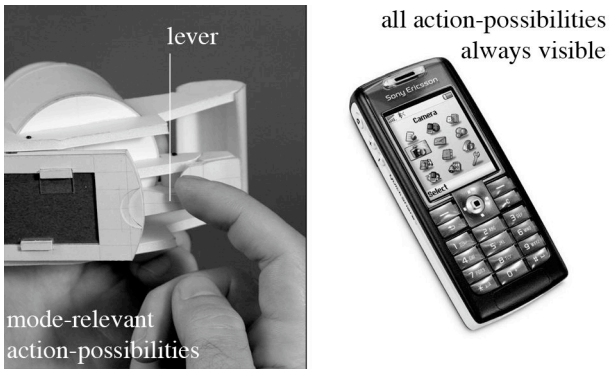

Figure 4, mode-relevant action-possibilites

Mode-relevant action-possibilities are action-possibilities that are only offered when they are relevant for the mode-of-use. They can be characterized as: (1) dedicated to a function, (2) offering meaningful integration of form and function, and (3) expressing functionality in form and interaction. For example the lever to browse saved pictures is only accessible when the 'Labelless Cam' is in view-mode. This contrasts with products with ordinary interfaces that often show all action possibilities all of the time, even if these action-possibilities have no function, see figure 4.

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Mode of use reflected in physical state (MURPS)

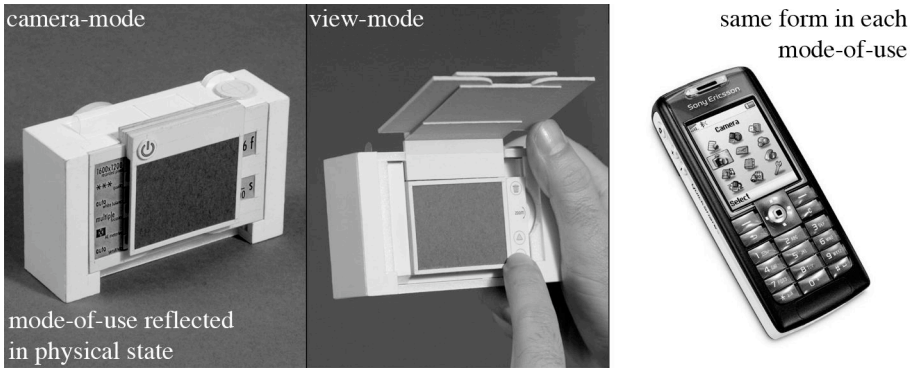

Figure 5, mode-of-use reflected in physical state

The camera reflects its mode-of-use in its physical state. That is, in each mode-of-use the form of the camera is different. MURPS can be characterized as: (1) offering integration of form and function and (2) offering autonomy (symmetry) in camera behaviour in relation to user actions. For example the 'Control per Function Cam' looks different when in camera mode than when in view-mode. This differs from ordinary interfaces which commonly don't change shape, but are always of the same form, see figure 5.

Exploratory user study: working prototypes and standardized form language

The 'camera without labels on its controls' (see figure 3) was chosen for use in an explorative experiment because it integrated the two typical characteristics most beautifully. It was compared to a more traditional camera on intuitiveness of interaction. For this experiment two cardboard mock-ups of the digital cameras were used. Both cameras performed badly. But in general the traditional camera performed somewhat better. Two main conclusions were drawn from the experiment.

First, to assess the quality of an interaction-style one needs working, interactive prototypes. For interaction is an intangible quality of products, that is only present while interacting. Imagined interaction is not interaction. The consequence of this is obviously that to assess the quality of rich interaction a prototype of the camera needs to be built that actually works and is interactive.

Second, people were unable to compare the use of the cameras because the difference in form was an obstacle. The form of the cameras proved to suggest different contexts of use, thus to imply different interaction possibilities. To minimize the influence of form it should be the same for each camera that is compared. That is, the form of the cameras should be, as much as possible, the same while the interaction style of the cameras is varied.

This means that to experimentally compare the rich interaction style with a more conventional interaction style one needs working prototypes that are as much as possible of the same form. To accomplish this I decided to build a working prototype of the digital camera that is modular so that it can accept different interface modules, each reflecting different interaction styles, see figure 6.

Previously two typical characteristics of rich interaction were identified that resulted from the integration of form, interaction, and function; 'mode-relevant action-possibilities' (MR APs) and 'mode-of-use reflected in physical state' (MURPS). These two characteristics adequately describe the differences between the rich interactive camera (RUI cam) and a camera with a conventional interface. The RUI camera has both MR APs and MURPS, a conventional camera

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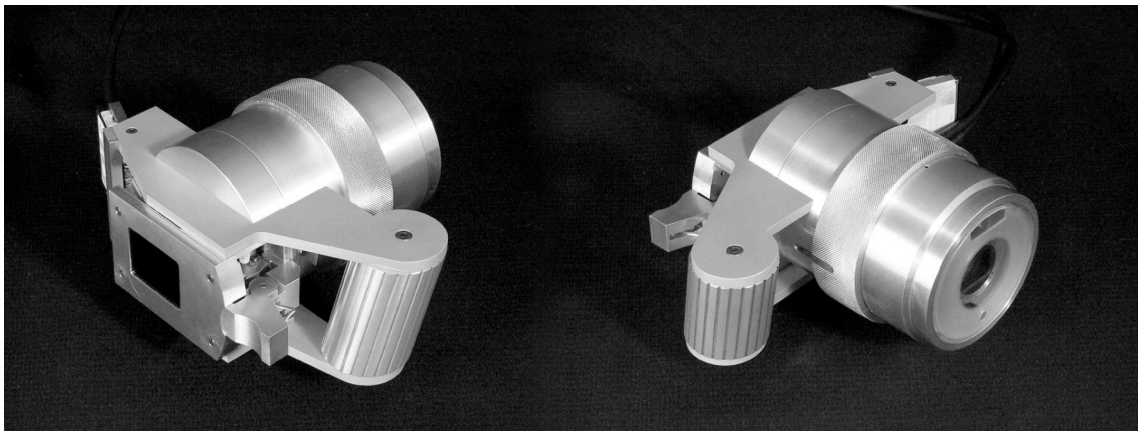

Figure 6, working prototype of the RUI camera

has neither. Four interface modules were designed. Each module has a different interaction-style, systematically varied based on the differences between the original RUI camera and conventional digital cameras. The first interface variation is an adaptation of the RUI camera, the fourth interface variation is an adaptation of a conventional camera. The second and the third interface variation each implement only one of the two differentiating factors. Together the four interface variations span a range of interaction-styles from rich to conventional, see figure 7.

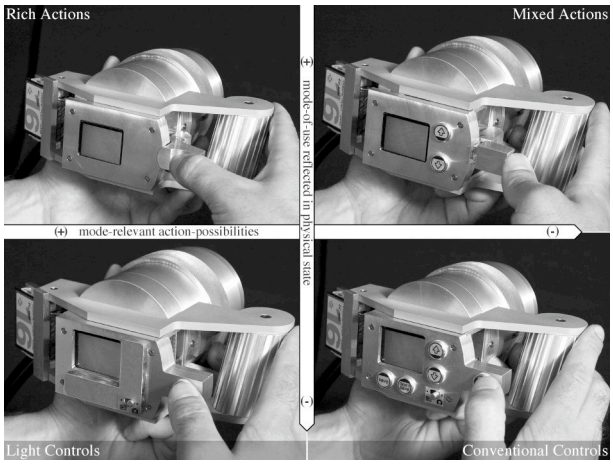

Figure 7, four interface variations in a grid

QUESTION THREE: HOW DOES SUCH A NEW INTERACTION PARADIGM COMPARE TO THE OLD ONE?

Experiment

An experiment is set up to compare the rich interaction paradigm to the more conventional interaction paradigm. The experiment is expected to provide insight into the concept of aesthetic interaction. In the experiment the influence of MR APs and MURPS is tested. Finally the experiment is expected to offer insight in the relevance of HCI usability measures for the domain of interactive consumer products.

Stimuli

In this experiment the four interface variations are compared. The interface variations are fitted on a working prototype of a digital camera, resulting in four prototypes of digital cameras with different interaction styles, see figure 7. A composition of books and vintage computers was set up to act as a still-life to be photographed in the experiment.

Procedure

Twenty-four participants, ranging in age from 19 to 29 years old, took part in the experiment. They were all students from the Architecture Department of the Technische Universiteit Eindhoven. Each participant observed and used all four cameras and finally compared them. The experiment consisted of three parts. Part 1: the camera was observed and a questionnaire was filled in. Part 2: the participants were shown a training video after which they used the camera, and again filled in a questionnaire. They were given the assignment to make three beautiful pictures of a still-life. Part 1 and 2 were repeated for each of the four cameras. When the participants were filling out the post-use questionnaire the experimenter exchanged the interface module out of view of the participants. Part 3: after four successive sessions of observing and using the cameras, the participants were asked to compare the cameras by means of a comparison questionnaire. The order in which the four cameras were shown and used was counterbalanced.

Main findings

The results of the experiment were extensively analyzed and reported (Frens, 2006). They break up into three parts.

Aesthetic interaction

The analyses of the experimental results indicates that aesthetic interaction is present in the RUI camera, the camera that has both MR APs and MURPS. Moreover, it was found that perceived beauty seems to influence the perceived goodness of a camera, regardless of the perceived ease-of-use. Finally, severe usability problems, hampering the functionality of a product, eliminate the presence of aesthetic interaction. It was concluded that there seem to be different kinds of 'hard-to-use'; a kind of 'hard-to-use' that renders a product 'inoperable' and a kind of 'hard-to-use' that doesn't hamper the operation of a product. (ineffective vs. effective)

The differentiating factors

The experiment also reveals that MR APs influence the perceived ease-of-use positively, moreover, the cameras that employ MR APs are preferred over the other cameras. MURPS on the other hand did not seem to influence perceived ease-of-use or preference, positively or negatively.

Classic usability measures

Finally, the RUI camera is not found to differ on efficiency and effectivity from the conventional camera. Only one of the cameras is found to differ on these measures, the camera that employs MURPS, but not MR APs. This is attributed to a usability problem that is found to be present in that camera.

Summarizing

In sum, it is possible to find an alternative for the conventional interaction style. The rich interaction style forms a viable alternative. Yet the rich interaction style implies not another

standardization of interaction style. Instead it offers variation in interaction as a logical consequence of the variation in form and function.

QUESTION FOUR: HOW CAN THIS NEW INTERACTION PARADIGM BE CHARACTERIZED?

Refined definition of rich interaction

This document set out to define, demonstrate, and investigate the concept of rich interaction. In the introduction I described the problem area of this document through a short history of interactive products. For me, most striking in that description was the observation that over time information-for-use became more and more abstracted from human skills. A lifetime of experience with the physical world (Ullmer, 2002) and a body that is capable of doing very refined things (Buur, et al., 2004) become obsolete. Therefore I argued for providing information-for-use through form, thereby making functionality immediately (i.e., not mediated) accessible for human skills.

I went on to describe rich interaction as 'starting from human skills, aiming at aesthetic interaction, and integrating form, interaction, and function'. Moreover, I provided a 'framework for exploration' that can be used to design for rich interaction. Still, rich interaction comes only to life in use, while interacting with products. But it is essential to realize that it is in the design process of interactive products that the conditions are created for rich interaction. Consequently I define rich interaction as follows:

Rich interaction: A paradigm for interactive consumer products that results in a unity of form, interaction, and function and taps human skills (perceptual-motor skills, cognitive skills, and emotional skills) for information-for-use thereby setting the stage for aesthetic interaction.

This definition emphasizes three aspects of rich interaction. I expand on each of these three aspects by reflecting on the work described here.

I Integrating form, interaction, and function

Previously a 'framework for exploration' was introduced that indicated six fields of exploration that need to be explored when designing for rich interaction. I want to highlight two consequences of the integration of form, interaction, and function.

Experiential: To integrate form, interaction, and function it is essential to explore the relations between them. Having chosen to design for rich interaction this needs to be done in an experiential way. For to know the quality of an interaction it needs to be experienced. Consequently the design process has to be taken from the 2D sketching practice to the 3D modelling practice. And from the 2D screen 'interaction simulation' to the 3D hands-on 'experience simulation'.

Specific functionality: The unity of form, interaction, and function also implies that rich interactive products are specific in the functionality they offer. This does not mean that rich interactive products can only offer single functions. Instead it means that rich interactive products express all of their functions and action-possibilities in their form. For example, a rich interactive mobile telephone that is capable of phoning and texting also expresses both of these functions and specific action-possibilities in its form. As a consequence, changing the functionality changes the form and action-possibilities, thus changes the product.

II Information-for-use inspired by human skills - affordances

Human skills are tapped for information-for-use. Consequently the actions that are needed to operate a rich interactive product need to be on a human scale, i.e., human skills presuppose a certain size, range, and diversity. The theory of direct perception with the notion of affordances offers inspiration.

Central to my 'implementation' of the concept of affordances is the question of how to get information-for-use to the user. Herein lies the reason for my consistent use of the term 'action-possibility' instead of control or button. Action-possibilities suggest that they can be designed, while controls suggest that they have been designed. It is therefore necessary for designers to get out of the mind-set of buttons, sliders, and switches and get into the mind-set of action-possibilities. Buttons, sliders, and switches are finished products and they generally express quite well how to act on them. But, they are generic and will therefore not express what will happen when they are used. In contrast, action-possibilities are completely designed from scratch to express how to act and what will happen then. Only after the action-possibilities are designed is there room to incorporate off-the-shelf sensors and controls.

III Aesthetic interaction

Aesthetic interaction was tentatively defined as: 'the aesthetic experience that can only be had while interacting'. I define aesthetic interaction in a narrow sense. I talk only about the aesthetics 'in' the interaction. From my experience in designing, building, and using rich interactive cameras I see three prerequisites for aesthetic interaction: (1) the absence of user-frustration, (2) the presence of rich action-possibilities (i.e., allowing for broad, expressive, and diverse actions), and (3) the presence of other kinds of aesthetics (i.e., aesthetics of appearance (Locher, 2005), aesthetics of context, (Hummels, 2000), or aesthetics of narrative (Dunne, 2001). If these prerequisites are met and arguing from the earlier working-definition aesthetic interaction is a dynamic quality of the interaction for it is only present while interacting. I therefore identify aesthetic interaction through how it impresses the senses during interaction. Aesthetic interaction can be found in the 'feel' of rich action-possibilities.

Closing remarks

I finish with a challenge for product designers and a plea for design as a generator of knowledge. In the introduction I stated that the design of the physical form and the design of the interface of interactive products became separated. I have advocated an integral approach to designing interactive products. I think that this integral approach of designing interactive products also changes the job of the designers of such products. For starters, they need not only skills in the traditional design process, they also need to develop new skills to get a grip on the interactive aspects. It is no longer sufficient to explore the static aspects of products, the dynamic qualities have to be tackled as well. Therefore I change the job of interaction designers from: 'designer of 2D screen graphics' to 'designer of interactive products'.

Lastly, I plea for design as a generator of knowledge. I have explored and defined the concept of rich interaction through the process of designing and building conceptual products. Only through building these highly experiential prototypes can the quality of interaction be assessed. Only through designing product concepts can the relevance of new ideas be tested. Designers ask different questions; what will be the use, how will it feel, why do we want that. Different questions lead to different answers. Answering those questions is only possible through designing.

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