Set Me Free, Give Me Degrees of Freedom

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***Abstract*— Computers and electronic products in general put heavy constraints on human-product interaction. These products demand people to adapt to their way of functioning instead of the other way around. In this paper we try to offer methods to free man from these constraints. To this aim we analyse the existing situation, and point to an approach we use in product design where man as a whole is taken into account, with his cognitive, physical and emotional skills, i.e., knowing, doing and feeling. We illustrate the point we want to make with examples from our work and that of our students.**

***Index Terms*—Computer Interaction, Degrees of Freedom, Industrial Design Engineering, Interaction Design**

INTRODUCTION

The computer plays an ever-increasing role in our lives. It has become part of every product. This (r)evolution cannot be stopped. But these products seem to backfire. People's frustration grows too. Imagine how many times you wanted to grab something that appears in the 2D world of the computer screen. But the glass won't let you in. Why are we forced to use a mouse that allows for only two degrees of freedom while the task demands at least five? And why do we have to communicate with a computer through language, while our behavioural repertoire is so much richer. Why the machine I'm now working on is not really helps me? Instead it shows me an annoying puppet tapping its foot because I cannot type fast enough. Why does my VCR not help me to obtain what I really want, enjoy a movie? Why do products make me feel stupid instead of happy? Why do I feel condemned to use them, instead of tempted to interact with them? Alan Cooper [1] has made a convincing analysis of this phenomenon. As a solution, he proposes to get away from "technological artefacts whose interaction is expressed in terms in which they are constructed"(p. 27). We should design the interaction with products from the viewpoint of the user.

How can we do this? In this paper I describe the approach we developed in the ID-StudioLab. It takes as its starting point respect for the human being firmly rooted in humanism in the sense Montesquieu, the 18th century French philosopher used it. Product (and computer) designers should take all the human skills, i.e. perceptual-motor, cognitive and emotional skills, into consideration.

So first I explain this approach, and then I will give examples of our, and our students' work.

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THE ID-STUDIOLAB APPROACH

A. A short story to begin with

The shop assistant threw the biscuit at my feet. I bent down and subserviently began to pick up the crumbs. After some fiddling, I managed to get my change out of his clenched fist.

Just imagine you were treated like this in a shop. No doubt you would be most offended. But this is, in fact, the way in which a vending machine treats us when we buy something from it.

Somehow we have come to accept a standard of respect in human-machine interaction which is very different from that in human-human interaction. Let us see what this example might tell us, and what the role of the designer is in this.

B. Respect

The user is in search of a positive experience. Therefore the designer needs to create a context for experience, rather than just a product. He offers the user a context in which he may enjoy a film, dinner, cleaning, playing, working … with all his senses. It is his task to make the product's function accessible to the user whilst allowing for interaction with the product in a beautiful way. Aesthetics of interaction is his goal. The user should experience the access to the product's function as aesthetically pleasing as possible. A prerequisite for this is that the user should at the very least not be frustrated. However, we are not promoting "ease of use" as a design goal. Interfaces should be surprising, seductive, smart, rewarding, tempting, even moody, and thereby exhilarating to use. The interaction with the product should contribute to the overall pleasure found in the function of the product itself.

The following example should clarify what we mean. Suppose the user wants to watch a movie for his enjoyment. He has to program his VCR in order to get it working at a later date. VCR manufacturers certainly give the impression of having done everything in their power to make the user as frustrated as possible. Why not make a machine that is a joy to use? We are not saying that "technical" design with a large number of functions and buttons should be avoided; some people actually like it that way. We call for diversity in product design. Not all VCRs should look the same. Why is there such a diversity in car design, and not in VCR design?

C. How can this be done?

We believe that respect for man as a whole should be the starting-point for design. For the sake of analysis, man's skills, which are used when interacting with products, may be considered on three levels: cognitive skills, perceptual-motor skills and emotional skills. In other words, knowing, doing and feeling. Research on human-product interaction, however, has shifted to cognitive skills. This shift is easily understood, as there is no electronic counterpart for the mechanical world-view that still dominates Western thinking. We understand the world of moving machines, since we understand the mechanics of our bodies. The electronic world is more opaque to us. What happens inside electronic products is intangible: it neither fits the mechanics of our body or the mechanical view of the world. We do not understand electronics since we do not understand the workings of our intelligence.

Furthermore, as Wensveen et al. [2] remark, mechanical artifacts give us feedback, i.e., information about what we did to them, and even intrinsic feedforward, i.e. visible information about what they are going to do. Electronic devices often give us no information whatsoever about what we did to them (you cannot see if you pressed a button) and about what they are going to do and why. From time to time you enter a nirvana of miscomprehension. When typing this text I tried to change the title of the template, the title shifted of the page into the void. What did I do wrong?

According to Flach [3] this is because these machines are designed badly. Design is about creating objects that mean something to us. Flach, very cleverly, makes the distinction between objective and subjective meaning. The objective constraints of a situation constitute the objective meaning. This is the world as it known through physics and engineering, Meaning as an *interpretation,* as an attribute of a person's awareness, constitutes subjective meaning. A well-designed system should allow the users of that system to function as experts. Thus a good design shapes the user's interpretation of "what is subjectively meaningful" so that it is congruent with the objective constraints that determine "what is objectively meaningful." However, what normally happens is that experts wrap their expertise in procedures, rules, that the user has to follow blindly. And procedures cannot foresee the unlikely. The designers of my word processor did not give me insight, they want me to follow rules.

From a product designer's point of view, electronic components do not impose specific forms or interactions. Products have become "intelligent", and intelligence has no form. Design research, quite naturally, turned to the intelligent part of humans and thus to the science of cognition to find answers. This has resulted in interface design placing a heavy burden on human intellect, mostly in the form of manuals

We all have senses and a body with which we can respond to what our environment affords [4]. Why, then, do designers not use these bodily skills more often and make electronic interaction more tangible? And, as humans are emotional beings, why not make interaction more fun and beautiful?

Therefore it is necessary to include the other two levels of human-product interaction into the picture: perceptual-motor skills and emotional skills.

FREE THE USER

How can we free the user form procedures and constraining rules? We give a few examples of our work.

A Cubby and Cubby+

Product designers do not like CAD programmes. That is strange, because they have been specifically developed for them. We think there are three major problems with these programmes. First, in the early phases of product design the designer typically searches for forms, while the mathematics in computer demand defining forms. Second, a mouse allows two degrees of freedom, while form manipulation asks for much more. People are extremely dextrous in manipulating objects in free space. And they certainly do not use a Cartesian co-ordinates system [5]. And third, designers get frustrated that they cannot touch the objects because of the glass screen. Their skills are in their fingers.

Furthermore, we believe that CAD programmes do not fully exploit the power of the computer. It allows for new ways of interaction that the designer does not have in the real world.

To remedy these problems we devised a system where display and manipulation spaces coincide and that allows for direct manipulation with the objects to be designed. Central to this system was the question: "What do people need to get a 3D impression?" Classical theory would answer this question with "two eyes". We looked a bit further and found out that standpoint and change of standpoint tells you a lot about spatial layout. Take someone looking at a scene depicted on a screen. When we measure the viewer's head movements, and feed through the image corresponding with every single point of view, the viewer gets a 3D impression of the scene on the basis of movement parallax. Djajadiningrat [6] developed Cubby a desktop-sized VR system with three orthogonal screens forming a cubic space of 200x200x200mm. Through the use of movement parallax on all three screens, the illusion is created that virtual objects stand within the cubic space. As the virtual objects appear in front of the screens, Cubby makes it possible to unify the display and manipulation space. A hybrid instrument (partly real, partly virtual) allows for accurate manipulation, as the virtual tip is rendered with the virtual scene (see Figure 1).

Fig. 1 The head movements of the person are recorded. A computer generates 3 images, corresponding with the person's viewpoint, and projects them on 3 orthogonal screens (left). The person sees a 3D object and has a hybrid instrument with which he can interact with this object (right).

We are currently updating the system to Cubby+ and investigating new ways of interaction that truly exploit the computer's power and the expressive power of the designer. With Cubby+ we are trying to create a system which supports 3D modelling in the early phases of the design process. As mentioned above, with current CAD systems the user has to know the geometry of the virtual object to be created. Also, with current CAD systems the virtual objects which are created, look highly finished and 'final' even though they may in fact be early attempts. With Cubby+ we strive for a type of modelling which has a sketchy feel both in terms of the actions that are required by the Cubby^{+} system and of the appearance of the virtual scene. We intend to experiment with two handed input and a mix of tangible and augmented modelling techniques (Figures 2 and 3).

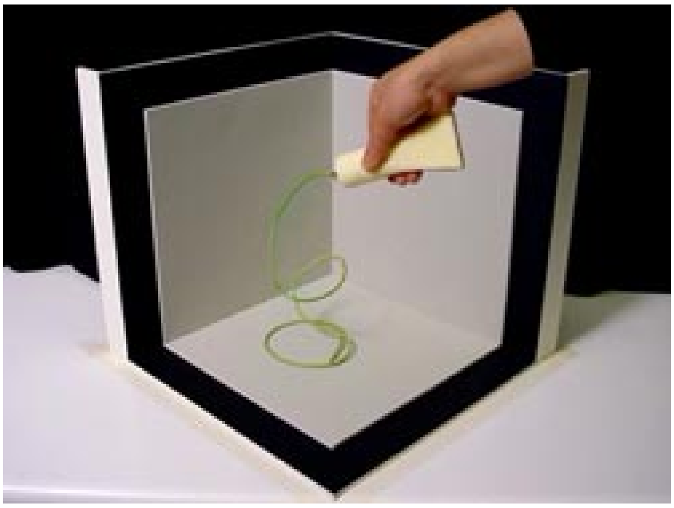

Fig. 2 Cubby^{+}: Squeezing a tube of paint leaves a 3D trace.

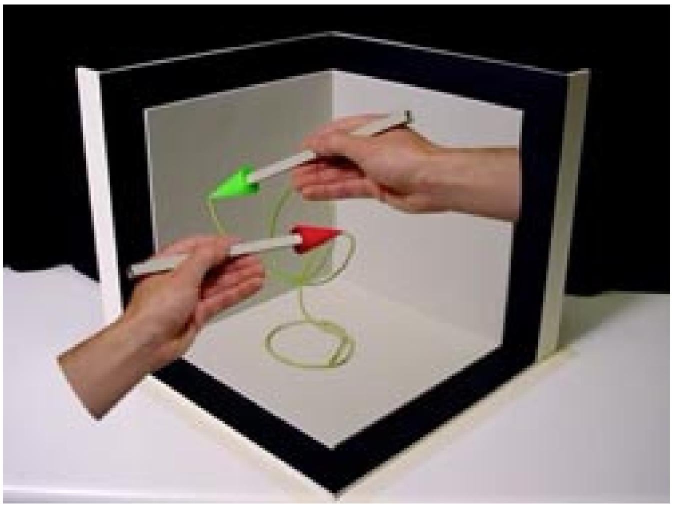

Fig. 3 Cubby^{+}: Two handed input by a mix of tangible and augmented modelling techniques

B The emotionally intelligent alarm clock

Products should not only take our perceptual-motor skills into account, but also our emotional skills, and how we use them in our live. Wensveen [2, 7] proposes a 3-step method for designing adaptive products on the basis of emotionally rich interactions. By emotionally rich interaction he understands interaction that heavily relies on emotion expressed through behaviour. The method addresses three questions (following Picard [8]): What are the relevant emotional aspects for a context for experience? How can a product recognise and express these aspects from the perceptual-motor skills of the user? How should the product adapt its behaviour to the person on the basis of this information? The essence of this approach is that a product not only elicits emotionally expressive actions, but that the feedback is inextricably linked to these actions.

1) The relevant emotional aspects

The first question is answered using the 'probes' technique developed by Gaver, Dunne, and Pacenti [9]. The method is used to capture people's emotional experience of waking up in words, images and sounds.

Wensveen's probe is a package (Figure 4) containing different tasks, coloured pens, question cards, a diary, an audio recorder and a disposable camera. The central task in the probe is a small diary in which the participants are asked to monitor their day during a week. The questions relate to what time they got up, what their plans are for the rest of the day and how their day has been. They have to mark images of facial expressions with differently coloured pens to indicate how they feel about it. Through the categorisation of the facial expressions on arousal and valence he found correlations between the time-related aspects of sleeping and waking up and the emotional experience of persons (for details see [10])

Fig. 4 The probe

The probe also contains a disposable photographic camera and an audio recorder. The participants are asked to explore and capture their experience of waking up by making pictures and recording sounds: sounds and images of themselves, their alarm clock, their bedroom, something pleasant, something irritating, something relaxing or beautiful. They are also asked to record sounds and images with which they want to wake up in different situations.

The probes return rich feedback from each individual, which helps to empathise with each person and give a good feeling for the context in which they wake up. Besides a better feeling for the context they also show the time-related aspects of sleeping and waking up, the degree of urgency of getting up and a person's current mood as important parameters for the expected emotional experience in the morning.

2) How can the product recognise these aspects?

The second question is answered by making an analysis of interaction and the resulting information (for details see [2]). When interacting with a product to put factual information into the system, we also express our emotions to a product. How can we make use of this emotionally rich interaction so the product can adapt to us? Industrial designers can offer an alternative approach to detect and recognise emotions instead of making use of physiological information like blood pressure, skin conductivity and heart rate. In this approach a product is designed in such a way that it elicits bodily actions which are rich in emotional content. The product exploits our perceptual-motor skills. Through our perceptual skills we perceive the possibility of acting in an emotionally expressive way (the product's affordance). And we can use our motor skills to express how we feel. To communicate that it understands us the product must also express that it received the information about the emotional aspects. By giving feedback a well-designed product can communicate that it received the emotional content of the action through inextricably linked feedback. This is visible feedback about what the product knows about us and what it is going to do with this information. The additional feedback should take the third question into consideration: how should the product adapt its behaviour to a person on the basis of this information?

3) How should the product adapt?

To answer the third question, Wensveen proposes the following scenario. How now would such an alarm clock function? Figure 6 describes how person, product and system interact, learn from each other and adapt. The numbers in the text correspond with the numbers in the figure.

1. In the evening a person wants the alarm clock to know at what time she needs to wake up (*t alarm*), how important it is for her to get up (*urgency*) and how she feels at that moment (*mood*). **2.** At the time *t set start* a person starts interacting with the alarm to input the factual information (*t alarm*). While doing this she also expresses how she feels about getting up (*urgency* and *mood*). **3.** A person is finished with setting the alarm at *t set end*. **4.** Because of the way she sets the alarm (interaction) the appearance of the alarm has changed and expresses the *urgency* and *mood* of the person. An LCD display shows the set wake up time (*t alarm*). **5.** The system has internal information about *t set*. It received information about *t alarm* and can roughly calculate the amount of sleep the person will have (*H sleep* = *t alarm* – *t set*). A categorisation of the *urgency* and *mood* is made based on the behavioural parameters, e.g., the time one takes to complete the task of setting the alarm time (*t set end* - *t set start*), the kind and the intensity of the actions and the distribution of the actions over time. **6.** Based on this information and history the alarm will make a decision for an appropriate sound.

It is important that the alarm clock knows the essential information, at what time you need to wake up (t alarm). It is of less importance that the product exactly knows your emotions as long as you can teach the product how you function. In order for the product to learn about the decisions it took, it needs feedback about these decisions. Again through a person's behaviour the product can receive this **7.** The next morning at *t alarm* the alarm produces the chosen sound. **8.** It will take some time (*t reaction*) before a person touches the snooze button at *t sound off start* and releases the button at *t sound off end*. **9.** After pushing the snooze button the expression of the alarm has changed. **10.** Based on the information the system received through *t reaction* and the behavioural parameters of pressing the snooze button *a categorisation of sleepiness* and *appropriateness* of the sound is made. This feedback will contribute to the learning process of the system. **11.** Based on this information and history the system will choose a new alarm sound and an amount of time it will let the person snooze (*t snooze*). **12.** After this snooze time the alarm produces a second sound. **13.** The person can repeat the sequence of pushing the snooze button until she decides to turn the alarm off.

Fig. 5 The working prototype. The user can set the time by sliding the knobs. And he can do this in many different ways, thus expressing his emotion

In the ID-StudioLab we believe in doing *research through design*. Therefor an actual working prototype of an alarm clock was designed and built (Figure 5). This prototype is currently being used to test the approach to the third question.

C The emotion aware office chair

Office chairs also confront us with degrees of freedom problems. Office chairs have many handles to heighten comfort when working. However, people use these handles but a few times, i.e., when the chair is new. The handles are too difficult to use on a regular basis. Typically a person has a feel for his desired body posture. But translating this feeling into actually changing the posture of the chair is too big a bother. Different handles change different "dimensions" of the chair. And people are no good in handling different dimensions separately [5]. The chair requires them to construct a mental model with many degrees of freedom, i.e., to decompose a movement in its Cartesian components. Instead of adjusting the chair when discomfort is experienced, people start to move. The chair does not exploit our perceptual-motor skills.

We studied the relationship between the visible movements of the user in a chair, so-called macro-movements, and user experience. Macro-movements can be seen as indicators of emotion. As people's behaviour changes with their emotional state, macro-movements may reflect that state. In an exploratory experiment, we compared macro-movements with data obtained through questionnaires and physiological measurements.

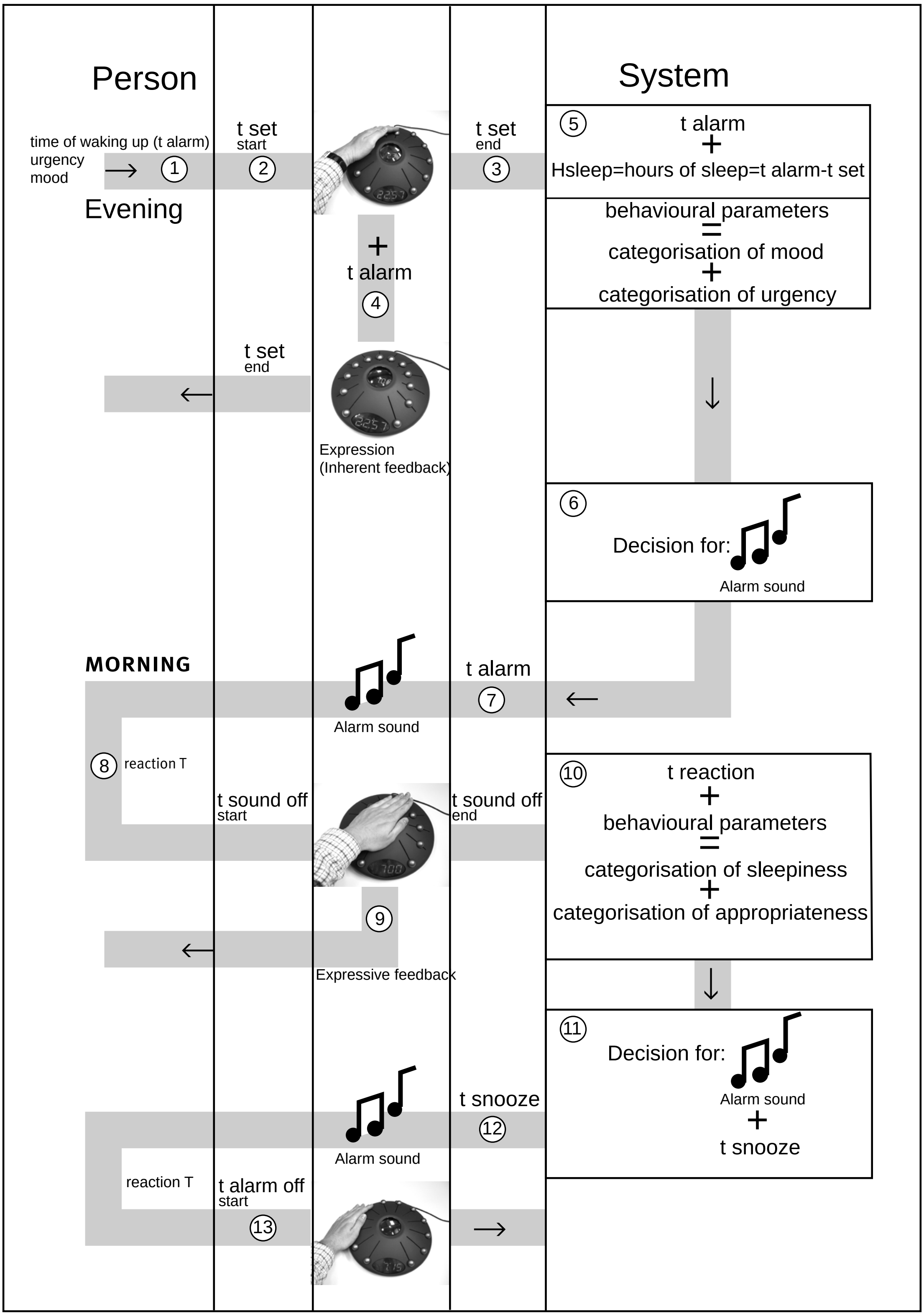

Fig. 6 Interaction between person, product and system

We then designed a conceptual chair that moves between four states, according to the situation the sitter is in and the task at hand. Remember we are designing a context for experience. We chose for two levels of communication with the environment (open-closed) and two levels of personal state (relaxed–concentrated). Furthermore we wanted the chair to be caring, and only dominant to prevent RSI. The chair should then have the technical capability to measure the four resulting situations. Examples and the position of the user for the four situations are given.

1. concentrated and closed
   For example when writing this text, during important telephone conversations.
   The user is sitting up straight and relatively still. The task is done individually and under high pressure
2. concentrated and open
   For example when cleaning your desk, consulting your colleagues.
   The user uses his chair infrequently and uses it more as a leaning support. He rushes around.
   The high priority task is done in collaboration with others under time pressure.
3. relaxed and closed
   For example surfing on the net, checking e-mail, reading.
   The user sits relatively still, straight, or shoved under the table.
4. relaxed and open
   For example taking a coffee break, talking to colleagues, Friday afternoon atmosphere.
   The user moves a lot, open to others and generally leaned back.

It follows from these four situations that the chair should at least be able to measure: leaning forwards, leaning backwards and its intensity, absence of macro-movements, nobody on the chair, orientation towards the desk, distance to the desk. All these measures are technically feasible.

Now that we have defined the four situations, how should the chair react to them? What should the chair do in the four situations?

1. concentrated and closed
   The chair gives a stable seat, whereby arm rests and back support are given. The chair shields the user from the environment as to heighten his concentration and to let his colleagues know (s)he is not to be disturbed.
2. concentrated and open
   The chair supports standing and leaning. The seat is under an angle inclined to the front and fixed.
3. relaxed and closed
   The chair is wobbly, and can be changed from straight up to inclining backwards. It shields off the user.
4. relaxed and open
   The chair is wobbly and can turn, the user can get in and out of the chair easily. It offers a great freedom of use.

As stated above we decided to give the chair a caring character. This means that when a user pushes backwards for a while, the chair will change its current position to the desired position. But caring also implies that sometimes dominant behaviour is required. To prevent RSI the chair will become dynamic (un-fix seat and become wobbly), and thus stimulate the user to move, when (s)he is sitting still too long. And caring also implies sometimes obedient. When the chair wants to change its position, it can always be overruled by simply giving it a jerk.

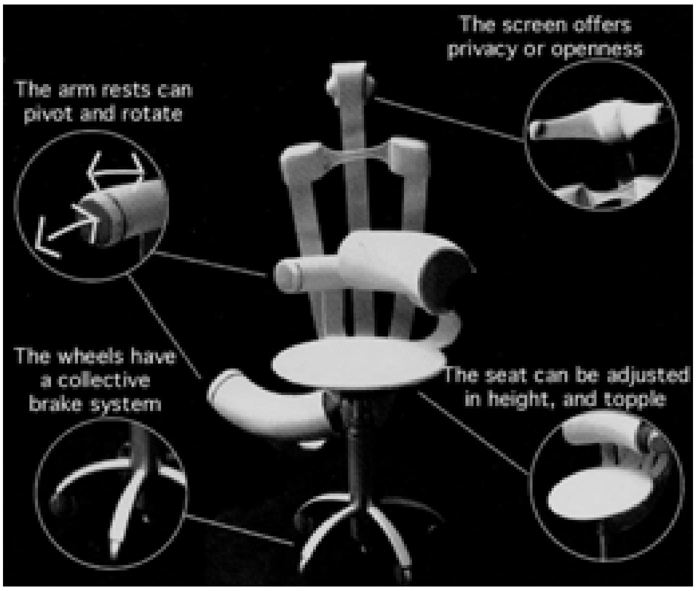

Fig. 7 The conceptual chair (design: Kin Fai Cheung, TU Delft)

Figure 7 shows how such a chair could look. Along with the usual office chair possibilities, this conceptual design offers more. Of course the chair knows things (and might even be equipped with learning capacities). But it has also new capacities. The armrest can be retreated or turned down to serve as a legrest. A screen can shield you from the environment. The chair itself is mounted on a spring so that it can wobble, or, when the spring is de-activated, remain still.

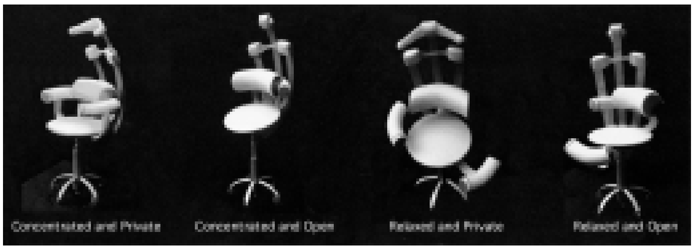

Fig. 8 The chair changes to different positions according to the sitter's state and the task at hand.

Figure 8 shows the different positions the chair alternates between according to the four situations. When concentrated and open, e.g., the chair is high like a stool, does not supports the arms or shields of the head. When relaxed and open the chair is low, turns away from the desk, and affords sitting in unconventional ways. This study is still in an exploratory stage. Further research is needed with respect to the way macro-movements are related to comfort and the state of emotion and also, a better insight is needed in whether the four chosen options are the most functional related to the task to be executed at the office.

Conclusion

Products should show what you can do with them and what they then will do by the way they look, feel, etc. Cooper [1] says that it is ironic that in the information age, products no longer inform us. On the contrary, they make us feel lost and stupid. We are creating a class of computer illiterates and introducing a new form of Apartheid (Chapter 2) because these machines are simply too difficult to use.

In this paper we tried to remedy this problem from the viewpoint of product design. We are not pleading to get rid of all new technology. It brought us plenty of good things. In fact, many of us might not be alive were it not for medical technology. We are pleading to make the technology more human by, from time to time, using our common sense, and by looking around at the real people and real skills.

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