1. PERSONAL MOTIVATION

The work resulting in this book was from the outset fed from two different sources: The first was a feeling of wonder over the complex tasks human beings could carry out without paying any attention to what they were doing; the second was my own frustration when I could not describe why a certain user interface was difficult to use and ought to be changed. Later, a third more sinister aspect arose: I experienced how inattentive use of electronic equipment increased the risk of work related injuries.

1.1 THE WONDER OF INATTENTIVE USE

I did my master thesis in user interface design where I made the user interface for a program for searching in a large database; it was a pretty straightforward job and I did not think about whether the users were inattentive or not. It was only later I started to notice some of the funny things that might happen when someone operates a piece of electronic equipment without paying attention.

I still remember an experience in 1985 or 86. At that time I worked in the Danish PTT, the national telephone company, and participated in a meeting where the representatives of a supplier presented their plans for upgrading a number of switches for the Danish phone system. We were a whole group of people from the Danish PTT including a manager who had brought his own newly acquired laptop computer—in those days something very new and very rare. During the meeting he sat down happily typing his notes directly on the laptop until suddenly he stopped typing and looked up with a very unhappy expression on his face. The representative from the supplier saw that and stopped his presentation: He obviously assumed that he had said something totally unacceptable and tried to figure out what it might be. There was a moment filled with deep silence that the manager was the only one who did not notice. He sat in deep thoughts and pressed finally two buttons, one after the other. A moment later his face lighted up in a big smile and he continued typing. The reason for his unhappiness was not anything in the presentation but some sort of problem with his laptop. Everybody, except him, took a deep breath and the presentation continued.

During my period in the Danish PTT I also worked on the user interface for the national paging system. The user could call the paging system from a normal telephone and a friendly voice would then tell him how to proceed. The work on that system taught me that the users of a system tend to be smarter than the designers: They can quite easily do things the designers hardly can imagine.

A few years later I moved to the, at that time, largest Danish manufacturer of cellular phones and two-way radio equipment, and I was given the opportunity to design the user interface for a hand-portable two-way radio. There was nobody in the company with any deep theoretical knowledge about the behaviour and requirements of users, but I had easy access to sales people and customers who could tell me how they wanted the radio to behave. I did not even have to send for them or set up meetings a long time in advance, they just dropped by and told me what they had on their mind.

In addition, I worked with a number of very experienced development engineers who came with a few suggestions of their own and in addition told me what it actually was possible to implement in the radio.

We ended up with a goal for the user interface for the radio: It should be possible to operate the radio while driving a bicycle in darkness. And we succeeded: Even though the radio had more than 90 programmable functions everybody told us it was easy to operate. However, we got a few complaints over the size: The radio was a big ruggedized type and not built to fit a shirt pocket.

Incidentally, I learned that a heavy radio could be an advantage for a policeman: When he felt threatened, he could and would whack the potential attacker with the radio—if he used his truncheon, he had to write up a report afterwards.

At that time the company I worked for had two addresses in Copenhagen. I had to travel back and forth between them for meetings almost every day and I did not have access to my own car, so I had to use a taxi instead. It was right at the time when taxi companies started to install computer systems that could display the trips for the driver and at the same time use information entered by the driver for dispatching the trips. The result was that I many times experienced how taxi drivers managed to operate their computer terminals while driving on the motor way or waiting at a red light while they explained to me how good the computers were and how difficult it was to make a living out of driving a taxi.

I started to believe it was the exception rather than the rule that users paid attention while they used a piece of communication equipment.

1.2 THE FRUSTRATION OF DESIGN

However, all that fun was too good to continue. The Danish company I worked for was taken over by a large American manufacturer of radio equipment that slowly spread its wings over the entire enterprise.

The take-over changed the work on user interfaces. The Danish company was a comparatively small and flexible one: If it could sell a thousand more units of a radio by making one of the keys on it red instead of green, it would do it. The Americans, by comparison, were used to dominate. They dominated the US market and no matter how they designed their user interfaces, they could still sell their products. They had what I will call a captive audience, but usually they were not close to it.

However, according to what I have been told, they experienced at least one close encounter with a customer. They had designed one radio with very small keys that were very difficult to operate. The radio, however, looked smart and sleek, and they believed they had made a really good user interface, until one day a member of the local fire brigade showed up. He wanted to talk to these F...... people who had designed this F...... radio, and when someone suggested that he described his complaint in more details, he slapped a big glove down on the desk and asked them how the F... they would press these F..... keys while wearing a working glove.

In Europe the American company left the design of the user interface for a new line of products to a team of software engineers together with a marketing guy who, as far as I remember, came with a solid knowledge about how to sell refrigerators. I was at that time product manager for a radio system with digital speech encryption, and I became involved in the new line of products because I had to assure that the functions needed for my systems were included in the new line of products, and I realised that the persons involved in the remaining part of the design did not even know the purposes of all the functions they were specifying.

I behaved something like a pain in the ass and felt the same way, partly because I could see the design was bad but lacked solid arguments telling *why* it was bad.

At that time I thought the American company did an exceptionally bad job on their user interfaces. However, I have later found that similar events occur in other companies.

I was told that a Danish company, that prides itself on its design, first realised that its hi-fi equipment was extremely difficult to operate when an old lady in its home city complained that her remote control continued to malfunction despite repairs. It turned out that the keys on the remote control were placed so close together that she could not avoid pressing two keys simultaneously when she tried to change the channel. That caused the malfunction.

I later found that the problems when the designers are far away from the actual users were described by a designer quoted by Donald A. Norman [1988: 158] in his interesting and entertaining book *The design of everyday things:*

> True, we often know the product too well to envision how people will use it, yet we are separated from the end users by multiple layers of corporate bureaucracy, marketing, customer services, etc. These people believe that they know what the customer wants and feedback from the real world is limited by the filters they impose. If you accept the problem definition (product requirement) from these outside sources without personal investigation you will design an inferior product regardless of your best intentions.

The problems when the designers of a piece of electronic equipment works without any real analysis of the requirements of the users are also described by Norman [1988: 156]:

> There is a big difference between the expertise required to be a designer and that required to be a user. In their work, designers often become expert with the *device* they are designing. Users are often experts at the *task* they are trying to perform with the device. [N.'s italizing]

Norman [1988: 156] continues quoting a designer telling that:

> People, generally engineers or managers, tend to feel that they are humans, therefore they can design something for other humans just as well as the trained interface expert. It's really interesting to watch engineers and computer scientists go about designing a product. They argue and argue about how to do things, generally

> with a sincere desire to do the right thing for the user. But when it comes to assessing the tradeoffs between the user interface and internal resources in a product, they almost always tend to simplify their own life. They will have to do the work, they try to make the internal machine architecture as simple as possible. Internal design elegance sometimes maps to user interface elegance, but not always. Design teams really need vocal advocates for the people who will ultimately use the interface.

I realised, that I only could function as a *vocal advocate* for the users if I either carried a big stick or had a real theoretical knowledge about the requirements of the users. That gave me the final impetus to start the work on this book.

1.3 SELF INFLICTED WOUNDS

When I was about halfway through the work resulting in this book my girlfriend got a working injury, a severe case of carpal tunnel syndrome, from working at a very non-ergonomic computer workstation, and not being any the wiser, I myself got a lighter damage about half a year later.

However, these working accidents made me realise that it is very easy to get injuries during inattentive use of a piece of electronic equipment. When the attention is focused on something else, it is not possible to perceive any beginning pain or discomfort.

Today, I therefore believe that a badly designed piece of electronic equipment not only is a nuisance, it can be dangerous for the health of the user.

2. DEVELOPMENT HISTORY

This chapter gives an overview of the work process leading to this book and describes how the contents are *not* the result of a systematic and orderly process leading directly to the final result.

As described in chapter **1. Personal motivation**, I was fed up with products that clearly were not designed for human beings, and I had had enough of persons who thought everybody could design a good user interface if only they were part of a committee.

In the summer of 1992 I therefore wanted to do something, but did not at first realise *what* I wanted to do.

Originally, I thought about working on mathematical models of signalling in communication systems. Fortunately, that project became impossible, and I started to think about what to do if I just wanted to have fun. The result was *Inattentive Use,* the theme of this book, and I had the good luck of meeting a tutor—Peter Naur—for a Ph.D. thesis who thought an investigation of *Inattentive Use* might lead to some interesting insights, so I could start the work on a Ph.D. thesis in december 1992.

However, I had no idea what I should do about the *Inattentive Use* so I started to draw little boxes while I read about experiments with mice running through mazes and signals running through nerves, and I could probably have spend three happy years in the same manner if my tutor had not ordered me to start reading William James, founder of the cognitive psychology.

In the beginning reading William James was very tough—I had to take frequent breaks and lie still with closed eyes when I was overwhelmed with his 1280 pages of massive words.

At the same time I had no grant and could not combine a decent job with the reading of William James, so I started working as a free-lance technical writer.

I spend a little more than one year in that manner—reading William James and writing user guides and a book about the use of cellular phones.

At that stage, I felt a need for some experiments; they should primarily provide information about the relation between patterns of thought and the perception of an external object. I knew that one of the secrets of successful bridge playing is the drilling of some fairly simple guidelines for bidding and playing, so it was fairly obvious to make an experiment with bridge players. The experiment had to be in the evening in march 1994, five kilometres from where I lived, and I had no car. When I had gone half the way on bicycle and was drenched by the rain, the whole enterprise seemed totally silly, and if it had not been even more silly to turn around when I was wet already, I would have gone home immediately. However, I made the experiment and got some useful results.

Shortly after, in june 1994, there was a conference in Copenhagen where I was asked to present a paper. That was very valuable for me: I had to start thinking about what I already knew and what I wanted to find out, and I decided to get a decent spell checker for my computer. Unfortunately, I could not find a decent contents checker.

I was still reading William James, but I wanted to find something more recent or at least something that looked more like a good clean technical model—something with square boxes, and words like *signals* and *processors* and *voting algorithms*.

The result was that I spend the time fighting with my tutor and digging myself deeper and deeper down in mud, until at last, in january 1995, I had a disastrous meeting with him: My working papers documented clearly that I had no idea about what to do with the project—and I had to admit that I during the past months had produced a significant amount of total garbage.

I hit the bottom, rebounded and swam towards the light. Something had snapped and I began to see a pattern in what I was doing and in all the different stuff I had read. At that stage I started to write chapter **7.**, the first part of the book as it appears today.

Then everything moved fast: I knew what I was looking for and I had the tools I needed for looking for it. Incidentally, I learned that approximately half of the times psychologists describe the results of experiments made by other psychologists, they misrepresent the results, so if the results shall be used for something serious it is necessary to go back and read the undiluted version.

In six months I found and wrote together most of the theory while I made user guides for a number of interesting machines, including a bulldozer and a heavy duty truck.

At that stage the speed of work slowed down somewhat.

As a result of the work I had made an invention, and an invention tends to influence human thinking in the same manner as rumours about gold in a nearby river. Therefore, I stopped thinking about the writing and made some experiments that confirmed the invention *technically* was a success. Later on it turned out that the invention *commercially* was no success.

At the same time I reached a stage where I wanted to demonstrate the ideas—preferably by using the different design principles in the design of something that resembled user interfaces for possible pieces of electronic equipment.

First, I planned to make a simulated phone with 37 or 48 different parameters whose influences I wanted to determine. The result was total confusion: It might be possible to use the result as a case study in something, but it could not be used for designing any meaningful piece of equipment.

After that I made an extremely disorderly description of a second phone. I believe the phone combined all the different principles for a phone for inattentive use, but it had to be a matter of belief, because even I found the description difficult to understand.

At the end I worked on three things in parallel: I tried to find ways of applying the different design principles, I designed some working user interfaces, and I found and described methods that could make a successful design easier.

And right now I am sitting late in the evening, with an almost completed book, a sink full of dirty dishes and a peculiar peace of mind.

February 3, 1996

[The editing of this project was completed in April 1996. For that reason, the date above the even numbered pages is *April 1996*.]

> Every Scientific conception is in the first instance a 'spontaneous variation' in someone's brain. For one that proves useful and applicable there are a thousand that perish through their worthlessness. Their genesis is strictly akin to that of the flashes of poetry and sallies of wit to which the instable brain-paths equally give rise. But whereas the poetry and wit (like the science of the ancients) are their 'own excuse for being,' and have to run the gauntlet of no farther test, the 'scientific' conceptions must prove their worth by being 'verified'.
>
> William James [1890: 1232]

3. INATTENTIVE USE MAY BE THE RULE RATHER THAN THE EXCEPTION

Users are often forced to use a piece of electronic equipment without paying attention to it:

- If the user must keep his attention on the environment while operating the equipment.
- If the user must keep in touch with another person while operating the equipment.
- When the user focuses his attention on the task and not on the equipment.
- When the user is tired, so he cannot focus his attention.

In spite of that, most people probably believe that they normally pay attention to what they are doing, and that other persons ought to do the same.

It can in fact be a little bit disconcerting when we experience someone who operates a piece of electronic equipment while carrying out some other activity. The situation may appear inherently dangerous and many people feel that it ought to be stopped, if not by their own parental authority then by the application of proper laws and regulations.

One example is the situation when someone operates a cellular phone while driving a car or while walking down the street. I have observed that drivers of other cars or other persons walking the sidewalk tend to get agitated and even though it is very unlikely that any traffic accidents can be attributed to the use of cellular phones, it is regularly proposed to ban the use of cellular phones while driving a car.

In fact, users of electronic equipment very often depend on their ability to do two tasks in parallel.

That is in particular apparent for users of communication equipment: The use of such equipment is very often time-critical so the user cannot postpone the use of it.

If, for instance, a policeman or security guard encounters a group of bored young men equipped with chains, knifes and similar equipment for inflicting serious bodily damage, it is highly desirable that the enforcer of the law can focus his visual attention on the group while operating his radio.

Another, more peaceful example is the use of a cellular phone: If the user must focus his undivided attention on the phone while he receives a call, it is in many circumstances impossible to receive a call, and the advantage of having a cellular phone is small or negligible.

In other cases, it is necessary to work intermittently on two different tasks. One example is the case where the user of the equipment is providing some service for a client.

When a travel agent is making a booking for a customer he must talk with the customer and intermittently operate the terminal used for making the booking. In that case it is both impolite and impractical if he continuously focuses his undivided attention on the terminal.

In other situations the user can operate the equipment without any external disturbances, but in order to complete the task he must focus his attention on the task and not on the equipment he uses to carry it out. Miyata and Norman [1986: 271] describe one such case where unskilled typists cannot focus their attention on the task of writing a text:

> They must focus so much attention upon the typing that it becomes the foregrounded activity, interrupting and suspending the development of ideas. This leads to severe disruption of the task of idea development, and as a result, many nonskilled typists cannot compose at the keyboard, but prefer other means of composition, one where the translation of thoughts to symbols is more automatic (for instance dictation or handwriting).

Even when the users primary task is the operation of a piece of equipment and he is allowed to do it in comparative peace and quiet, it is impossible for the user to pay continuous attention to the equipment for a prolonged period of time. Wagner [1988: 70-71] reports on a number of experiments describing how the operators vigilance, his ability to concentrate his attention on the task, varies over time:

> After the first 30 minutes there is a sharp increase in the number of missed signals with an eventual planing out after approximately 60 minutes.
> In addition, vigilance performance is also relative to the time of the day (shift work) and our circadian rhythm. Generally vigilance is at its lowest ebb early in the morning and rises to a peak in the evening.

In one of the experiments described by Wagner [1988: 71] the proportion of missed signals rose from 15 % to 30 % after 30 min of vigilance.

I will conclude that it only is possible for the user to continuously focus his attention on the equipment he is operating if all of the following requirements are fulfilled:

- The user can operate the equipment without any external disturbances.
- The user does not need any information from other persons or from the environment while he operates the equipment.
- The user has sufficient time to stop other activities and focus his attention on the equipment whenever it seems necessary.
- The user is well rested and can take a break at least every 30 minutes.

In all other cases the user is inattentive to the equipment part of the time he operates it.

This means that *if a piece of electronic equipment shall be used by human beings, the design must take into account that the user at least occasionally is inattentive while operating the equipment.*

4. TOPICS DESCRIBED IN THIS BOOK

This chapter describes the goals of this book—the questions I shall answer in it. In addition, the chapter includes a list over related topics that are *not* addressed in it.

4.1 OVERALL GOAL OF THE BOOK

The examples in chapter **1. Personal motivation** indicate that inattention makes it more difficult to use a piece of electronic equipment. I will therefore formulate the following three points that I shall prove or disprove in this book:

- When the user is inattentive to the equipment it becomes more difficult for him to carry out any useful action:
  - The users perception of the equipment may be erroneous.
  - The user may not become aware that he in a particular moment must make a conscious decision. Instead of making a conscious decision he will then act out of habit and make an error.
  - Even if the user perceives the state of the equipment he may act in a manner that does not lead to the proper result.

- When the equipment draws the attention of the user, he will not always be aware of events happening in his environment and his actions or personal well being can therefore be degraded.

- However, it is possible to design equipment where the limitations of the user are taken into consideration, minimising the problems caused by the user not paying full attention to the equipment when using it, and the problems caused by the equipment drawing the full attention of the user when he should be aware of the environment.

In order to prove or disprove the three points above I will describe the specific limitations of the user when he is inattentive, and I will describe how a piece of electronic equipment can be designed such that the consequences of the user being inattentive are minimised.

Some of the characteristics of a piece of electronic equipment cannot be specified beforehand but evolve gradually during the design process, it is therefore also necessary to describe some special precautions that must be taken during the design process.

4.2 SUBGOALS FOR PARTS OF THE BOOK

The different parts of the book have the following subgoals:

- *Chapter 6* shall describe the methods that can be used for describing the thoughts and activities of the user.
- *Chapter 7* shall describe the elements in the stream of thought, what attention is, how it moves from one thing to another, and the possible types of inattention.
- *Chapters 8, 9, 10 and 11* shall describe perception, thinking and physical actions when not paying attention.
- *Chapter 12* shall describe the special requirements for a piece of communication equipment for inattentive use
- *Chapter 13* shall describe how the usability of a piece of electronic equipment for inattentive use can be evaluated.
- *Chapters 14 and 15* shall describe how equipment for inattentive use can be designed.

4.3 TOPICS NOT ADDRESSED IN THE BOOK

In order to reduce the size of the book, I am leaving out a number of topics:

- The requirements for equipment for attentive use is already well described in other literature—I will therefore focus on the requirements for electronic equipment for inattentive use and only discuss the requirements for equipment for attentive use when necessary.
- I will not discuss how stress and fatigue influence the attention of the user. That discussion is not necessary for the goal of the book.
- With a few exceptions, I will not discuss what the minimal standard can be for equipment for inattentive use: The goal of this book is to describe the best possible design of equipment.
- I will not discuss how electronic equipment can be adapted to users with reduced sight, hearing, motoric or mental functions or who are functionally illiterate. The requirements for equipment for inattentive use by users with disabilities are similar to the requirements for equipment for normal users, and the goals of the book can be fulfilled without discussing how the needs of users with disabilities can be met. Given that, the figures given by Brandt [1994: 445] from the Danish Centre for technical Aids for Rehabilitation and Education indicate that equipment fulfilling the requirements described in this book can still be used by approx. 80 % of the adult population.

4.4 CONCLUSION ON THE GOALS OF THE BOOK

The chapters 1**5. Unsolved issues** and **16. Conclusion** shall describe to what extent the goals and subgoals listed in this chapter are fulfilled.

5. DEFINITION OF TERMS

In this book a number of terms are used in ways that are slightly different from the normal usage. These terms are defined here:

A: *Action* includes both mental actions, for instance a decision, and physical actions.

- *Association* is only used for designating the association from one object of thought to another, see **7.3 The changing stream of thought** for a more detailed description of the meaning of association.
- *Auto answer* unhooks—opens the microphone and loudspeaker—in a phone when it has been ringing for a pre-set period of time.
- *Automatic call transfer* transfers an incoming call to another phone if a pre-set condition is met, for instance if the called phone has not been answered within a pre-set period of time.
- *Automatic redial:* When a phone number is occupied this function can be set so that the phone automatically makes another call to the number a pre-set period of time later.

B: *Browsing* and *trial and error* are used respectively to designate the search for a specific element in the equipment by looking one after the other on a number of elements and to designate the search for a function which operation gives a specific result by trying to operate the different functions.

C: *Call waiting* tells the user of a phone that there is a waiting call and makes it possible for him to switch back and forth between the currently active call and the waiting call.

- *Communication equipment* includes both the terminals operated by users and any additional equipment used for passing the signals from one terminal to another. See chapter **12. Unreliable use of communication equipment** for a more detailed definition.
- *Conference Call:* Phone call where three or more persons, each using a phone, can talk together.

D: *Designer:* Person defining the different parts of the user interface and their functions, similar to an engineer designing an electronic circuit. The person defining the look and appearance of the equipment is termed an *appearance designer*.

E: *Electronic Equipment:* Includes all types of electronic equipment, for instance communication equipment, kitchen timers and hard- and software for information processing.

- *Element:* Part of the equipment that can be perceived by the user. The word *element* is *not* used for any things in the users environment outside the equipment.

M: *Manual call transfer* makes it possible for the user of a phone to transfer an active call to another phone.

- *Menu* or *scrolling menu:* List over items, the user can see one by one, scroll in and select an element in.

N: *Number list:* List over pre-coded phone numbers, or over names or addresses of other subscribers the user of a phone can select as receiver of a call.

O: *Object* is only used for designating *objects of thought,* not for designating any things outside the thoughts of the user.

P: *Perception* consists of sensing something *and* getting some sort of meaning out of it.

R: *Remote user* is someone the actual user of a piece of communication equipment communicates with.

- *Review* is a process where one or more persons goes through the descriptions of a user interface in order to evaluate the usability of each part.

S: *Sensation* is something sensed.

- *Short message* is a written message, normally on less than 160 characters, that can be transmitted or received by communication equipment.
- *Short number facility* or *list* makes it possible for the user to press a special key, for instance #, and then enter a two- or three-digit number instead of the full phone number. The full phone number is found in the list through a reference to the entered two or three-digit number, and a call is then made to the full phone number.
- *State* is always identified by a separate text or designator by the equipment. The change of a parameter in the equipment does therefore not necessarily lead to a change in the state of the equipment.

T: *Task* consists of a number of actions the user carries out in order to reach a result. When using a piece of electronic equipment some, but not all of the actions, consists of operating that equipment.

- *Terminal* is a piece of communication equipment directly operated by the user.

U: *Useful action* is an action that leads to an outcome desired by the user or otherwise considered useful and at least accepted by the user. It therefore includes all types of work, but excludes actions the user does not know the consequences of.

- *User* : In order to minimise any confusion, the user is consistently described as *he,* even though I am well aware that female persons also may operate the equipment.

W: *We* is used in statements that presumably are true for all human beings without any special disabilities.

6. METHODS BETWEEN HARD FACTS AND SOFT FEELINGS

This chapter describes why a theoretical basis is necessary when designing a user interface for inattentive use, and it describes the problems when assuming a computer-inspired model of the human thinking. After that, the three main sources of knowledge about the behaviour of human beings in general and the inattentive user in particular are described:

- Research assuming an information-processing model of the human mind
- Neurophysiological results
- William James's description of the human mind

It is finally described how the applicability of the results is ensured.

During the evaluation of the different methods the concern is not primarily whether or not the methods yield so-called true results or whether the results are in conflict with any philosophical considerations. The main and only criteria in the choice of methods is whether or not they are suitable for defining the requirements for equipment for inattentive use.

6.1 THE NEED OF A THEORETICAL BASIS

Some people believe that a good user interface can be made simply by using common sense.

That method of design is similar to the one used by the traditional craftsman that step by step improved his product based on information from his customers or his own experiences when using the product. Unfortunately, it is very difficult to apply the same method to mass produced items: The development, programming and tooling of a new product is costly, and in order to recuperate the costs it is necessary to manufacture a large number of units before any modifications are made. In addition, the user will often first start using the product when it is released for sale and even then it can take months before the designer receives any comments on its use. The result is that whereas a traditional craftsman can implement a small improvement every month, the manufacturer of a piece of electronic equipment at the most can implement any necessary improvements only once every year.

In addition, when we are not paying attention, we are not behaving according to common sense. I will give one example [own observation]:

> I am using a cellular phone that is equipped with a Pin—Personal Identification Number—code. When I turn it on, I shall enter a number and press the M for Memory key before I can make a call. While using the phone I shall press the same M key after I have entered a number that I want to store in the phone. The procedure is a little bit different when I am making a call: I shall then enter the number to be called and after that press the UNHOOK key. These functions seem very easy to use. However, when I do not pay attention, I press the UNHOOK key instead of the M key half of the times I have turned the radio on and entered the Pin code.

This could be a coincidence, so I will give a similar example [own observation]:

> Two eight-digit phone numbers that I call very often have the first two digits in common. When I start entering one of the numbers, I often end up entering the last six digits of the other number.

Such errors are typical of the inattentive use of electronic equipment, and they defy common sense so they cannot be taken into consideration by a designer who operates according to his own common sense while sitting down in peace and quiet defining the structure of the user interface for a piece of electronic equipment.

It is sometimes claimed that the best course is simply to let the users decide:

- In marketing lore, it is often assumed that most problems can be solved by asking the customers.
- When new equipment, for instance computers, is introduced into an organisation, it can be a labour relations issue that the group of users shall influence the choice of equipment.
- In lack of any good theories or design guidelines the best solution may be to leave the decision to the customers.

If all users always knew how a piece of equipment for their use should be designed, all the decisions could be left to a group of users and there was no need of any theoretical understanding of the requirements for a good user interface.

However, the requirements stated by users are often erroneous.

Some users want equipment that is difficult to use, so that they can demonstrate their skills operating it. I have myself experienced a case of that [own observation]:

> I discussed computers with two boys who were approx. 16 years old. They laughed when I began talking about a computer that was easy to use. They indicated that if you wanted a computer that was easy to use it must be because you were not very smart.

Norman [1992: 177] describes a similar experience:

> ..."My secretaries persist only because I insist," I said, pointing out the obscure commands and lack of standards for terminology and procedure, to say nothing of the ways by which Unix could destroy months of work through a moment's mishap... I was attacked by hundreds of professional programmers across the country. If I didn't approve of Unix, they told me, I had no business using it.

In other cases users may prefer equipment that is difficult to use because it improves their job security when other persons only with great difficulty can learn to operate the equipment. That has for instance been the case for type-setting equipment: When that equipment only could be operated by someone who had learned a large number of codes for the different functions, the typesetting for a newspaper could only be done by skilled typographers and not by secretaries or directly by the journalists.

Some users feel ashamed when they cannot operate the equipment properly. They will therefore not report all problems they encounter while operating the equipment. Norman [1988: 35] has the following story:

> ...we went together to some of the secretaries and asked them whether they had ever hit the "return" key when they should have hit "enter." And did they ever lose their work as a result?
> "Oh yes," said the secretaries, "we do that a lot."
> "Well, how come nobody ever said anything about it?" we asked the secretaries. After all, they were encouraged to report all problems with the system.
> The reason was simple: when the system stopped working or did something strange, the secretaries dutifully reported it as a problem. But when they made the "return" versus "enter" error, they blamed themselves. After all, they had been told what to do. They had simply erred.

In some cases users do not realise that they are making errors [own observation]:

> When I worked on an article on user guides, I did a thorough analysis of the washing machine I had been using for more than a year, and I found that I never had used the proper two-key setting for washing non-iron shirts. During that period I had ruined a number of shirts without suspecting any error in my operation of the washing machine— I thought the shirts were of such a poor quality that they inevitably became wrinkled after having been washed a few times.

Incidentally, I later found out that the user instructions for most washing machines are erroneous—if they are followed to the letter, the clothes may be ruined.

If the users are very dissatisfied with a piece of equipment, their complaints can become almost a ritual. That can for instance happen when a product is so badly designed that almost everybody gives up before learning to operate it, and it can happen when equipment is introduced in an organisation without consulting the users. I experienced that when working with radio equipment [own observation]: When the users in an organisation had decided that the equipment could not be used, it was next to impossible to identify what the actual problems were.

It is finally possible that the information does not come from real users but only from pseudo users. I have experienced that salesmen can be such pseudo users [own observation]: If a salesman had offered a specific feature to a customer in order to close a sale, he often came back and told the designers of the equipment that the particular feature was essential for use of the equipment. In other cases journalists can be such pseudo users when they review new equipment, because it is the exception rather than the rule that a journalist finds time for using the equipment for a prolonged period of time before making a review. A recent example was in an article in the Danish newspaper Politiken [1995: sec. 3, p.1]. The journalist described a particular automatic ticket machine as easy to use, even though parts of the design are illogical, and it is quite common to see persons having difficulty using it.

I will conclude that it is impossible to design a good user interface for inattentive use only by the use of common sense and information from the user. A deeper understanding of how the user acts and reacts during inattentive use is also necessary, and in the following I shall therefore describe the basis for such a deeper understanding.

6.2 USE OF COMPUTER-INSPIRED MODELS OF THE USERS MENTAL PROCESSES

A large part of the existing work on user interfaces is seemingly without any theoretical foundation. However, this does not imply that the persons working on the principles for user interfaces know no theories or models of the behaviour of the user.

The problem is that the majority of the theories or models are based on superficial similarities between human thinking and the operation of a computer. These models cannot fit the actual problems, so in order to avoid total confusion the creators of these models must limit their own use of them.

As an example I will use an article by Miyata and Norman [1986: 265-284]. They have made the only previous study I have encountered that describes the problems related to inattentive use of electronic equipment. They describe their computer-inspired model in more details than usual, and the limitations of the computer-inspired model are therefore apparent.

Miyata and Norman [1986: 266] describe their model of human thinking as follows:

> A reasonably approximate model of the Human Information Processing system divides processing structure into conscious and subconscious operations and memory into two classes of structure, short- and long- term memory (STM and LTM). In this approximate model, we treat working memory and STM as the same structures, and in the chapter we primarily refer to working memory. For current purposes, all that matters about STM is to recognize its limited capacity—for example as described by the "5-slot model of memory"..., working memory can be thought of as having a capacity for only 5 items at any one time. Long-term memory (LTM) consists of organized knowledge units called schemas, that structure knowledge and also contain the procedural knowledge information necessary to control actions.

Miyata and Norman's model is based on the assumption that if a person does two tasks in parallel, one of them will consist of a "conscious" activity whereas the other will consist of a "subconscious" activity, that is some sort of activity that the person is neither conscious nor aware of.

Later in the article Miyata and Norman [1986: 267] write:

> The other system, subconscious control, seems to develop specialized procedures for tasks that are relatively independent of one another. As a result, we can treat subconsciously performed tasks as resource unlimited, so that several can be done simultaneously (as long as they do not require joint use of the limbs or sensory organs)...
> The conscious limitations do not preclude a person from simultaneous conduct of subconscious or automatized activities...

And they (Miyata and Norman) [1986: 271] continue:

> Backgrounded activities result whenever a task is performed "automatically" without conscious supervision, thus allowing other activities to be done at the same time.

Miyata and Norman equate "subconscious operations", "backgrounded activities" and an activity that is performed "automatically". The descriptions above can therefore be interpreted in one of two ways:

- As the activity in itself being subconscious, that is performed without the person doing it being aware of its going on. That interpretation does not fit the everyday experience: If I for instance is typing something while speaking, where the typing is a "backgrounded activity" I will normally be aware of the fact that I am typing even though I do not pay attention to it.
- As the task being under "subconscious control" even though the person doing it is conscious or aware of the action going on. However, that interpretation cannot result in any meaningful distinction when a simultaneous "conscious" activity only consists of the thinking about something, since it in general is not possible to control consciously where the associations in a stream of thought lead. In that case both the "foregrounded" or "conscious" activity and the "backgrounded" or "subconscious" activity can be described as being under "subconscious control".

It is not possible to interpret Miyata and Norman's description in a manner that fits our everyday experience, and part of the reason may be that Miyata and Norman's model excludes the distinction between being aware of something and paying attention to it.

However, Miyata and Norman [1986: 269, 270] try to describe the difference between being aware of something and paying attention to it by introducing two other computer-inspired terms, "Task-driven processing" and "Interrupt-driven processing":

> In a task-driven state, people are so occupied by the processing of the ongoing task that there is apt to be an effective decrease in sensitivity to events external to the activity... Although people remain aware of the existence of activity around them while concentrating upon a task (while under task-driven processing), they can do only minimal processing of this external activity, not enough to draw meanings and implications.
> ...The phrase "interrupt-driven" processing refers to the situation in which people are especially sensitive to extraneous events, easily distracted by extraneous thoughts and external signals... Internal

> interruptions occur as a natural result of thought, as new ideas and new topics get suggested by the processing for the current topic. The result can be captured by some other thought, perhaps unrelated to the task that is supposedly being performed.

Miyata and Norman describe here that the reduced perception of something that we do not pay attention to belongs to a "task-driven state" of mind, and they describe that associations from one object of thought to another belongs to another "interrupt driven" state of mind. According to Miyata and Norman's description these two phenomenas should therefore be mutually exclusive and cannot occur in the same state of mind or in the same situation. That description does not fit our everyday experience, where it indeed is possible that our perception of the surroundings are reduced while one object in our stream of thought is associated to another and yet to another.

When trying to describe the normal process of thinking Miyata and Norman [1986: 270] introduce the term "extraneous thoughts and external signals", where they imply that some of the users thoughts are external, probably in relation to what they consider the real thoughts of the user. That viewpoint is definitely in conflict with our everyday experience: We normally experience our mind as one unity, even when we are daydreaming or making associations to topics that are completely unrelated to the task we are supposed to carry out.

I will conclude on the above that Miyata and Norman's model conflicts with our everyday experience, and when Miyata and Norman tries to explain the difference between their model and one aspect of our everyday experience it only leads to another more detailed model that cannot be reconciled with our everyday experience.

However, these are not the only problems in Miyata and Norman's model. Norman [1986: 55] gives earlier a description of what he calls the STM or short-term memory that is similar to the one in Miyata and Norman's model: "Short-term memory consists of 5 slots, each capable of holding one item...".

Norman's description continues from there and lists some other characteristics of the so-called short term memory or STM, and Norman [1986: 55] then makes the following comment to the description: "Although the approximate model is clearly wrong in all its details, in most practical applications the details of the STM do not matter: This approximate model can be very valuable."

However, the described model consists of a number of details, so if all details are wrong, it is highly likely that the model in itself is wrong.

Miyata and Norman's model describes finally what they call our "long-term memory" consisting of "organized knowledge units called schemas", and they (Norman and Miyata) [1986: 266] write that they "...are under active study and there is no general solution of the appropriate theoretical mechanism."

I have not found any experiments that supports the existence of a "long-term memory" consisting of such "organised knowledge units" in the mind of the user, and it is likely that they cannot be defined in a manner that covers all the different types of objects that a human being can think about.

The points listed so far relate each only to one part of Miyata and Norman's model of the users thinking and behaviour. In addition to these points it is a more basic and serious problem that the model excludes all abilities that the user does not share with a computer: The user can for instance consider, feel and evaluate and sense a meaning in the processed information. One consequence of the computer-inspired model of human thinking is that even though Miyata and Norman [1986: 268] state that the user must make some "planning" of the activities, they cannot give any clue to what such a "planning" might consist of.

It may be possible to describe some of the limitations of the user within a computer-inspired model, but within the model it cannot be described how the user overcomes these limitations, or even why it is the user that operates the computer and not the computer that operates the user.

In the last part of their article Miyata and Norman [1986: 275-284] make a number of suggestions on how to design a user interface that supports multiple activities. They could, however, have made the same suggestions without any model of human thinking: The model of human thinking stated by Miyata and Norman do not contribute to the results of their article.

It is perhaps understandable that Mayhew [1992: 93] later can quote Norman [1987] for the following statement:

> We must ... discard our hopes of finding neat, elegant, mental models, but instead learn to understand the messy, sloppy, incomplete, and indistinct structures that people actually have.

Norman is obviously aware of the limitations of computer-inspired models and he is one of the most experienced cognitive psychologist working on the principles of design of user interfaces. The article by Miyata and Norman [1986] indicates therefore that it is very difficult if not actually impossible to base a detailed description of the users actions and thinking on a computer-inspired model.

In spite of that, use of simplified computer-inspired models similar to the one used in Miyata and Norman [1986] can be found in Norman [1988: 43-53] and in Mayhew [1992: 30-43] whereas Suchman [1987: 178-185] first discards such a computer based model of the user and then ends up discussing how to construct it.

There seem to be an almost universal human disposition towards finding some sort of mechanical model that ostensibly explains why human beings think and behave as they do. The successes of books by Douglas Hofstadter [1979] and Tor Nørretranders [1991] and a number of popular self-help books support that notion.

As described in chapter **2. Development history** I have myself very strongly during the work felt an urge towards stating some sort of model that reduces the thinking of the user so that it fits into a number of boxes of—for me—comfortable size.

I have, however, found that the use of computer-inspired models of human thinking in general does more harm than good when describing the requirements for user interfaces: *The computer-inspired models add no new insight, but tend to obscure and restrict the description of the capabilities of the user.* At the same time they may appear very attractive, and it is therefore necessary to make a concerted effort to avoid them.

6.3 THE VALUE OF OBSERVATIONS MADE FROM AN INFORMATION-PROCESSING VIEWPOINT

When the information-processing approach is used, human thinking and behaviour is described as being the result of some information-processing activity. It is assumed that human thinking consists of the storage, communication and processing of packages of information, and that it in principle is possible to determine both the structure and size of each such information package.

The use of computer-inspired models of human thinking is part of the information-processing approach, but it includes much more.

The definition of an information-processing approach fits the different directions within contemporary cognitive psychology as described by Eyseneck and Keane [1990: 7-34], and it covers therefore a number of different schools of cognitive psychology including semantic networks, production systems and connectionist networks as described by Eyseneck and Keane [1990: 16-23].

This means that a large part of the available research on user interfaces and on human thinking and behaviour in general during the last 40 years has been based on the information-processing approach. The result is a very large amount of very detailed observations that can be used for describing the inattentive use of electronic equipment.

However, the use of research results based on the information-processing approach raises some problems.

When the information-processing approach is used, the user is seen as a sort of very advanced computer or information processor, and the researchers will often try to formulate their results in a manner that supports that notion. In some cases it is therefore difficult to separate the experimental results from the interpretation of them, and even though a number of different interpretations often fits the results equally well, no experiments are set up that tests the validity of the interpretation chosen by the researcher. Examples of that can be found in Shallice [1982: 199-209] and in Schank and Abelson's [1977: 37-67] much quoted description of so-called scripts. In some cases a model is even offered with no empirical evidence whatsoever, that is for instance the case for Baar's [1988] description of the working of the human consciousness.

Such descriptions do not follow sound scientific principles: It is normally advantageous if Occam's Razor is applied as judiciously as possible, so that the results depend as little as possible on assumptions.

When the information-processing approach is used, a concerted effort is therefore necessary for separating the facts—results and observations—from the fiction—the models with none or only a very weak basis in results and observations.

The information-processing models of human thinking are all simplified, so each model can at the most only cover the results of a few experiments or one small aspect of human thinking. This means that a total description of human thinking and behaviour cannot be based on the results obtained by using the information-processing approach. Eyseneck and Keane [1990: 461], who are proponents of seeing the cognitive processes as some sort of information processing, writes:

> There is a strong sense in which thinking research has failed to capture the dynamic qualities of everyday thoughts. We think this is the result of the often-lamented, fragmented nature of the field. As researchers have tried to come to grips with the phenomena of thinking. [*sic*] They have carved them up into bite-sized chunks and undone a wholistic [*sic*] conception of a set of processes working together. We have said a number of times that many of the divisions in the field are created by researchers rather than inherent in the phenomena. In everyday life we use a rich mixture of deductive and inductive reasoning and problem-solving strategies. The one shades imperceptibly into the other.

I will conclude that specific results and observations obtained by researchers using the information-processing approach can be used in the following. However, the information-processing approach cannot be used as a basis for a coherent description of the inattentive use of electronic equipment.

6.4 THE VALUE OF OBSERVATIONS MADE FROM A NEUROPHYSIOLOGICAL VIEWPOINT

The neurophysiological approach makes it possible to get information about what happens in the brain or nerves of a person when he does a particular activity. Several different types of information are available:

- Material describing the consequences of specific brain damages. That was the first material available for determining how different human capabilities were related to different parts of the brain.
- Anatomical information describing for instance the structure of the eye and the function of each type of nerves in it.
- Information about measured brain activity and its correlation with what the person reports he experiences or observations of the activity that he does.

One result of the neurophysiological approach is that more and more areas are found where the function of the human brain differs from the function of a computer or other electronic equipment.

An example is the function of the vision as described by Crick [1994: 91-159] where almost every detail functions in a different manner than the one expected from a computer-based model.

The human brain is the result of a very long evolutionary process, and it seems that the probability of that at any point taking the same direction as the most feasible one when building digital computers is extremely slight. It is possible this is the primary reason that all attempts of modelling human thinking with computer-based models are doomed to fail.

The neurophysiological approach makes it possible to describe a range of phenomenas that we cannot experience directly, for instance details in the perception, interference between different activities done at the same time, and the timing and delays when we initiate an action.

However, the neurophysiological approach cannot result in a more detailed description of the human thinking itself. Marr [1982: 15], who was one the leading researchers on vision, and whose work depended on the neurophysiological approach, wrote:

> ...Suppose, for example, that one actually found the apocryphal grandmother cell [a cell that only fires when ones grandmother comes into view]. Would that really tell us anything much at all? It would tell us that it existed ... but not *why* or even *how* such a thing may be constructed from the outputs of previously discovered cells. Do the single-unit recordings—the simple and complex cells—tell us much about how to detect edges or why one would want to, except in a rather general way through arguments based on economy and redundancy?... [M. italizing]

I will conclude that the neurophysiological approach can give valuable information about the users ability to think and act, but that the information must be used within a framework where it is possible to describe the various thoughts and experiences of the user.

6.5 THE DESCRIPTION OF THE HUMAN MIND MADE BY WILLIAM JAMES

In 1890 William James completed his *Principles of Psychology* [1890] where he tried to describe all the aspects of human psychology that were known at that time.

The major part of his description is still valid and within that it is possible to describe and analyse aspects of the human thinking that cannot be described when using the information-processing or neurophysiological approach.

William James [1890: 185] writes:

> *Introspective observation is what we have to rely on first and foremost and always*. The word introspection need hardly be defined—it means, of course, the looking into our own minds and reporting what we there discover. *Everyone agree that we there discover states of consciousness*. So far as I know, the existence of such states has never been doubted by any critic, however sceptical in other respects he may have been. [W.J. italizing]

William James starts with his own experiences—introspective observations—these are what he can observe and recollect about the working of his own mind.

Introspective observations can in some cases be a dangerous approach, namely if someone assumes that everybody else thinks in precisely the same manner as himself. However, compared to the information-processing approach and the neurophysiological approach it offers two advantages:

- It is possible to assure that the results are valid for at least one person. In particular use of the information-processing approach can result in a description that is not valid for any human being. That is for instance the case when Schank and Abelson's [1977: 37-67] much quoted description of so-called scripts is taken as a description of the structure of human memory.
- The method is very cost-effective. The introspective observations can be used as a basis for identifying areas of special interest and to determine what experiments it is worth the effort to perform. In a work like this, it is much more cost effective if I identify situations where I find it difficult to operate a piece of equipment and then investigate the sort of problems other users encounter in a similar situation, instead of trying to investigate all the possible problems in all possible situations of use.

William James starts his analysis with the experience of consciousness and the different types of thinking. In a work like this, where the different qualities of the attention is of prime importance, that is the logical starting point, and his description of human thinking makes it possible to describe the different types of inattention.

Such a description cannot be based solely on the information-processing and neurophysiological approaches. Within them the feeling of consciousness and different types of inattention appears to be foreign elements. One example is the earlier quoted article by Miyata and Norman [1986: 267] where they cannot differentiate between being aware of doing something and paying attention to doing it. Another example is Crick [1994: 265-68] that ends his "search for the soul" by speculating that the free will or consciousness may be situated in a small area in the front of the brain.

William James draws on many different sources: His own introspective observations, reports from other persons, descriptions of cases of mental illness and the results of a large number of experiments. He tries to describe them all within the framework used for describing human thinking, but he excludes nothing and leaves his description open for additions.

In comparison both the computer based models and the information-processing approach tend to result in closed systems where new knowledge cannot be fitted in.

The framework created by William James is so large that it can encompass newer results obtained using the information-processing or neurophysiological approach, whereas the information-processing and neurophysiological approaches have not even managed to create frameworks that make a consistent description of their own results possible.

There are of course some areas where William James's description today is inadequate. One area is his descriptions of human neurophysiology where newer and more precise results in most cases are available, another area is the control of a series of movements, where his observations were limited because he had no access to using film or video.

I will conclude that a description of the different types of inattention and their consequences when operating a piece of electronic equipment only is possible if it is based on the framework created by William James.

In addition, William James's *Principles of Psychology* is more lively reading than literature created by the newer psychologists whose personal experiences seem to be limited to models and parameters.

However, it is not possible to accept everything written by William James: Some of his results are superseded by results from newer observations or experiments.

6.6 VERIFICATION OF RESULTS

Use of the introspective method will typically yield qualitative results that cannot be treated statistically. In addition, use of the introspective method means that I in some situations will be directly involved and cannot act as a detached objective observer.

It is therefore necessary to set up some criterias to ensure that this results are usable for other persons and not only covers my own subjective impressions. For that purpose I will adopt the criterias defined by Krefting [1991: 215-217]:

- Interpersonal validity, or as it is termed truth value: The researcher shall report the observations as adequately as possible, so other persons sharing the same experiences as the researcher immediately are capable of recognising their own experiences in the researchers descriptions.
- Generality, or as it is termed applicability: It shall be possible to use the results in other situations than the specific situation where they are obtained. In order to fulfil that, it shall be possible to generalise the results, and it shall be possible for other persons to evaluate whether or not the results may be applicable in another specific setting. In an extreme case a result may be obtained that cannot be replicated or used in any other setting, and even when a result can be generalised, the user of the results has to determine whether or not it fits the situation where it shall be applied.
- Consistency: If the observations are repeated with the same participants or in a similar setting they shall give the same results. In other words, the results may depend on the participants, the setting and the environment, but they must not be completely random.
- Neutrality, not of the researcher, but of the data: The researcher cannot function as a detached objective observer, and the neutrality of the results are therefore best ensured by clearly describing the researchers possible biases, making it possible for others to evaluate their influence.

In order to ensure that the criterias are fulfilled, I will when feasible use the following methods described by Krefting [1991: 217-22]:

- Use a varied sample of information collected over a prolonged period of time.
- Reflect over the observations, for instance in a journal written while the data is sampled.
- Do triangulations, compare information collected with two or more different methods with the final description or model.
- Do coding and recoding, ensure that the same observations yield the same results when interpreted a second time.
- Use of a peer review or an audit determining if another researcher with a similar background will interpret the observations in the same manner.
- Reflect over the observations and determine and describe what personal biases that have influenced the interpretation of the results.

I believe these safeguards make it possible to produce correct and usable results even though a large part of the used material is based on introspective observations.

6.7 OVERVIEW OVER THE CHOSEN METHODS

It is definitely not possible to define the requirements for electronic equipment for inattentive use simply by using common sense and some suitable inputs from users of similar equipment.

It is, however, possible to do worse: The computer-inspired or information-processing models of human thinking exclude aspects of the human thinking that are vital for a work like this, as for instance a description of the different aspects of awareness and attention. The result when using these frameworks may therefore be worse than if the requirements are based solely on observations and common sense.

The only possible theoretical basis for my work is therefore William James's [1890] description of human thinking as published in *Principles of Psychology*.

The results of a number of newer experiments supplements or supersedes the experiments quoted by William James. However, his framework for the description of human thinking is so large that it can encompass newer experimental results.

William James [1890] starts with introspective observations—his own experiences. That method makes it easier to identify areas of particular interest at an early state. However, such introspective methods may be the victims of wishful thinking or lead to results that only applies to the person who made them. In this book the influence of wishful thinking is minimised and the applicability is ensured primarily by use of triangulation where the introspective observations are corroborated with results from other sources.

7. THOUGHTS WITH AND WITHOUT ATTENTION

This chapter describes some characteristics of human thinking and of the different types of inattentive use.

The user can be inattentive in different manners, and his ability to sense and react depends on the specific manner of his inattention. It is therefore necessary to describe the characteristics of paying attention and of each type of inattention.

As described in subchapter **6.5 The description of the human mind made by William James**, this project is based on the description of the human mind in William James's [1890] *Principles of Psychology,* and because William James's description of the human mind is not generally known the most basic parts of it are described briefly in this chapter. The very detailed argumentation for each part of his description is not treated here, interested readers may consult William James [1890], Naur [1995] and Barzun [1983].

Based partly on William James [1890] the effects of focusing the attention are described, and that description of the *attention* is necessary for understanding what *inattention* is.

Three different types of inattention are described:

- *Reduced conception* where the user neither conceives of nor thinks about what he senses.
- *Shifting attention* where the user only pays attention to the equipment for a short period at a time.
- *Automatic processes* where the user operates the equipment in a habitual manner.

Inattentive use of a piece of electronic equipment is only possible when the user has had some training: The relationship between training and inattentive actions is therefore finally described in this chapter.

7.1 THE BENEFITS OF INATTENTION

Our range of thoughts and experiences when paying attention is very impressive, and attention is often seen as something beneficial: If someone pays attention to us we may feel it is a gift and sometimes our right, and when we want to do a good job we focus our attention on the task we are carrying out.

However, we can only pay attention to one thing at a time, so when we can do a task without paying attention to it, our attention is free for planning the next steps of the task or for other more pleasurable or creative thoughts.

In addition, automatic movements can be effortless, gracious and done with a minimal use of energy; when we pay attention to movements and try to control them consciously, they will often be abrupt and require more energy.

7.2 THE THOUGHT AND ITS OBJECT

This subchapter describes the relationship between our thoughts and their objects. That description is necessary for understanding the difference between paying attention to something and merely being aware of it.

The duality between the thought and its object

William James [1890: 214] describes cognition, the act of knowing something, as follows:

> *It is a thoroughgoing dualism.* It supposes two elements, mind knowing and thing known, and treats them as irreducible. Neither gets out of itself or into the other, neither in any way *is* the other, neither *makes* the other. They just stand face to face in a common world, and one simply knows, or is known unto, its counterpart. This singular relation is not to be expressed in any lower terms, or translated into any more intelligible name. [W.J.'s Italizing]

The dualism between the mind knowing and the thing known is similar to the dualism between the thought and its object, and the description above fits both equally well. William James [1890: 262] writes that:

> *Human thought appears to deal with objects independent of itself; that is, it is cognitive, or possesses the function of knowing.* [W.J.'s Italizing]

The dualism means that even though the thought and its object are separate entities, we cannot experience an object without any thinking about it, and we cannot think a thought without it having an object.

I will not discuss the philosophical ramifications of this dualism between subject and object, but only describe some of the consequences that are relevant for this project.

<u>One thought, one object</u>

William James [1890: 266, 268] gives the following descriptions:

> The object of every thought, then, is neither more nor less than all that the thought thinks, exactly as the thought thinks it, however complicated the matter, and however symbolic the manner of the thinking may be... *Whatever things are thought in relation are thought from the outset in a unity, in a single pulse of subjectivity, ... feeling, or state of mind*. [W.J.'s Italizing]

If the user thinks of *How to find a Special function in the Equipment,* the object of the thought corresponds neither to *Special function* nor to *Equipment,* but to *How to find a Special function in the Equipment*, and that is the object of the thought.

In the same manner, there is not one thought of the *Special function* nor another of the *Equipment,* but only one thought of *How to find a Special function in the Equipment.*

If the thoughts of the user are interrupted, the user will not have a thought of, say, *How to find a Special* instead of *How to find a Special function in the Equipment*—the whole thought will be lost.

<u>It is possible to describe a thought and its object separately</u>

Our thoughts can have different qualities. Each thought is for instance influenced by

- How well we can focus our attention for a period of time.
- Whether or not we are tired or under stress.
- What we feel in the particular moment.
- Anything we at the same moment are aware of.

The object of our thought may at the same time have different characteristics. Our perception of it may for instance be foggy or full of details, we may be more or less familiar with it or associate it with previous good or bad experiences.

What the user can do in any particular moment is determined both by the qualities of the thought and by the characteristics of the object, and when the thought and its object are treated as two different elements, their influences on the actions of the user can be described separately.

Whether or not a thought will catch our interest depends on its object

The occupation of the consciousness by one thought and not another is determined by the characteristics of its object: In the moment we experience the thought we can be interested in the object of the thought, but while we have a thought we can only *feel* the qualities of it, not treat them as objects that may catch our interest—we cannot reflect on them.

Whether or not a particular object will draw the attention of the user of a piece of electronic equipment, does not depend on the quality of the thought it is object of; it depends solely on the users dispositions and the characteristics of the object.

The result of our thinking depends on the qualities of the thought

William James [1890: 227] gives the following description:

> Every thought we have of a given fact is, strictly speaking, unique, and only bears a resemblance of kind with our other thoughts of the same fact. When the identical fact recurs, we *must* think of it in a fresh manner, see it under a somewhat different angle, apprehend it in different relations from those in which it last appeared. And the thought by which we cognize it is the thought of it-in-those-relations, a thought suffused with the consciousness of all that dim context. Often we are ourselves struck at the strange differences in our successive views of the same thing. [W.J. italizing]

Our thought in a given moment depends on all our previous experiences and on our mood and constitution at the same moment.

In order to find out what the limitations are for the thoughts and actions of the user, it is therefore necessary to describe the qualities of the thought and part of the situation where the user experiences it.

Thoughts may have different shapes

William James describes how thoughts with the same end point may take different directions [1890: 260]:

> One gets to the conclusion by one line, another by another; one follows a course of English, another of German, verbal imagery. With one, visual images predominate; with another, tactile. Some trains are tinged with emotions, others not; some are very abridged, synthetic and rapid, others, hesitating and broken into many steps. But, when the penultimate terms of all the trains, however differing *inter se*, finally shoot into the same conclusion, we say and rightly say, that all the thinkers have had substantially the same thought. [W.J. italizing]

The users may employ different ways of thinking. Some trains of thought move swiftly—other stop at all stations. Some will use words, some pictures and some may try to feel what is right. Both words, pictures and feelings may be part of the thought.

It is therefore essential to take all the possible shapes of thoughts into consideration when trying to describe the qualities of a thought.

Words carry a special meaning

It is always an advantage if part of a thought can be put into words. William James [1890: 256] writes:

> Now words, uttered or unexpressed, are the handiest mental elements we have. Not only are they very *rapidly* revivable, but they are revivable as actual sensations more easily than any other items of our experience. [W.J. italizing]

This means that even if the object of thought is the most vivid picture or the strongest possible feeling it is easier to recall if it can be put into words. However, it means also that when the thought is recalled— for instance when we use introspection and try to reflect on it—the part of the object of thought that easily can be expressed in words may dominate other parts of object of thought.

It is therefore an advantage when we can find words that cover the object of thought as precisely as possible.

The centre of a thought

William James describes how every thought has a centre [1890: 250]:

> In all our voluntary thinking there is some topic or subject about which all the members of the thought revolve. Half the time this topic is a problem, a gap we cannot yet fill with a definite picture, word, or phrase, but which ... influences us in an intensely active and determinate psychic way. Whatever may be the images and

> phrases that pass before us, we feel their relation to this aching gap.

If we shall solve a specific problem but are thinking about something else, it is of no use: Our thinking about something else will even prevent any thinking about how to solve the problem.

It is therefore essential that the equipment leads the user towards a good topic of thought, not away from it, and a good topic of thought is one that fits the problems the user must solve in order to operate the equipment.

The fringe of the object

An important part of the object of thought is the so-called fringe. William James [1890: 249-50] describes:

> ...that the difference between those that are mere 'acquaintance', and those that are 'knowledge-*about'* ... is reducible almost entirely to the absence or presence of psychic fringes or overtones. Knowledge *about* a thing is knowledge of its relations. Acquaintance with it is limitation to the bare impression which it makes. Of most of its relations we are only aware in the penumbral nascent way of a 'fringe' of unarticulated affinities about it. [W.J. italizing]

The fringe consists of our interests in the thought and all the abstract entities and emotions that are part of the object of thought, and the fringe is therefore crucial for the way we feel and think about an object and for which new objects of thought it can be associated to.

Being aware of something

We cannot think without thinking about something—the object of thought. In the same manner, we cannot be aware without being aware of something. The question is, whether or not that something always is part of the fringe of our object of thought.

I will use an example: A user is operating a piece of electronic equipment while driving a car. He may be making a call on a cellular phone. He thinks about how to operate the phone but is still aware of driving the car.

At first glance, it makes no sense to see his *driving the car,* as part of the fringe of *how to operate the phone.* After all, unless he has an accident, his *driving the car* will not disappear when he stops thinking about *how to operate the phone*.

However, everything he perceives or thinks about in one moment is interrelated. It all has to be experienced and conceived in the same mind. There will always be a larger or smaller interference between everything passing through his mind in the same moment.

His thinking at any moment is at the same time dominated by the topic of his thought, it will revolve around that one topic. If the topic is *how to avoid error messages,* that will also influence what he perceives from the road while he is driving.

So, taken moment by moment, everything he perceives or thinks about is part of one object.

The user cannot control what he in a given moment is aware of: *The user may focus his attention on something and decide what to think actively about, and when he has made that choice, he cannot decide what other things he will be aware of.*

When the user cannot pay attention to the equipment, because he is thinking actively about something else, he may or may not be aware of the equipment, and he may not even be aware of not being aware.

The dynamics of thoughts

Every thought has one object, and the object is different from the thought. In addition, all thoughts have a centre it revolves about, and all objects have a fringe consisting of so-called overtones of the object. We are aware of that fringe, but we cannot control what associations or perceptions to include in it.

7.3 THE CHANGING STREAM OF THOUGHT

Our stream of thought is always changing. William James [1890: 233] describes it in quite a poetic manner:

> A 'river' or a 'stream' are the metaphors by which it is most naturally described. ... *let us call it the stream of thought, of consciousness, or of subjective life.* [W.J. italizing]

William James's metaphor captures at least three of the characteristics of our stream of thought: It has a rhythm, it is unbroken and it is next to impossible to control.

The rhythm of thought

William James [1890: 236] has another poetic metaphor for the rhythm of the stream of thought:

> Like a bird's life, it seems to be made of an alternation of flights and perchings. The rhythm of language expresses this, where every thought is expressed in a sentence, and every sentence closed by a period... *Let us call the resting-places the 'substantive parts', and the places of flight the 'transitive parts' of the stream of thought.* [W.J. italizing]

The stream of thought is always changing, and it has a rhythm marked by the changes between the transitive and the substantive parts. The rhythm may wary depending on the qualities and object of the thought.

The duration of thoughts

The thinking of a thought consists of a number of different parts: A new thought arises from something we sense or from something we imagine, we sense some meaning and may decide to act upon it or to forget it. The duration of these parts determine the rhythm of thought.

The most basic unit is probably the shortest moment we can experience, the shortest duration of a thought or of its substantive part. Blumenthal [1977: 30] writes: "...rapid attentional integrations are ... brief pulses of integration that fuse a set of events or impressions into a unitary experience".

This means, that if two events happen within the same attentional integration, it is impossible to determine which comes first, and if they are both experienced they are experienced as one thought.

Blumenthal [1977: 32] finds that a number of different experiments agree on values for the attentional integration between 50 ms and 250 ms with a normal value on 100 ms. That is the shortest duration of the substantive part of a thought.

However, the thoughts are a stream with things continuously passing through them. The speed of their passing is also of relevance.

Blumenthal [1977: 50] describes that it takes between 430 ms and 600 ms to recognise an item. Humphreys [1989: 276] describes that the duration of the so-called saccades, eye movements during reading, are between 100 ms and 500 ms with a typical value of 250 ms. The results reported by Blumenthal include some time needed for reacting on the thing seen, and some of the saccades can be random movements where no letters are recognised. It is therefore likely that the recognition of an item takes between 200 ms and 500 ms.

Even when we recognise an item, for instance the letters of a word, it is not given that we perceive the meaning of it. We need more time for perceiving the meaning of it. Blumenthal [1977: 60] reports that this so-called "preattentive buffer delay" is between 500 ms and 2 s with a typical value of 750 ms. These figures are in good accordance with Blumenthal's [1977: 50] figures on between 630 ms and 1100 ms for reaction times when the meaning of something shall be recognised; the experiments were presumably with comparatively simple figures making values in the lower part of the range likely.

These periods are for the time it takes to perceive a thing and to act in some manner on it. Libet et al. [1983: 641] has tried to measure the time it takes for a person to decide to do a specific action—the transitive part of the thought. They identified electrical activity that seemingly was related to thoughts about the particular action, and that activity started between 150 ms and 500 ms before the person being tested became conscious of an intention to act.

I will conclude that the shortest possible duration of a thought, of the total of the substantive and transitive parts of it, varies between 200 ms and 2 s, where the actual value depends on the complexity of the fringe of the object we think about.

It is possible to estimate the longest duration of the substantive parts of the thought. Blumenthal [1977: 63] reports that if we have not paid attention to something we have perceived, it will fade out after approx. 1.5 s. If we pay attention, but cannot do any rehearsal, think once more over the same thing, Blumenthal [1977: 74] reports that the thought will fade after 10 s to 20 s.

That figure fits well with Blumenthal's [1977: 80,82] figures on between 10 s and 15 s for attention waves, that is the duration of each thought when someone is speaking and can use the time he wants for each thought.

I will conclude that even though the duration of our thoughts can vary between 200 ms and 20 s, we are most comfortable with a rhythm of thought where each thought has a duration between 10 s and 15 s.

Consequences if the rhythm is broken

If the rhythm of thought is broken, for instance by a powerful perception, the stream of thought will not reach the next substantive part, and it will of course not reach any conclusion. That is likely to happen if we are interrupted with shorter intervals than 10 s to 15 s.

Such interruptions of the rhythm of thought are common for inattentive users: If the user of electronic equipment must change his attention back and forth between the environment and the equipment, his thoughts are often interrupted before he can reach a conclusion.

Association

During the transitive part of the stream of thought one object of thought calls forth another by association. Once more William James [1890: 519] offers quite a poetic description:

> ..the restless flight of one idea before the next, the transitions our minds make between things wide as the poles asunder, transitions which at first sight startle us by their abruptness, but which, when scrutinised closely, often reveal intermediating links of perfect naturalness and propriety...

In psychology, the word *association* is often used in different manners and on occasion very loosely. William James [1890: 163] describes for instance how the so-called associationists tried to describe every object as consisting of atomic parts united by associations, and the connectionists as described by Eyseneck and Keane [1990: 239-45] use a similar description. However, I will not discuss the problems resulting from the introduction of associations as a sort of glue keeping the chip boards of objects together.

In this project I will only use the word association as it is described by William James [1890: 522]:

> *Association*, so far as the word stands for an *effect, is between* THINGS THOUGHT OF *- it is* THINGS, *not ideas, which are associated in the mind*. We ought to talk of the association of *objects*, not of the association of *ideas*. [W.J. italizing and capital letters]

In other words, the process of association occurs during the transitive part of the stream of thought where one object of thought calls forth another one. If our power of association in a particular situation is limited, our actions in the same situation will also be limited: If we cannot make an association to a specific action, we cannot carry it out.

The associations made by inattentive users of electronic equipment will always be limited: The user will always feel a pressure when he must take care of both the environment and the equipment at the same time, and that pressure will limit his power of association and therefore his decisions and actions.

The rising thought

It is impossible introspectively to see the transitive parts of the thought. As William James [1890: 237] writes:

> The rush of the thought is so headlong that it almost always brings us up at the conclusion before we can arrest it.

However, if no conclusion is possible, we may be conscious not of a thing, but of a hole waiting to be filled out. William James [1890: 240] describes that we have "feelings of tendency", and he (William James) [1890: 243-4] continues:

> Suppose we try to recall a forgotten name. The state of our consciousness is peculiar. There is a gap therein; but no mere gap. It is a gap that is intensely active. A sort of wraith of the name is in it, beckoning us in a given direction, making us at moments tingle with the sense of our closeness, and then letting us sink back without the longed-for term...
> There are innumerable consciousnesses of emptiness, no one of which taken in itself has a name, but all different from each other. The ordinary way is to assume that they are all emptiness of consciousness and so the same state. But the feeling of an absence is *toto cælo* other than the absence of a feeling: it is an intense feeling. [W.J. italizing]

If we are under pressure, the pressure itself makes it difficult to fill the gap—perhaps because our consciousness then is filled with the pressure itself rather than with something from which we can associate to an object that may fill the feeling of tendency.

In addition, the feelings of tendency are whorls in the stream of thought and even under ideal circumstances it takes some time to fill them.

If a user must move his attention back and forth between the environment and the equipment, he will often not have time for filling any feelings of tendency. He may be stuck or try to stick something into the hole hoping that it may fit by some miracle even though the size and shape is wrong.

The continuous stream of thought

Despite sudden perceptions and changes in the stream of thought, it is always continuous. William James [1890: 233-34] describes the relation between the stream of thought and the sudden changes in the things it is aware of:

> The things are discrete and discontinuous; they do not pass before us in a train or chain, making often explosive appearances and rending each other in twain. But their comings and goings and contrasts no more break the flow of the thought that thinks them than they break the time and the space in which they lie. A silence

> may be broken by a thunderclap, and we may be so stunned and confused for a moment by the shock as to give no instant account to ourselves of what has happened. But that very confusion is a mental state, and a state that passes us straight over from the silence to the sound. The transition between the thought of one object and the thought of another is no more a break in the *thought* than a joint in a bamboo is a break of the wood. It is a part of the *consciousness*, as much as the joint is a part of the *bamboo.* [W.J. italizing]

The continuity of our thoughts means that a thought cannot disappear and make room for another in the same moment. It is therefore impossible for the user to change instantaneously back and forth between thinking about the environment and thinking about the equipment.

The stream of thought, decisions and actions

Our thoughts have a rhythm of their own, consisting of transitive and substantive parts, with occasional open questions and associations from one idea to the next, all borne forward in a personal rhythm and a continuous stream.

When the user must divide his attention between the electronic equipment and the environment, the rhythm of the flow is often interrupted or otherwise hampered, and the decisions and actions of the user are impeded.

7.4 CONCEPTION

Subchapter **7.1 The thought and its object** described how the fringe of an object is crucial for the way we think about it. The fringe consists of everything we are aware of in the moment we think the thought, and it is next to impossible that everything will be the same as at any earlier time we tried to think the same thought. If we remember that we have tried to think the same thought before that alone will make our thought different from the last time. We will therefore never be able to remember that we have thought precisely the same thought before.

This subchapter describes how, in spite of every thought being unique, it is possible for us to know that we have thought of the same thing before. Without that ability we could never use any of our past experiences.

The relation between conception and memory

In order to make a clear description of what William James [1890: 434-56] calls "conception", it is first necessary to describe the difference between conception and the act of recalling something from memory.

Our memory is described by William James [1890: 610] as:

> ..the knowledge of a former state of mind after it has already once dropped from consciousness; or rather *it is the knowledge of an event, or fact,* of which meantime we have not been thinking, *with the additional consciousness that we have thought or experienced it before.* [W.J. italizing]

Our memory makes it possible for us to recall something we have earlier experienced; conception makes it possible for us to find some thing well known, a meaning, in what we experience. The act of conception is therefore essential for the way we learn and how we use what we have learned for governing our actions.

The sense of sameness

William James [1890: 434] describes our knowledge of having had a former similar experiences as follows:

> ..."*The same matters can be thought of in successive portions of the mental stream, and some of these portions can know that they mean the same matters which the other portions meant...* This *sense of sameness* is the very keel and backbone of our thinking." [W.J. italizing]

We experience the sense of sameness, every time we believe we recognise something we have seen before, and we experience it every time, we base any thoughts or physical actions on any previous experiences. The sense of sameness is therefore necessary both for doing any sort of useful action and for learning and applying any new skills, including any sort of inattentive use of electronic equipment: The outcome we expect from any such activity depends on our previous experiences.

We experience a sense of sameness, but it may not be real. William James [1890: 435] describes it as follows:

> ... we do not care whether there be any *real* sameness in *things* or not, or whether the mind be true or false in its assumptions of it. Our principle only lays it down that the mind makes continual use of the *notion* of sameness... [W.J. italizing]

The actions of the user will always be based on his sense of having used the same piece of equipment or function or earlier having been in the same situation or carried out the same task, but the similarity is felt and not necessarily real.

In some cases the user will not feel a sense of sameness, he may continue operating the equipment without any sense of purpose or goal, or he may be confused and stop carrying out any actions; in other cases, the user will be deceived by appearances and gladly continue working towards an unknown result.

I experienced a similar example during a hike in the forest [own observation]:

> It surprised me how different the path looked compared to last time I went there, I even saw a lake I had not noticed before. At last the path ended by the sea. I could not disregard that and from conceiving of the situation where I followed a well known path I changed to conceiving of the situation where I had lost my way.

Conception and concepts

Conception is an act whereas concepts are thoughts with a special quality: The sense of sameness. William James [1890: 436] describes the difference between the two terms as:

> *The function by which we thus identify a numerically distinct and permanent subject of a discourse is called* CONCEPTION; and the thoughts which are its vehicles are called *concepts*. [W.J. italizing and capital letters]

And William James [1890: 437] later describes the result of the conception as follows:

> Thus amid the flux and opinions and of physical things, the world of conceptions, or things intended to be thought about, stands stiff and immutable, like Plato's Realm of Ideas.

However, there are some significant differences between the philosophical world of ideals and the results of our conception.

All our concepts are personal and individual: They are based on our own personal experience. *The users conception of a piece of electronic equipment is therefore the result of his total experience and it is different from the designers conception of the same piece of equipment.*

We can only experience a concept when we think about it, and the concept we experience depends on the situation when we are thinking about it. William James [1890: 959] writes:

> "When we conceive of S merely as M ..., we neglect all the other attributes which it may have, and attend exclusively to this one. We mutilate the fulnes of S's reality. Every reality has an infinity of aspects of properties. Even so simple a fact as a line which you trace in the air may be considered in respect to its form, its length, its direction and its location. When we reach more complex facts, the number of ways in which we may regard them is literally endless... All ways of conceiving a concrete fact are equally true ways. *There is no property* ABSOLUTELY *essential to any one thing.* The same property which figures as the essence of a thing on one occasion becomes a very inessential feature upon another." [W.J. italizing and capital letters]

The user will conceive of the equipment in different manners depending on the type of situation when he conceives of it. It is in particular likely, that the concept that the user describes when asked, are different from what he conceives while using the equipment.

Different types of concepts

When we conceive of something, we find something we can identify the concept by. William James [1890: 437] expresses it as:

> Any fact, be it thing, event, or quality may be conceived sufficiently for purposes of identification, if only it be singled out and marked so as to separate it from other things. Simply calling it 'this' or 'that' will suffice. To speak in a technical language, a subject may be

> conceived by its *denotation* [its name], with no *connotation* [implied meaning], or a very minimum of connotation, attached. The essential point is that it should be re-identified by us as that which the talk is about; and no full representation of it is necessary for this, even when it is a fully representable thing. [W.J. italizing]

We may conceive of almost anything. William James [1890: 436] writes:

> We may conceive realities supposed to be extra-mental, as steam-engine; fictions as mermaid; or mere *entia rationis*, like difference or nonentity. [W.J. italizing]

The user of a piece of electronic equipment can conceive of things that he has experienced or just thought about. The concept can be very specific, for instance the concept of a specific computer. I have such a concept of the computer I currently am working on [own observation]:

> It is a laptop, but I experience the computer as the same, no matter if it is on the table connected to a large size screen, in its bag or in my lap with no peripherals, and no matter if it is turned on or off.

It is possible to conceive of a whole class of things, of what William James [1890: 447] calls "universals". I have for instance thought about or experienced a large number of computers, and have a concept covering all the computers of the same type as I am working on, another larger concept covering all computers that I know to exist, and an even larger concept covering all the computers that I imagine might be created.

From a group of things it is also possible to conceive, what William James [1890: 447] calls "abstractions": From a number of *white things* we may conceive the abstraction *white*. In a similar manner, a designer may from dreams of future equipment conceive the abstraction *user-friendly* and believe it actually is embodied in the piece of equipment he is designing.

Conception of situations

The actions of the user in a specific situation are to a large extent determined by his concept of the situation.

Our conception of a situation means that we experience a sense of sameness and it means that we can use our previous experience with similar situations: We will have a knowledge or at least some expectations of what is likely in the particular situation:

- *The environment*, including other persons and things for instance a piece of electronic equipment we are going to operate.
- *Possible actions*, some we can do and some we must do in the particular situation.
- *Expected outcomes* of each action.
- *An order of possible actions and events*, our actions and the different events must occur in a specific order.
- *Some Goals* we want to reach.
- *Dispositions*, tendencies to act in specific manner in the particular situation.

Our concept of a situation makes it possible for us to carry out some action: We can limit our choices to what we can experience, do and want to accomplish in the situation we conceive of.

Our conception of a work situation when we use a computer may include:

- The equipment reacts in the same manner each time we do the same operation on it.
- We are supposed to operate the keyboard or a mouse.
- The outcome of our actions shall fulfil some already determined goal for the task we are carrying out.

Our conception of the work situation when we use a computer will probably not include:

- Our tools reacts in slightly different manners even though we seemingly do the same operation.
- We shall take whatever is on the table apart and use pieces of it for decorating the walls.
- We can work as long as we want to, and stop when we feel we have done enough, before a specific goal has been reached.

However, such actions and their possible outcomes are perfectly natural when we do not conceive of using a computer but instead conceive of a situation where we decorate a room with strips of coloured paper for a party.

Conception and recognition

Conception makes it possible for us to recognise something, even though only part of our new experience is similar to a former experience. That ability is essential for recognising any things we earlier have experienced: We cannot have an experience we know is perfectly identical with a former one, so we could never recognise any things if every detail in our new experience had to be identical with what we earlier had experienced.

The act of conception is therefore essential for understanding how the user thinks about his previous experiences when operating a piece of electronic equipment. When using the equipment, he will not recall every time he has used a particular piece of equipment, he may not even recall the particular type or piece of equipment but only conceive of situations where he has carried out similar tasks or operated equipment with similar functions and buttons. Experienced users often take their ability to conceive for granted [own observation]:

> I have myself often experienced the following situation when I had to learn to operate a new piece of equipment: Even when I saw the particular piece of equipment for the first time and knew next to nothing about its function, I could always recognise the control panel and the buttons used to start and operate it. I did not know the specific function of each button, and the control panel could be large or small, on a computer screen or in hardware, but I could always recognise the control panel and knew the equipment should be operated by manipulating it one way or another.

In other situations the recognition may be false or misleading. My own experience indicates that two such situations may arise when a user gradually changes an element stored in a computer:

- When the user a number of times accesses the element and changes parts of it, it is impossible to describe the precise moment when he should conceive of the element as a new and different one. In most cases the user will therefore conceive of the element as the same, even though he actually has changed the element into a completely different one.
- In other cases the user may store the same or almost identical elements under different titles. In that case the user may often conceive of each of the copies of the element as a different element.

I have asked a number of computer users [own observation] when a document, being processed in a computer, is changed so much that it ought to be conceived of as a new and different document. Most users indicate that they feel the answer is evident, and I have received a number of very precise answers—however, most of the answers I have received are different and conflicts with each other.

An imprecise or misleading conception of the different elements presented by a computer can therefore cause problems or at least add to the confusion when specific elements or information are processed electronically.

Conception as an advantage and a disadvantage

If, for some reason or another, we cannot conceive of the things we experience, we may experience a feeling of wonder and of experiencing something for the first time, or we may experience utter panic as we cannot make any sense of our experience. In both cases we cannot carry out any useful action.

Our conception is therefore a prerequisite for any sort of purposeful action and obviously an advantage.

Our perceptions and actions will at the same time always be limited by our conception in and of that moment. Because of that limitation our conception of the situation can be seen as a disadvantage [own observation]:

> When I should make a description of a user interface for a database program, I found errors in my work and could neither trouble-shoot them nor find out what I did wrong. At last I did a systematic testing of my work and found that the faults were caused by the database program itself being faulty. My conception of the program did not include any errors, so I spent a long time looking for errors in my own work where a simple test could have identified the real errors in the database program.

In the same manner, users may spend a long time setting different parameters in the program for a printer before they realise that the printer problems are caused by a small mechanical problem or by the power supply for the printer being turned off. Their concept of the operation of the printer includes only actions that can be done from the computers keyboard, it does not include any clips or wires hidden below or behind the computer.

7.5 ATTENTION

It is only possible to describe the different types of *inattention,* when we know what it means to pay *attention.*

Attention is a quality of the thought as described by William James [1890: 381-382]:

> Everybody knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seems several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of it essence. It implies withdrawal from some things in order to deal effectively with others...

However, even though everybody knows what attention is, it is neither simple nor invariant. In order to describe its range, I will show its variance and not limit my description to one aspect of it.

The benefits of paying attention

When we focus our attention on something, it is easier to act on it.

According to William James [1890: 401]:

> The immediate effects of attention are to make us:
> *a)* perceive –
> *b)* conceive –
> *c)* distinguish –
> *d)* remember –
> better than otherwise we could—both more successive things and more clearly. It also
> *e)* shortens 'reaction-time'. [W.J. italizing]

The effects of attention on perception, conception and discrimination can be described in more details. Treisman et al. [1977: 357] write:

> The visual search results suggest that identifying conjunctions of separable dimensions or features is one of the main factors precluding parallel processing and requiring focal attention to particular spatial locations at particular moments in time. ... The results of the successive matching experiments suggest that conjunctions of separable properties cannot always be held as unitary representations in memory, that they tend to dissolve into free-floating features which may wrongly recombine, and that retrieving and matching their conjunctions

> to a current input when the task requires it constitutes an independent and identifiable stage of processing. These conclusions apply both to the different dimensions of shape and colour and to different features within shapes, even when these are part of schematic faces.

In other words, it is difficult to perceive, conceive or distinguish between complex figures without paying attention to them, even when the figures are of well known types. If a user of a piece of electronic equipment only is aware of something without paying attention to it, his perception of it is limited: He must pay attention in order to recognise a complex element shown by the equipment correctly—merely being aware of it is normally not sufficient.

In the same manner, even though it is possible to perceive single words without paying attention to them, it is impossible to perceive the meaning of sentences without paying attention to them. When we do not pay attention to someone speaking, we may be capable of repeating the last spoken sentence even though our reactions, or rather our lack of reactions, revealed that we did not perceive any meaning while the sentence was spoken.

If we pay attention to something for a period of time, we may be able to remember it. However, the descriptions by William James [1890: 529] and by G. Miller et al. [1960: 134-135] indicate, that the crucial factor is the number and strength of the associations we make between the things to be remembered and other objects. It is not proved that paying attention in itself has any effect.

Finally, attention shortens the reaction time, William James writes [1890: 406]:

> Usually, when the impression is fully anticipated, attention prepares the motor centres so completely for both stimulus and reaction that the only time lost is that of physiological conduction downwards... As concentrated attention accelerates perception, so, conversely, perception of a stimulus is *retarded by anything which either baffles or distracts the attention* with which we await it. [W.J. italizing]

This means that if the attention of the user shifts between sensations from the equipment and from the environment, his reactions will be slower with more hesitation and more errors.

Attention can be on objects of sensations or on objects of thought

We can focus our attention on the objects of either external sensations or internal thoughts. William James [1890: 393] writes that attention can be:

> ...either to
> *a)* objects of sense (sensorial attention); or to
> *b)* Ideal or represented objects (intellectual attention).
> [W.J. italizing]

In order to reach a conscious decision and act on it, we must not only pay attention to the sensorial impressions, we must also pay sufficient attention to our thoughts of the object. Even if the user pays full attention to the elements presented by the equipment, his use of the equipment is affected if his attention to his thoughts about the use of the equipment is reduced.

Active or passive attention

Our attention to a specific object may be either active or passive.

William James [1890: 394] describes the active and voluntary attention as follows:

> *Voluntary attention is always derived;* we never make an *effort* to attend to an object except for the sake of some *remote* interest which the effort will serve. [W.J. italizing]

When our attention is voluntary, we decide to focus our attention on an object and make an effort to keep it there.

The passive, reflex or non-voluntary attention may be either of a sensorial or of an intellectual type. William James [1890: 394-396] describes the two types as follows:

> In *passive immediate sensorial attention* the stimulus is a sense-impression, either very intense, voluminous or sudden,—in which case it makes no difference what its nature may be, whether sight, sound, smell, blow or inner pain,—or else it is an *instinctive* stimulus, a perception which, by reason of its nature rather than its mere force, appeals to some one of our normal congenital impulses and has a directly exciting quality...
> *Passive intellectual attention* is immediate when we follow in thought a train of images exciting or interesting *per se;* derived, when the images are interesting only as means to a remote end, or merely because they are associated with something which makes them dear. Owing to the way in which immense numbers of real things become integrated into single objects of thought for us, there is no clear line to be drawn between immediate and derived attention of an intellectual sort. [W.J. italizing]

It shall be noted that William James [1890: 1028, 1030, 1039] uses the word "instinctive" to describe not only what is inborn but also dispositions shared by a larger number of people. His "instinctive stimulus" includes therefore all stimuli we react to out of habit: A stimulus whose content rather than its force makes us react because of inborn traits or, probably more common, because of habits we later have acquired.

The passive immediate sensorial attention is an automatic action, no matter if it is caused by an inborn trait or by a habit we later have acquired.

Our attention may be drawn towards sense-impressions that are intense voluminous or sudden or whose contents makes us react—the attention of most people will for instance be drawn towards someone screaming or even only saying *Help*.

In these cases, our attention will often be drawn so fast that we cannot prevent it by making a conscious effort.

In addition, it is very difficult to keep the attention focused on a thing that does not change or where it is possible to perceive the changes without paying continuous attention to the thing.

Moray [1969: 54] writes:

> ...it is from easy, rather than from difficult messages, that the attention wanders. If listeners are required to shadow [repeat loud] unusually redundant materials, such as nursery rhymes or Christmas carols, they will tend to report material from the rejected passage [the one they are told not to pay attention to].

I have myself a few times reacted in a similar manner in work situations [own observation]:

> When I have been writing something with a radio turned on in the background and felt bored, I have sometimes by accident included a sentence from the news in the radio in the piece I was writing—*Here is the weather forecast...*

When we are bored, our sensorial and intellectual attention wanders easily off to something else, and we can then keep our attention on the same thing only by making a conscious effort.

In such a situation it is apparent, that the voluntary and the reflex attention are two different forces struggling over where to focus the attention, similar to two boys struggling over whose turn it is to control a turned on flashlight.

We have two different processes vying for directing the attention, and that has implications for how the attention moves during inattentive use: The attention of the user may be drawn by a reflex even when the user makes an effort to focus his attention on a particular object or perception.

The changing qualities of the attention

Even when our attention is of the same type, for instance passive and sensorial, its characteristics may be different from one situation to another.

The attention can be focused on a larger or a smaller area

Eyseneck and Keane [1990: 106] describe visual attention as:

> ...rather like a spotlight. That is, everything within a relatively small area can be seen very clearly, but it is much harder (or impossible) to see anything not falling within the beam of the spotlight. Furthermore, most spotlights have adjustable beams, so that the area covered by the beam can be enlarged or decreased.

We can compare our visual attention to a spotlight that highlights a certain area, obscuring what is around it, and, in a similar manner, we can compare our auditive attention to a radio receiver that can be tuned to receive a certain tone or voice excluding all other.

The attention can be focused to a larger or a smaller degree

William James [1890: 382] describes a case where the attention is very unfocused:

> The eyes are fixed on vacancy, the sounds of the world melt into confused unity, the attention is dispersed so that the whole body is felt, as it were, at once, and the foreground of consciousness is filled, if by anything, by a sort of solemn sense of surrender to the empty passing of time.

William James [1890: 396-397] describes another case, where the attention was focused to a very large degree, so even a severe pain was not sensed:

> "He has frequently begun a lecture, whilst suffering neuralgic pain so severe as to make him apprehend that he would find it impossible to proceed; yet no sooner has he, by a determined effort, fairly launched himself into the stream of thought, than he has found himself borne along without the least distraction, until the end has come, and the attention has been released; when the pain has recurred with a force that has over-mastered all resistance, making him wonder how he could have ever ceased to feel it."

The things the attention is not focused on may be treated in different manners

Kahneman and Treisman [1984: 31] give two different descriptions of how the attention focuses on one part while ignoring another:

> We define the *filtering paradigm* by three features: (1) the subject is exposed simultaneously to relevant and irrelevant stimuli, (2) the relevant stimuli control a relatively complex process of response selection and execution, and (3) the property that distinguishes the relevant from the irrelevant stimuli is usually a simple physical feature and is different from the property that determines the appropriate response... In the *selective-set paradigm* ... the

> subject chooses which of several *possible* stimuli to expect or search for rather than which of several actual stimuli to analyze.

According to Kahneman and Treisman [1984: 30] the psychologists are divided into two groups: One group has made experiments that shows the attention acts as a filter, the other group has made experiments that shows the attention acts as a process of selection. In the first case any sensations considered irrelevant are filtered out almost offhand, whereas in the second case all sensations are considered in order to select the ones needing attention.

I believe that a description of how our attention focuses on one thing and not on another must combine the two viewpoints: Most of the things outside the area of attention are filtered out, and from the things passing through the filter we select one thing and not another. Depending on the quality of our attention in the particular moment, the filter can be more or less exclusive, and we can be more or less apt at selecting things among the impulses that passes it.

The perception of the things we are aware of but do not pay attention to depends therefore on the characteristics of our attention in the particular moment.

<u>Consequences of different qualities of the attention</u>

The qualities of the attention in each particular moment determines how the user perceives both the things he pays attention to and the things he only is aware of: If his attention is very narrow he may not even perceive all the equipment, if his attention is very diffuse he may not even perceive things he pays attention to, and if his attention is very strong anything outside its focus is not perceived.

The things the user pays attention to are finally limited both by something similar to a filter and by what he selects from the sensed: Some things are not sensed by the user at all, but even if the things are sensed they may not catch the attention of the user.

Attention and inattention

When a user operates a piece of electronic equipment, his attention may be directed towards one thing or another and it may be more or less focused, and both the focus of his attention and its qualities are crucial for how he can perceive the equipment and act upon what he perceives.

Being inattentive is therefore not simply the matter of having turned off the attention. When a user of electronic equipment is inattentive, his attention may for instance:

- Be directed towards the environment instead of the equipment
- Be entirely unfocused
- Be directed only towards his own thoughts or only towards his perceptions

In addition, when the user makes an effort to focus his attention on a particular object or perception, his attention can be turned in another direction by a reflex.

7.6 DIFFERENT TYPES OF INATTENTIVE USE

This subchapter describes the types of inattention that may occur for users of electronic equipment. Similar to the different qualities of each thought and each moment of our attention our inattention can also posses different qualities.

However, the subchapter describes only the types of inattention, or states of consciousness, where the user at least occasionally is aware of the equipment and capable of doing some physical actions affecting it.

If the user is totally unaware of the equipment and cannot influence it in any manner, he cannot use the equipment at all: The states where the user is unconscious, asleep or totally preoccupied by his own thoughts or perceptions from the environment require no further analysis.

Reduced conception

I have a few times experienced this state [own observation]:

> I had worked until late in the night programming a user interface for a database. The result showed one record from the database at a time and had on the screen a yellow virtual key with a very attractive design resembling a partially opened door. Each time the virtual key with the door was pressed, clicked with the mouse, the currently displayed record from the database would be erased and the next one would pop up.
> I had completed the database and entered a number of made up records in order to test it, and I just sat there. I pressed the virtual key with the yellow door. Another record from the database appeared. I pressed the virtual key again, and another record appeared. I could clearly see what I was doing, and if someone had asked me, I would probably reply that I was erasing records in the database. However, I continued pressing the virtual key until a blank record showed up. The sensation of that one stopped me for a moment, and I did not hit the yellow virtual key again. At that time, I had erased five or six records from the database.

I later found out that what I had experienced was a state of reduced conception very similar to some of the states that are experienced by persons immersed in meditation. In this state of reduced conception there is full attention on the external sensations but very little conception and no attention to any thinking about what is sensed. A person in that state will either do no physical action at all or repeat the same physical action one time after the other.

This state of reduced conception is most likely to occur if we are tired without any urgent tasks, with our eyes focused on a vivid object without any emotional characteristics and without any sudden or violent sensations that may turn our attention away from where we are looking.

This type of inattentive use may seem pleasurable for the person experiencing it, but he cannot do any useful work. On the contrary, as my example shows, he may cause substantial damage if he acts while his conception is reduced.

Shifting attention

Temporary inattention is very common for persons trying to do two things at once. Personally, I am often forced into a state of shifting attention and can offer an example [own observation]:

> I had produced a document and send a draft to someone who collaborated with me on the completion of it. He called me on the phone and wanted to discuss a small correction to the document.
> I did not have a paper copy, so I said "just a moment", turned my attention to the computer, found the document and *double clicked* on it in order to open it.
> The program the document was written in was not active: It took approx. 10 to 15 s for the document to open, so I had to turn my attention back to the phone conversation and tell my caller, that it took just a moment more before I was ready.
> I became aware of the document being open—it had drawn my attention—and I could turn my attention back to my caller and ask him what the correction was.
> When I had heard what the correction was, I had to turn my attention back to the computer and find the position to be corrected in the document.
> After having read the text my attention was drawn to a few thoughts about how to make the change in the document. When my thoughts had reached a conclusion I had to move my attention back to the caller and tell him that I agreed on the change in the document
> When I had heard the reply, I once more had to turn my attention back to the computer and enter the correction, turn my attention back to my caller, tell him the correction was entered and then once more turn my attention to the computer and read the change aloud for him.
> When that was done, I could turn my attention back to the caller, discuss the completion of the document with him, exchange a few pleasantries and hang up.
> Finally, my attention was drawn to the mug of tea on my desk, I had not been aware of it during the duration of the call, and I found that its contents no longer were warm.
> In total, I moved by attention more than 15 times in about 3 minutes.

In this state of mind I was fully conscious. I focused my attention on one question at a time, perceived, conceived and thought about one problem after the other. My attention moved back and forth, either because of my own active effort or because it was drawn in a particular direction by a reflex. In such a situation it can be difficult to reach a conclusion on each thought: While my attention continuously moved back and forth or was interrupted, the shifts could easily have interrupted my thoughts before they reached a conclusion.

This state of mind is common for work situations where the attention with short intervals must move back and forth or where it often is moved by a reflex from one object to another. It is only possible to move the attention back and forth if the attention is moved between two well known tasks or if our conception of the situation is very tight, so the next action is determined by the perceived state of the object being operated on.

Only people who are alert and fully awake can function in this manner and only for a short period of time, and some people find it almost impossible to shift their attention back and forth between two things or more.

When the attention moves back and forth between two or more objects it is likely that some aspects of an object are not perceived and it is possible that the thoughts of the user are interrupted before they reach a conclusion. The user may become nervous or confused and incapable of completing any task.

Automatic processes

A large proportion of our daily actions are governed by what William James [1890: 109-31] calls *habits*, and what later psychologists as reported by Eyseneck and Keane [1990: 118-31] call *automatic processes*.

During our daily activities, we very often depend on such automatic processes—it is not possible for us to think consciously about every part of every movement we make.

An automatic process may consist of a single movement of a duration shorter than the duration of a single thought [own observation]:

> When I save a document by pressing the function key and at the same time presses the key with the letter *S* for *Save*.

In that case the total movement can be done in one short moment—in some cases it may even be completed before we have had time to think about whether or not to do it.

In other cases an automatic process consists of a series of movements that are done one after the other [own observation]:

> I lifted the handset, heard a dial tone and entered the digits of the number. When I had pressed the key with the first digit, the next one came automatically into my mind and I pressed it. It is possible that I looked at the keypad while pressing the keys, but I cannot remember whether or not I did it.
> I waited for a few seconds, heard a ringing tone and continued my waiting until the handset in the other end was lifted. Then I said *hello* and my first name.
> If I know the number well, I can make such a call almost without being aware of it between the time I start making it until I have the connection. Only the cases when something goes wrong draws my attention: If I do not get a dial tone, if somebody rings on the door while I am making the call, if the number is occupied, or if I get an answering machine when I did not expect one.

In such a situation the order of all parts seems to be decided beforehand. The result of each of the separate actions associates strongly to the next action in the series.

It is finally possible that one movement in the automatic process is started before the former one is completed [own observation]:

> In the morning when I enter my office and turn on the computer, I reach out for pressing the ON/OFF switch on the computer before I have stopped moving towards the computer. I do not wait until I have completed my forwards movement before I lift my hand for pressing the switch.

The different movements are then integrated into one continuous stream of movement.

An automatic process requires less effort than a conscious action

An automatic process is often experienced as effortless. This feeling of effortlessness is a result of the process not needing any conscious control: The process determines our motions, and each part in it triggers the next without any hesitation or interference. And the process may be so fast and so smooth that we are not aware of the process until after it has occurred.

William James [1890: 117 & 119] describes how automatic processes makes it possible to act in a more effortless manner:

> *...habit* [automatic processes] *simplifies the movements required to achieve a given result, makes them more accurate and diminishes fatigue...*
> When we are learning to walk, to ride, to swim, skate, fence, write, play or sing, we interrupt ourselves at every step by unnecessary movements and false notes. When we are proficients, on the contrary, the results not only follow with the very minimum of muscular action requisite to bring them forth, they also follow from a single instantaneous 'cue'. [W.J. italizing]

An automatic process makes it unnecessary to consider the next action

When carrying out an automatic process, it is normally only necessary consciously to decide to do the first action of it. William James [1890: 121] writes:

> In habitual action... the only impulse which the centres of idea or perception need send down is the initial impulse, the command to *start.* [W.J. italizing]

William James [1890: 119] describes how one action then triggers the next:

> ... *habit* [automatic processes] *diminishes the conscious attention with which our acts are performed.*
> One may state this abstractly thus: If an act requires for its execution a chain, *A, B, C, D, E, F, G,* etc., of successive nervous events, then in the first performances of the action the conscious will must choose each of those events from a number of wrong alternatives that tend to present themselves; but habit soon brings it about that each event calls up its own appropriate successor

> without any alternative offering itself, and without any reference to the conscious will, until at last the whole chain *A, B, C, D, E, F, G* rattles itself off as soon as *A* occurs, just as if *A* and the rest of the chain were fused into a continuous stream. [W.J. italizing and capital letters]

During an automatic process each action is triggered when we sense a specific combination of sensations—I may for instance start lifting a cup when I sense that my fingers are holding it. William James [1890: 120] writes:

> In action grown habitual, what instigates each new muscular contraction to take place in its appointed order is not a thought or a perception, but *the sensation occasioned by the muscular contraction just finished.* A strictly voluntary act has to be guided by idea, perception, and volition, throughout its whole course. In an habitual action, mere sensation is a sufficient guide, and the upper regions of brain and mind are set comparatively free. [W.J. italizing]

The automatic process is initiated by one perception or thought, and the sensation of the result of each action will then initiate the next action with a minimal conscious effort.

<u>An automatic process makes it unnecessary to consider if two actions interferes with each other</u>

If I, for instance, entered my office and wanted to turn on the light *and* the computer, and reached out both for the ON/OFF switch on the computer and for the light switch, I could theoretically be stuck because I could not press one of switches while I reached for the other.

However, in real life I will probably never be stuck in that manner; even though I may reach for both switches at the same time, I will without any conscious thinking do it in a manner where I can press first one switch and then the other.

Norman and Shallice [1980] and Shallice [1982: 200] describe that there must be an automatic function that solves such conflicts between different actions. They introduce a function called *contention control* that inhibits some processes [actions] in order to make room for other, so that less important or mutually exclusive processes [actions] are inhibited in order to make room for more important or compatible ones, and so that two mutually exclusive actions are prioritised so one action is completed before the next is attempted.

My own observations indicate that the *contention control* orders the different actions according to:

- *First come first served*: If one action has progressed further than another, that action is completed first. If my right hand for instance is closer to the ON/OFF switch on the computer than my left hand is to the light switch, I may press the ON/OFF switch on the computer before I press the light switch.
- *Order of importance*: If I in the particular situation feel that it is more important to turn on the light than to turn on the computer, I may turn on the light first even though my hand in the moment I start the movement is closer to the ON/OFF switch on the computer.

The contention control seems to be capable of handling contradictory requirements, but its function is not yet described in details.

An automatic process can be stopped by a sensation or a conscious decision

Even though the result of each action in the automatic process calls forth the next action, the process can be stopped:

- If a strong sensation draws the attention as a reflex action.
- If we focus our action on the process and consciously decide to stop it.
- If the contention control results in another process being given a higher priority. I may, for instance, stop writing on the computer and scratch my nose.
- When the automatic process is completed.

However, it is important to remember that an automatic process normally continues until it is stopped by a strong sensation or by another action.

Automatic processes frees our minds for other tasks

During an automatic process the attention is free to do other tasks, and the automatic processes make it possible for us to do a large number of everyday activities without paying continuous attention to them.

One example is the formulation of a specific meaning in words: We can express ourselves in grammatically correct or at least understandable sentences without paying attention to any rules of grammar.

Such an automatic process is highly complex. Putting words in the proper order with the proper clauses, tenses and gender is a very varied and complex task; using Michael Swan's *Practical English Usage* [1980] as an example, a description of just part of the rules the result shall fulfil consists of more than 190.000 words.

Shiffrin and Schneider [1977: 159-160] describes the difference between processes where we pay attention and automatic processes as follows:

> Control processes... are limited-capacity processes requiring attention. Because these limitations prevent multiple control processes from occurring simultaneously, these processes often consist of the stringing together in time of a series of single controlled unitary operations ... automatic processes often appear to act in parallel with one another and sometimes appear to be independent of each other.

If we are carrying out a task that demands our attention, the work on other processes demanding our attention will be slowed down or stopped, but if we are carrying out one automatic process and then starts doing another one, it is possible that the speed or the error rate of the first one is unaffected.

The speed and error rate of a process that requires our attention depends on the complexity of the process, a more complex process will always take more time; if we are carrying out an automatic process, it is possible that our speed and error rate will be the same, no matter the complexity of the process.

The difference can be summarised as: *Processes that require our attention must be done serially and are limited by our attention whereas automatic processes or parts of them can be done in parallel so they do not interfere with each other.*

Inattention and the stream of thought

The stream of thought is always changing: When using a piece of electronic equipment we will continuously move our attention between the environment, the equipment and perhaps nowhere in particular.

During most of our everyday activities the three types of inattention are mixed: While writing, I am for instance carrying out an automatic process that controls the movements of my fingers over the keys, and I am carrying out another automatic process that fits my thoughts into words and sentences following the normal grammar, and my attention may at the same time shift between the writing I am doing and thoughts of what to do in the weekend.

7.7 THE LEVEL OF TRAINING IN RELATION TO INATTENTIVE USE

Inattentive actions must be learned before they can be done: It takes training before all unnecessary movements in an automatic process are smoothed out so that the process feels effortless, and it takes training and many repetitions before the associations from the result of one action to the next proceeds without hesitation or blunders.

The learning of inattentive actions consists of three parts:

- The creation of new concepts
- The creation of more and stronger associations from one action to the next
- The training of automatic processes, in particular physical actions

This subchapter describes shortly the effects and development of these three parts of the learning.

Learning and concepts

When we learn something, our learning is very closely related to our creation of new concepts.

We start by conceiving something, drawing out a few characteristics and disregarding other. When we later find the same characteristics in another object, we conceive of the same thing and feel the thing is the same as we earlier have experienced. Our concept will gradually encompass more and more experiences of the same thing.

That happens, when we learn to use a piece of electronic equipment in more and more different situations: Our concept of its operation grows to encompass more and more situations.

We also create new concepts as our discrimination gradually is improved. William James [1890: 483-84] writes:

> *The effect of practice in increasing discrimination must then, in part, be due to the reinforcing effect, upon an original slight difference between the terms, of additional differences between the diverse associates which they severally affect...*the difference is always concreted and made to seem *more substantial* by recognizing the terms. [W.J. italizing]

The improved discrimination consists of two parts: As we have more experiences, we can gradually learn to discern small differences between them, and if we coin a name for the difference it becomes easier to recognise.

A novice computer user may call everything with a screen and a keyboard a PC; when the same user has used a number of different computers, he will discriminate between different brands of computers, computers with different operating systems and with different peripherals.

With more experiences of similar phenomenas it becomes possible to make abstract concepts. William James [1890: 478] describes the process as:

> *What is associated now with one thing and now with another tends to become dissociated from either, and to grow into an object of abstract contemplation by the mind.* [W.J. italizing]

If we have several similar experiences, their common parts can be the basis of an abstract concept.

A less experienced user must choose between the different concepts of typing, scanning and the reception of a file by electronic means, whereas an experienced computer user can use concepts as input or data acquisition to cover both the use of keyboard, scanner and modem. A more abstract conception of input or data acquisition makes it easier for the experienced user to consider how he shall get the text into his computer: The concept makes it possible for him to see that the result is the same, even though the process depends on the specific method.

The development of concepts is crucial for the inattentive use of computers: If the user does not have the proper concept of the equipment he cannot conceive of the proper action to do for carrying out the task.

The associations are fixed by repetition

The association from one action in an automatic process to the next becomes more and more fixed as the actions are repeated one time after the other. William James [1890: 529] has the following description:

> *... objects once experienced together tend to become associated in the imagination, so that when any one of them is thought of, the others are likely to be thought of also, in the same order or sequence or coexistence as before.* [W.J. italizing]

When the result of one action repeatedly is associated to the next action, it becomes more and more likely that the result of one action will activate the next by association. If the actions always happen in a specific setting or type of situation, the actions will also be associated to the same setting or type of situation. The situation becomes well known: When we have identified the situation we can take a lot of things for granted and predict the results of our actions.

We will end up conceiving of a task or a process consisting of a number of specific actions done in a specific order in a specific type of situation.

However, there is a large difference between the associations made when we only are looking on some activity and when we actually are doing it. When we are looking on someone carrying out a task, our thoughts can move hither and thither no matter what is going on—the first times we are carrying out a task we must think about the task and how to do it. This means that even though we have conceived of the situation where we looked on someone doing a task, it does not mean that we have any concept of the situation when we are doing the same task.

Habits are honed through training

William James [1890: 117] presents the following description of the training of a skill:

> ...The beginner at the piano not only moves his fingers up and down in order to depress the key, he moves the whole hand, the fore-arm and even the entire body, especially moving its least rigid part, the head, as if he would press down the key with that organ too...
> The more often the process is repeated, the more easily the movement follows, on account of the increase in permeability of the nerves engaged.
> ...the more easily the movement occurs, the slighter is the stimulus required to set it up; and the slighter the stimulus is, the more its effect is confined to the fingers alone...

With increased training the different movements can become one object and the total activity can be done more fluently and with less effort. When that happens the different movements are combined into one fully automatic process.

The different levels of learning

When we learn to do some actions without paying attention to them, our learning passes through several stages.

The first stage is the one of single experiences: We have tried to do the actions once or a few times, and if we pay attention, we may be capable of repeating them—the first times often with hesitation and errors.

My own experience indicates that our conception of a chain of actions changes when we have done it between 5 and 9 times: It becomes difficult to remember each time we have done the chain of actions and we have a conception of the chain of actions that is separate from the individual experiences.

If we repeat the same actions enough times, we may learn to do each action with less and less effort and at last as a fully automatic process. That is only possible after substantial training.

Shiffrin and Schneider [1977: 133] report that a comparatively simple action had to be done between 600 and 1500 times, before it could be done as an automatic process. These values are in good agreement with the time it takes to learn to do touch-typing and other physical skills. A touch typing course typically takes about 40 hours—with 5 seconds on average for the writing of one character, each character is written 1000 times during the course. During exercise for a sport, I have found that it takes at least 500 repetitions before I can do a complex physical action as a seemingly automatic process.

The user needs considerable training before part of the operation of a piece of electronic equipment can be done as an automatic process: It is likely that he must use the equipment every day or be drilled in the use of it before he can perform an automatic process that is specific for the equipment. Most of his automatic processes will therefore be based on his general experiences with electronic equipment and not on his experience with a specific piece of equipment.

Experienced users

Inattentive use of electronic equipment can only be done successfully by users with a significant amount of training: Inexperienced users must pay attention while they are operating the equipment.

8. PERCEPTION DURING INATTENTIVE USE

This chapter describes what happens when the user perceives the equipment he is operating, how his perception is limited when he is not continuously paying attention to the equipment and how things he senses can draw his attention from one thing to another.

The description of the users perception during inattentive use is based on the following arguments:

- The users perception is the result of a combination between the users sensation and his previous experience in the world.
- The user will by habit perceive phenomenas occurring in the equipment he is operating in the same manner as he perceives the physical three-dimensional world around him.
- The perception during inattentive use is similar to the users perception when he is paying attention, although it in some aspects is more limited and prone to error.

The relationship between perception and consciousness is not described: It is sufficient to state that even when we do not pay attention to something, we can still perceive it, but we cannot perceive something without being aware of it. When we try to determine the limits for our perception of specific objects we will always encounter the same limits as for our thinking about the same objects: If we cannot hold the thought about them in the consciousness for a short period of time, we cannot know that we have perceived them.

8.1 THE NEED OF PERCEIVING THE EQUIPMENT

The user can only operate a piece of electronic equipment if he is aware of its existence. In addition, it is often necessary for the user to perceive what the actual state of the equipment is and whether or not it needs his attention.

That is only assured if the equipment can draw the attention of the user every time it needs his attention. At the same time, the equipment should only attract the attention of the user when necessary: The equipment must not stress the user by attracting his attention when it is not necessary, and it must not draw the users attention away from the environment when his attention is needed there.

The equipment should therefore be designed so the user can perceive the actual state of the equipment, and so it attracts his attention when and only when he must focus his attention on it in order to decide what to do.

8.2 PERCEPTION, CONCEPTS, HABITS AND EXPECTATIONS

Our perception of physical things consists of two parts. William James [1890: 724] describes it as follows:

> *Sensational and reproductive brain-processes combined ... are what give us the content of our perceptions*. Every concrete particular material thing is a conflux of sensible qualities, with which we have become acquainted at various times. Some of these qualities, since they are more constant, interesting, or practically important, we regard as essential constituents of the thing. In a general way, such are the tangible shape, size, mass, etc. Other properties being more fluctuating, we regard as more or less accidental or inessential. [W.J. italizing]

William James [1890: 724] later describes his perception of a table:

> Reproduced sights and contacts tied together with the present sensation in the unity of a *thing* with a name, these are the complex objective stuff out of which my actually perceived table is made. [W.J. italizing]

Our conception of a thing is therefore an essential part of the perception of it. Our perception consists of what we sense in a given moment, our conception of it and a whole fringe of characteristics called up by our conception.

This means, that our perception in some cases can be wrong, even though our eyes or ears are fully capable of sensing the physical thing in front of us. William James [1890: 731] describes the causes of errors of perception as follows:

> *The so-called 'fallacy of the senses,' of which the ancient sceptics made so much account, is not fallacy of the senses proper, but rather of the intellect, which interprets wrongly what the senses give... The wrong object is perceived either because*
> 1) *Although not in this occasion the real cause, it is yet the habitual, inveterate, or most probable cause of 'this';* or because
> 2) *The mind is temporarily full of the thought of that object, and therefore 'this' is peculiarly prone to suggest it at this moment.* [W.J. italizing]

When we in a given moment are paying attention to one or more things, we are picking out either what we usually expect or what our thoughts in a given moment are full off.

This means that the user of a piece of electronic equipment in most cases sees or hears what he is prepared to see or hear, and if he is prepared to see or hear something, it is likely that he does not see or hear anything else.

Perception and universal concepts

Kahneman and Treisman [1984: 36] describe the so-called category effect:

> The essential result is that it is much easier to find any letters among digits, or any digits among letters than it is to find either a specified digit or a specified letter among items of the same category.

That result can be explained by us having more and stronger associations to universal concepts as letters or digits than to a specific letter or digit.

It is therefore easier for a user of electronic equipment to perceive different things from the equipment, if the users conception of the things includes some universal concept, he can use for distinguishing it from other things displayed by the computer.

Habits and characteristics

William James [1890: 728] describes how our perception is shaped by the habitual or most probable cause of the sensation:

> *...where the sensation is associated with more than one reality*, so that either of two discrepant sets of residual properties may arise, the perception is doubtful and vacillating, and *the most that can be said of it is that it will be of a* PROBABLE *thing*, of the thing which most usually have given us that sensation.
> In these ambiguous cases it is interesting to note that perception is rarely abortive; *some* perception takes place. The two discrepant sets of associates do not neutralise each other or mix and make a blur... [W.J. italizing]

A newer example of the influence of habits, that is investigated in depth, is the so-called Stroop effect. In order to demonstrate that, a person shall as fast as possible go through a list and tell with which colour the name of another colour is written. In most cases—before reaching the middle of the list—the person will start reading the names of the colours written, instead of telling with which colours they are written. The habit of reading dominates even over an active attempt on perceiving the colour of each word.

However, Kahneman and Treisman [1984: 46] conclude that:

> ... the Stroop effect only demonstrates that people do not easily ignore irrelevant *properties* of an attended object. On the other hand, our results further support the conclusion of other studies of filtering that irrelevant *objects* can be rejected quite easily. [K. and T. italizing]

I will conclude, that results similar to the Stroop effect are likely for users of electronic equipment: After all, everything played or displayed by the equipment can be perceived as characteristics of the equipment rather than as separate things. The users attention to one characteristic of the equipment rather than to another will therefore be governed by habit.

Perception and expectations

When we perceive something, our conception of it is an integral part of the perception, and it can shape our perception in such a fast and automatic manner that we are not even aware of it.

Kahneman and Treisman [1984: 33-34] describe the relation between the expected and the perceived. They use the terms *filtering paradigm* and *selective set paradigm* as described in subchapter **7.5 Attention**:

> In marked contrast to the filtering paradigms, results in the selective-set paradigm often reveal a rather impressive ability to process multiple stimuli, even in the same modality and of the same type. In many search tasks, for example, the target appears to "pop out" of the field of distractors regardless of their number...

Kahneman and Treisman [1984: 34] add that the perception of: "...priming stimuli may disrupt the subjects intended response to targets..."

In other words, our perception of a specific thing can be very fast, but it can be distracted by other sensations at the same moment, even when we try to disregard them. Kahneman and Treisman [1984: 37] write:

> In this view "pop out" or very rapid search is the normal state of affair with targets that are simple, familiar and adequately distinguishable from the background items. Another condition for rapid search is that the distractors should also be familiar, perhaps because unfamiliar characters attract attention...

This *pop out* is triggered when we sense something that resembles what we are looking for, and if our expectation is so strong that we will react even when we only detect a slight resemblance between the sensed and what we expect. William James [1890: 740-47] offers a number of examples, among them the so-called "proof reader's illusion", where he believed he had read a particular word even though another word was written and he (William James) [1890: 740] writes:

> ...we perceive a wrong object because our mind is full of thoughts of it at the time, and any sensations which is in the least degree connected with it touches off, as it were, a train already laid, and gives us a sense that the object is really before us.

William James [1890: 406] writes about experiments on attention and expectations:

> The peculiar theoretic interest of these experiments lies in their *showing expectant attention and sensation to be continuous or identical processes, since they may have identical motor effects*. [W.J. italizing]

William James continues to discuss whether or not it only is the motor action that is the same, or if the perception in the actual moment is the same no matter if it is the result of a sensation or only of an expectation filling the mind. My personal experience makes me believe that the latter at least in some cases can be true: In the moment I believe that I have had the particular sensation, it is only afterwards I realise I reacted on my expectation and perhaps on a small and irrelevant sensation.

The *pop out* effect means that we with very little effort can perceive something we expect to see. At the same time it is very difficult to perceive something if we do not expect the particular thing. That was confirmed by two experiments I carried out [appendix a].

In the *Bridge experiment* [appendix a] a total of 29 bridge players looked on a set of 13 playing cards printed on one side of a sheet. Then they turned the sheet around, looked on the set of cards printed on the other side and told whether or not they thought the distribution or the point value of the second set of cards were different from those of the first set. Both distribution and point values are very basic and well known parameters for bridge players.

The total results were distributed as follows:

1. Identical distributions:

Identical distributions spotted as identical	80 %
Identical point values spotted as identical	81 %

2. Different distributions:

Different distributions spotted as different	59 %
Different point values spotted as different	74 %

The differences between the 1. and 2. groups of results are statistically significant with a better than 99 % probability.

I will ascribe the result to the expectations of the bridge players. They expected that the second set of cards was very similar to the first set and spotted easily the similarities—they might even have searched for similarities and concluded the sets of cards were identical when they had spotted a number of similarities. On the other hand, the bridge players could not before turning the sheet expect a specific difference between the first and the second set of cards, making it much more difficult to search for differences than for similarities. The differences were therefore more difficult to spot.

The result can alternatively be explained as a result of the players finding it difficult to remember a given set of cards, However, if that was the case the errors would be symmetrical; the participants were in addition bridge players with some routine and could often remember the particular sets of cards played in the last two or three games.

In the *Text and figure experiment* [appendix b] the participants saw 90 % of the identical figures as identical but only 65 % of the different figures as different, and the difference is statistically significant with a better than 99 % probability: The participants were significantly more inclined to see two figures as identical than as different.

I will conclude on the relationship between expectations and perception:

- If we expect to perceive something it is easy to perceive even with a background of well known distractors.
- It is difficult to perceive something when we expect to perceive something else.
- In some cases we can perceive something we expect, even though it is not there at all.

Users of electronic equipment may therefore experience two problems:

- It can be difficult to perceive items seen or heard from the electronic equipment, if neither the items to be perceived nor the clutter they are hiding in are familiar for the user.
- The user will tend to perceive what is expected and not the unexpected, as for instance error messages or other indications of infrequent problems.

The perception of electronic equipment

Our perception is governed by habits and expectations—we perceive things in the manner we are used to. The user of a piece of electronic equipment will therefore perceive all phenomenas in a piece of electronic equipment in the same manner as he perceives other things in his normal physical world. The user will for instance perceive figures on a screen as 2 1/2 or 3-dimensional figures in precisely the same manner as visual illusions on paper are perceived as figures with a depth.

The relationship between sensations, perceptions and the users expectations also means that even an attentive user of a piece of electronic equipment in most cases sees or hears what he expects to see or hear, and if he is expects to see or hear something, it is possible that he does not see or hear anything else.

8.3 PERCEPTION DURING REDUCED CONCEPTION

During a state of reduced conception everything looks fresh and new as if we see it for the first time. William James [1890: 727] has the following description of the perception in a situation where the conception is reduced, he is seeing a picture upside down:

> We lose much of its meaning, but, to compensate for the loss, we feel more freshly the value of the mere tint and shadings, and become aware of any lack of purely sensible harmony or balance which they may show.

In this state it is possible to perceive new and unexpected aspects of otherwise well known things. The perception is, however, not related to any concepts or prior experiences. It can be repulsive, indifferent or pleasurable, but it carries very little meaning and cannot be associated to other thoughts.

Our perception during a state of reduced conception is different from our perception when we experience something for the first time and therefore are incapable of conceiving of it or associating our experience with previous experiences. When we experience something for the first time we may feel confusion or even panic, but we do not feel any confusion during a state of reduced conception: Confusion is only possible when we expect some meaning or relevance in what is perceived, but during a state of reduced conception we are not even aware that what we perceive usually carries some sort of meaning.

If the user of a piece of electronic equipment is in a state of reduced conception, he cannot find any meaning in what he perceives from the equipment or see the relevance of it, and he does not even miss the meaning: He can only feel wonder, repulsion or pleasure from the different sensations he experiences.

8.4 PERCEPTION, SHIFTING ATTENTION AND AUTOMATIC PROCESSES

Our perception of the external world is far from perfect: We make errors, and our perception of the external world is always biased towards what we expect to perceive. However, in most cases we can correct our errors and no harm is done:

- Often it does not matter if we make an error: In some cases what we need to perceive is gradual differences where a small error does not make any difference, in other cases our perception consists of a lot of details, so even if we perceive one of them wrongly or not at all, we can still make the right conception and decide what to do.
- It is very seldom that a thing we perceive only appears for a short moment and then disappear forever: We can get a second impression and perhaps correct the first one.
- When we make associations from what we have perceived, something may feel wrong or be amiss: We can then focus our attention on the discrepancy and correct the error we made or even conceive the whole situation once more all over.

The situation is different for a user operating a piece of electronic equipment without paying attention to it. In that case, one of two things may happen:

- The user perceives some of the displayed information wrongly.
- The user focus for a period of time his attention on the equipment in order to perceive the displayed information, and he will therefore be unaware of other things happening in his environment.

When a person is using a piece of electronic equipment, errors in his perception tend to matter: The change of one setting, letter or digit can change the whole meaning of the information displayed by the equipment. And to make matters worse: There are none or only a few superfluous details, so if *the* one significant detail is perceived wrongly, that is it.

When the user shifts his attention back and forth or does some actions as part of an automatic process, he will not get an opportunity to change an erroneous first impression.

- If his attention is shifting, it will only be focused on the same thing for the shortest possible time.
- If the user carries out an automatic process, he will act on the first clue without waiting for a second impression.

If the user does not pay attention to a specific object for a period of time, it is impossible for him to make associations from it to something else, and he cannot think about whether or not what he has perceived is right or wrong. Even when his conception is wrong, it will remain unchallenged: He can only make a new conception after he has had a new thought or a new perception, and before that can happen his attention has moved on to something else.

The perception of images

Bruce and Green [1990: 66] describe the structure of the visual areas of the brain as follows:

> The pattern of connections has proved not to be a simple chain from one area to the next; instead, each area sends output to several others, and most if not all connections are matched by reciprocal connections running in the opposite direction.

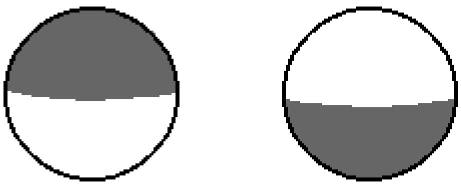
Bruce and Green [1990: 71] later conclude on the relationship between the processes behind the sensation of images and other processes of the brain:

> Extrastriate pathways do not function independently of other brain processes to deliver a presentation of the visual world, but ... their operation, beyond the earliest stages, is strongly influenced by processes responsible for attention, memory and the organisation of behaviour.

Our perception of images does not resemble some conveyor belt process where the sensory impressions are processed and moved from one centre to another in the brain, it is more similar to the painting of a picture where, given time and partly through feedback and trial and error, more and more background and details are filled in.

When we sense a well known object, it can be perceived very fast: The perception of it has formed a habit and conception and memory can add any parts and details that are not sensed in the first moment.

When we sense a new object, we will out of habit try first to perceive it in a manner that gives meaning when perceiving well known objects. One example is the perception of depth, when some part of a figure seemingly is covered by a shadow: If the top of the figure is darker than the bottom, we will see it as concave, if the top is lighter than the bottom, we will see it as convex.



Figures seemingly concave (left) and convex (right)

Inattentive users of electronic equipment perceive things shown by the equipment in the same manner as things seen in the normal three-dimensional physical world.

The limited field of vision

In most cases we cannot sense the total picture in one moment. Bruce and Green [1990: 23] describe how the cones that make it possible to perceive fine details all are concentrated in the central area of the eye, the macula lutea. The density of the cones decreases with the distance from the centre of the macula lutea, so there are no cones further away than 10° from the centre of the macula lutea. The 10° equals a width on 9 cm with a viewing distance on 0.5 m, a realistic viewing distance when a user looks on the display of a piece of electronic equipment.

However, the field of vision is normally smaller than that: According to the *filtering paradigm* for attention as described by Kahneman and Treisman [1984: 33] almost all sensations from outside the area where the attention is focused is filtered out and cannot be perceived. The area that in a given moment is excluded by the filtering effect of the attention therefore determines the actual field of vision.

According to Humphries and Bruce [1989: 148] the attention in a given moment can be focused in a field with a width down to 0.5°. Humphries and Bruce [1989: 124] report also on a number of experiments with saccades or eye movements during reading, and concludes that their average length is 6-8 characters equalling a vision field on 2°, and they (Humphries and Bruce) [1989: 276] report that the saccades can be up to 25 characters in length with the length being more dependent on the number of characters than on the angle of vision required for sensing them.

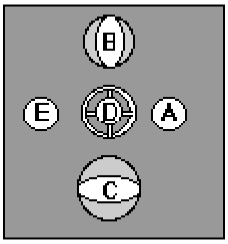
It is likely that the reader of a text does not move his eyes more times than necessary, so the length of each saccade equals the width of the central field of vision. Based on that, and with a calculation of the maximum size based on a 14 pt. letter size and a viewing distance of 0.5 m, I will conclude that the width of the central field of vision varies between 0.5° and 5° with a typical value around 2°. Therefore, with a viewing distance of 0.5 m the largest element that can be seen in total without moving the eyes is between 0.4 cm and 5 cm with a typical value of 1.8 cm.

The central field of vision is often smaller than the width of the screen used on a piece of electronic equipment: For hand held equipment the width of the screen can be as small as 4 cm, whereas normally the screens on both lap tops and fixed computers are wider than 20 cm; if the user cannot or does not move his eyes all over the screen, he may therefore miss some information on it.

I had the opportunity of observing some users of a software package for financial calculations [own observation] and found that the users scanned the screen from left to right and from top to bottom and stopped their scanning before reaching the proper information:

- During a selection in a menu, the users consistently selected the first line that might fit the actual problem. When that line did not activate the proper function, the users found it difficult or impossible to continue and try a line below.
- When the value of a field depended on some information to be set to the right of the field, the setting of the information was overlooked and the users experienced considerably difficulty.
- When the entry of some information in a field only was possible after a button below the field was pressed, the users experienced considerably difficulty in finding the button.

I have later [own observation] seen an example of a control panel, where the order of the different elements made the operation very difficult, similar to the following drawing where the letters show the order in which the different keys and knobs should be activated.



Control panel: At start-up the different keys and knobs and the wheel should be activated in the order shown by the letters, at closedown they should be operated in the opposite order: From E to A.

Our normal direction of viewing follows our normal direction of reading from left to right and from top to bottom. The user may therefore overlook some elements on the equipment if his scanning of the field of vision starts below the elements, or if it is interrupted before it reaches the elements.

<u>The perception of artificial images</u>

The images displayed by electronic equipment are artificial, their characteristics are determined by the designer of the equipment, and they are very often different from the characteristics of things we see in the physical world.

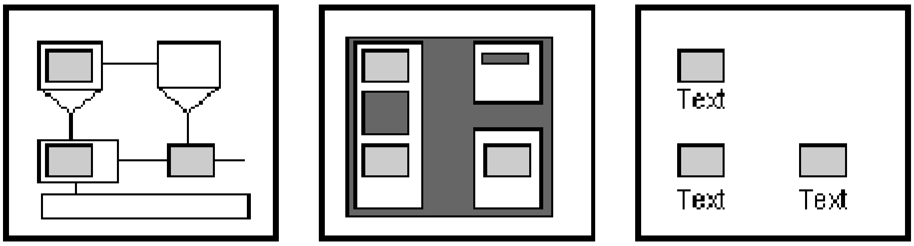
I have already described how inattentive users of electronic equipment because of habits perceive the images displayed by the equipment in the same manner as they perceive physical things in their environment. Bruce and Green [1990: 127] describe that type of perception as follows:

> Because the same kind of surface reflects and absorbs light in the same kind of way, the different subregions of a single object are likely to look similar. Because matter is cohesive, adjacent regions are likely to belong together, and will retain their adjacency relations

> despite movement of the object. The shapes of natural objects tend to vary smoothly rather than having abrupt discontinuities, and many natural objects (at least those which grow) are symmetrical. A solid object stands upon (and hence is at a different depth from) the surface on which it rests, and objects tend to be small compared with the ground.

If the objects presented by the electronic equipment look and behave in a similar manner as described for the natural objects, the habits of the user will support the perception of the objects. This does not necessarily mean that the picture on the display of the equipment should be designed to look like a room or landscape, but it means that the picture should consist of clearly discernible symmetrical objects with a uniform background.

The picture on the display is more difficult to interprete, if it resembles a flat technical drawing, as the diagrams shown on the screen for some control applications [as in Wagner 1988], or if the different objects are stuck away in pigeonholes in the graphics. Whether the graphics are pure decoration or whether they are designed for showing relationships between the functions matter less: The graphics make the first part of the perception where the elements are discerned more difficult.



Three displays: With diagrams for control applications, with heavy graphics and with explanatory text only.

The habits of perception cause problems when the user is confused by conflicts between the images displayed and characteristics of the display media.

It is very common that parts of an image displayed on a screen have jagged or blurry edges. Even when the object is large and has a good contrast to the surroundings, such blurring can cause problems.

Marr [1982: 54-74] describes how one stage in our perception of images are the detection of edges, or rather lines in the image where the light intensity changes, and he describes a mathematical model that fits well with the experimental results. In that model the second order derivative is used for the detection of changes in light intensity: When there is a change in light intensity the curve for the second derivative always crosses zero. His description of human vision is therefore based on the detection of zero-crossings, where such a zero-crossing can be the edge of a thing or the border of a shadow falling on the thing.

Such a detection of zero-crossings is done with different resolutions: A detection of zero-crossings with a high resolution will detect very abrupt changes in light intensity, as for instance along the edge of a thing, whereas a detection with a lower resolution will detect more gradual changes in light intensity, as for instance the gradual change from light to darkness where a shadow falls over the thing. In addition, it is further a characteristic of almost everything we see in the physical world that if we detect zero-crossings with a lower resolution we will also detect zero-crossings with a higher resolution. This means that if we detect lower resolution zero-crossings, but cannot detect any zero-crossings with a higher resolution, we become confused, and our perception of the image is more difficult.

The edges of an element shown on the screen or display of a piece of electronic equipment are often blurred. They may in fact be so blurred that the users vision is affected. F. W. Campbell and Robson [1968: 554] have measured our perception of lines. They found, that we could distinguish more than 40 line for each degree of field of vision; with a viewing distance on 0.5 m that equals 4.5 lines/mm. However, the screen on a piece of electronic equipment cannot normally show more than 2 lines/mm—the typical value for CRT, Cathode Ray Tubes or television type, displays are 1.7 lines/mm. It is therefore impossible to generate zero-crossings with the highest resolution from a screen picture.

The user may try to overcome the blurring by squinting slightly with his eyes: When he does that, he cannot see the absence of higher resolution zero-crossings. However, with or without squinting the lower resolution of the screen is an added strain of the eye, and it may cause temporary or chronic fatigue of the eyes.

My own experience confirms, that even a slight blurring may cause problems [own observation]:

> I have used a graphic program made for DOS, where each element was more blurred than on a normal graphic screen. The blurring caused confusion and reduced the work speed, even though the elements on the screen clearly could be discriminated from each other. It was impossible to use such a program without paying continuous attention.

In addition, I have experienced that LCD, Liquid Crystal Display, screens appear to be easier to use than normal CRT, Cathode Ray Tube, screens—the pixels on the CRT screen are slightly blurred whereas the pixels on the LCD screen have very sharp edges.

The observations fit with Gould et al. [1987: 514] who found that people often read more slowly from CRT's, computer screens, than from paper and that one of the major reasons was that the letters on the screen had a lower resolution than the letters on paper.

According to Bruce and Green [1990: 146] the perception of depth is essential for our perception of objects. They (Bruce and Green) [1990: 143, 152, 155, 1576] describe that depth can be perceived in a number of different ways:

- By stereopsis, that is by combining the pictures from the two eyes.
- By the interpretation of contours of the things shown, for instance by one thing overlapping another or by distributions of light and shadow showing the contour.
- By pictorial clues—smaller things are perceived as being further away than larger things.
- By changes in the sensed as the position of the observer or the thing observed move slightly.

Marr [1982: 114] describes that stereopsis depends on the presence of fine details in the image:

> ...it is perhaps worth pointing out here that since the grouping processes has to be rather catholic in what they are prepared to group together, the larger and more abstract tokens appear to be less reliable than the very early and primitive things in the raw primal sketch. This is particularly relevant to stereopsis for another reason: Large-scale tokens are quite large, perhaps several degrees, whereas useful disparities tend to be rather small, on the order of minutes.

Our perception by stereopsis of the depth of a thing is therefore easier when we can discern some fine details in it. However, as described in the preceding part, our eyes can separate 4.5 lines/mm whereas the screen of a piece of electronic equipment cannot show more than 2 lines/mm: The user will therefore miss some of the details that he normally uses for perceiving the depth of a thing.

The different methods of perceiving the depth of or distances to an object may give contradictory results when the object is shown on a computer screen:

- The stereopsis may be difficult or even downright impossible, because the user cannot discern any small details in the elements presented on the screen.
- The stereopsis and changes in the sensations because of movements may be distorted by parallax in the screen. That is in particular a problem for some LCD displays with a thick protective glass in front of the active part of the display.
- The overlapping of contours and shapes and sizes of the different elements may be contradictory, so different parts of the figures give different clues to their distance and depth.

The display media can show irrelevant patterns or details, for instance drivers for LCD displays that under some circumstances can be as visible as the elements displayed on the screen. The interference of the irrelevant patterns or details are similar to the interference of the mask used when preparing pictures for printing. According to A. Campbell [1985: 89] such a mask is normally made with lines at angles of 45° because lines at that angle are not perceived as easily as horizontal and vertical lines. However, the drivers or other disturbing elements seen on the screens and displays of electronic equipment normally consist of horizontal and vertical lines, so it is difficult to perceive the displayed elements without interference from lines in the irrelevant patterns or details.

Bruce and Green [1990: 227] describe shortly the theories of Gibson, according to which the texture of objects are crucial for our perception of them. It is very common that items displayed on the screen for a piece of electronic equipment lacks or has totally inappropriate textures making the users perception of them more difficult.

Perceiving complicated things

Some items—for instance letters or the shape of a face—are so familiar, that they form distinct concepts in our memory: If we see such an item it will tend to pop out from the background. However, the user of a piece of electronic equipment must sometimes perceive combinations of different forms, colours and figures that are less well known, or the user must perceive more than one item at the same time or at the same moment.

Treisman et al. [1977: 347-57] describe an experiment where the participants should identify different combinations of colours and schematic faces, and where the error rates and response times were measured. Even though both colours and the shape of faces are familiar, the combinations are not.

Treisman et al. [1977: 354] conclude on the manner in which the participants identified combinations of colours and faces:

> They first look for the presence of target features in the test display, checking each display position serially. In this way they avoid detecting illusory conjunctions among the stimuli which are physically present ... If they find a matching pair of features which are conjoined in the test display, they only then check whether these matching features were also conjoined in memory.

The different features are perceived serially, one at a time—the perception takes time and demands attention, and it is therefore impossible when the attention is shifting or as part of an automatic process.

Treisman et al. [1977: 354] continue:

> The large number of errors on trials containing test display conjunctions of wrongly paired matching features suggests that the features do tend to break loose in memory. The errors on positive trials suggest that the features recombined to form incorrect conjunctions in memory. Thus neither the coloured shapes nor the schematic faces formed stable well-integrated memories, even with targets that remained constant over several hundred trials.

The results of Treisman et al.'s [1977: 352-53] experiment show that the errors have the same bias as in my own experiment with bridge players [appendix a]: It is more likely that the participants reports false matches than that they erroneously discard combinations that actually fit together.

Treisman et al. [1977: 351] describe that each subject made approx. 500 comparisons of features, but—in spite of the large number of comparisons—the participants perception of each combination of features did not improve during the experiment. It is therefore likely that the perception of objects consisting of several seemingly unconnected features, is not, or only to a very limited extent, aided by habits.

Treisman et al.'s experiment describes the perception of things made up of several different features. Another problem is the perception of several things at the same moment. Eyseneck and Keane [1990: 139] report on G. A. Miller's classic experiment from 1957:

> Miller ... pointed out that the span of immediate memory is generally "seven plus or minus two" whether the units are numbers, letters or words. More specifically, he claimed that approximately seven *chunks* of information could be held in shortterm memory at one time. [E. & K. italizing]

The *magical limit* of seven *chunks* has been very widely accepted as the limit of what we can perceive in one moment: In order to perceive something and afterwards use the information, we must hold the perceived in the consciousness or "immediate" memory for at least a short moment.

However, the size of a chunk is not very well defined: It is likely that *chunks* in general are bigger than bits but smaller than pieces, but that is in itself not a sufficient description of their size.

Simon [1974] tried to estimate the relationship between the size of the *chunks* and the number that could be perceived and held in the consciousness. He (Simon) [1974: 484] found the following relationships between the types and number of things, or *chunks*, that could be held in memory:

Type of *chunks*	Number of *chunks*
Digits	7.98
Constants (visual)	7.30
Nonsense syllables	2.49
Geometrical designs	5.31
Concrete words (visual)	5.76
Paired associates (pair)	2.50
Abstract words (visual)	5.24
Commands *	2.42
Sentences of 6 words	1.75

* Each command equals 2 related objects

Users of electronic equipment must often perceive things that resemble nonsense syllables, paired associates, commands or sentences. In addition, the actual number of things that with some certainty can be perceived in one moment during inattentive use must be lower than the values stated above: The user is not attentive and individual differences and the actual circumstances may result in an even lower limit.

Simon [1974: 487] further reports on experiments with chess players—including grand masters—ability to perceive and reproduce the position of pieces in a game of chess. The results indicate that chess masters could remember up to 25 pieces at a time, by grouping them in half a dozen chunks. My own experience when perceiving eight digit Danish phone numbers indicates that the perception is improved when habit makes it possible to perceive each phone number as four chunks of two digits each.

The masters perception of pieces in a game of chess and my own perception of numbers have both been done many times, so the habits are very strong. I will therefore conclude that it is possible that persons can perceive more things in one moment when they through habit learn to group more things together into one chunk, but that such an improvement only is possible with very strong habits, and it is not proved that persons through habit can become capable of perceiving more chunks of the same complexity at the same moment.

Based on the above I will conclude that *when the attention of the user is shifting or when the user is perceiving something as part of an automatic process, he can at most perceive one thing at a time, and he cannot perceive things consisting of several seemingly unconnected features,* and that only very strong habits may make it possible for him to perceive more than one thing at the same moment.

Consequences for the design of images

The limited capabilities of the user during inattentive use means that images to be perceived during inattentive use should fulfil the following requirements:

- Each element in the picture should have a small size: Less than 2 cm in width so the user normally can perceive the element without moving his eyes.
- The order of the elements should be from left to right and from top to bottom.
- When the equipment changes from one state to another the element the user shall use should, if possible, appear in the position the user already is looking at on the screen or, when that is not possible, beneath and to the right of the position the user is looking at.
- The elements in the image should resemble items in the physical world with a uniform background: The screen should resemble a landscape more than a relief or a wall where the elements are perching in holes.
- The screen should have a good resolution, if necessary it should be equipped with anti aliassing (an artificial softening or blurring of the jagged edges caused by the pixels of the screen), the screen should have the lowest possible blurring of elements, and it should not

exhibit any parallax because the light from the active elements of the screen are refracted by the glass of the screen. The last requirement should be fulfilled even when the screen is viewed at an angle.

- The elements should appear small and therefore distant, so that no stereopsis is expected.
- There should not be any disturbing patterns, for instance from drivers for an LCD display, not even when the screen is viewed from an angle or at a distance. If disturbing elements cannot be avoided totally, they should be placed in sloped angles and not in a pattern with horizontal and vertical lines.
- The perception is easier if elements on the screen are made with textures found on natural objects, and if the different types of textures are used to show the shape and type of object: One type of objects may for instance have rugged textures resembling stones, another soft textures resembling flowers.
- It should be possible to identify each element without perceiving any unrelated features, for instance unconnected shapes or combinations of shape and colour. In particular, it should be possible to recognise all warning indicators, even if only one feature of an indicator is perceived.

During inattentive use it is always easier to perceive physical things than pictures displayed on a screen: It is possible to see physical things with stereopsis and they will always be more distinct and less blurred than an image on a screen. If the different elements can be labelled in an easily understandable manner—with the specific functions and not for instance with F1 or F2—it is therefore better to have physically distinct indicators and keys instead of virtual indicators and keys shown on a screen.

The perception of text and icons

The perception of the meaning of written text is essential when operating most electronic equipment. In order to perceive the meaning of written words it is necessary to:

- Read at least part of the written words.
- Understand the meaning of at least some of the words.
- Combine the words that are understood to sentences and perceive the meaning of the sentences.

Most of us have experienced that there is a considerable feedback in the perception of the meaning of written words; if, for instance, it is impossible to read one of the words in a text, we may infer the meaning by comparing the words that may result in a meaningful sentence with any readable parts of the word in the text. Such an inference can often be done as an automatic process: We may for instance infer the proper word and believe we have read it, even though the actual word in the text is misspelled.

However, if it is difficult to read a word, so the meaning must be inferred from the meaning of the total sentence, the reading becomes more difficult, and it is more likely that we will misinterpret the meaning of the sentence.

Reading of words

F. W. Campbell and Robson [1969: 554] found that the human eye is most sensitive to lines with a width equalling 4 lines/degree. If the width of the lines are reduced to a width equalling 12 lines/degree, the contrast sensitivity was reduced to 20 % of the former value. With a viewing distance of 0.5 m the densities of lines equal respectively
4.6 lines/cm and 9 lines/cm. These figures equal an optimal size of capital letters on 1.1 cm—if the size of the letters are reduced to 4 mm, the contrast shall be 5 times better to compensate for the reduced size.

I will conclude, that words to be read while shifting the attention or as part of an automatic process ideally should be written with a size of capital letters of 11 mm or approx. 30 pt. (pt. or points are the standard unit used for measuring the size of letters, 1 pt. equals 0.353 mm or 1/72 of an inch). In addition, the readability may be best for **bold letters** where the lines in each letter are wider than for the normal font (type of letters).

In particular when the size of the letters are comparatively small, for instance 10 pt. or 12 pt. equalling approx. 3.5 mm and 4 mm, the type of font affects the readability. The results of Silver et al. [1994: 824] indicate that a serif font, that is a font with feets and tops, is easier to read than a sans serif font—a font without feets and tops—even when the text consists of only a few words. That is an additional argument for implementing keys and other parts of the equipment in hardware instead of as virtual elements on a screen: Because of the low resolution it is normally difficult to show serif letters of a sufficient quality on a computer screen.

Perceiving the meaning of words

Words are not immediately understandable, the meaning we associate with them depends on our conception of the situation when we read them. One example is the word warning: I have myself experienced, that if it is the heading on a sign on a piece of equipment, I most often perceive it as *must be read;* if it is the heading in a user guide I most often perceive it as *tells nothing about how to operate the equipment.*

William James [1890: 255] writes:

> Each word... is felt, not only as a word, but as having a *meaning*. The 'meaning' of a word taken thus dynamically in a sentence may be quite different from its meaning when taken statically or without context. [W.J. italizing]

The first meaning we perceive from a text will therefore always depend on the conception of the whole situation we have made already.

When we pay attention, we may find out that the meaning we first perceived was wrong; If our attention is shifting, or if we read the word as part of an automatic process, we will act upon the first false perception of the meaning.

When the users attention is shifting or when the user operates the equipment as part of an automatic process, his conception of the actual situation will therefore determine the meaning he perceives from any words shown on the electronic equipment.

Perception of sentences

It is only possible to perceive the meaning of several related words, if the mind can hold them all at one time and then find their relationship and total meaning.

I made an experiment on the perception of written texts [appendix b]. During that experiment a total of 22 participants should determine if the text printed on one side of a sheet had a different meaning than the text printed on the other side. The experiment was done with a total of six texts, each with a length on approx. 50 words.

In the 1., 2. and 4. sets of texts, similar words were used in the first and second text, but the meaning was completely different:

- In the 1. set of texts one sentence in the second text conflicted with the remaining part of the texts.
- In the 2. set of texts half of the content conflicted with the remaining parts of the texts.
- Both texts in the 4. set of texts were parts of user guides for electronic equipment where the first sentence in the first and in the second set of texts were clearly conflicting.

The following percentages of the participants spotted the differences between the texts:

Set of texts	
1.	36 %
2.	77 %
4.	55 %

Different words were used in the 3., 5. and 6. sets of texts, but with no changes in the meaning of the text apart from the substitution of single words:

- In the 3. set of texts the word *he* in the first text was replaced by the word *she* in the second text, without essentially changing the meaning of the text.
- In the 5. set of texts some words in the technical vocabulary was changed, without essentially changing the meaning of the text.
- In the 6. set of texts the word *secret* in the first text was changed to the word *sacred*.

The following percentages of the participants spotted the differences between the texts:

Set of texts	
3	64 %
5	77 %
6	64 %

The differences between the results are statistically significant with a better than 99 % probability.

The experiment shows that the meaning of a single sentence tends to be overlooked, and that the meaning of a text is perceived as different from the meaning of another text, only when the meaning of more than half of the text is different. The experiment shows in particular that the perception of one changed word can be as easy as the perception of half part of a text contradicting the rest.

It is likely that it only is possible to understand the meaning of several related words or whole sentences, if the attention can be focused on them for such a period of time, that they can be read and perceived. In some cases it is even possible that the last words in a series of words are not read, or, if the reading starts in the middle of a sentence, that the first words in a series are overlooked. This may in particular cause problems if the words *not* or *do not* are overlooked.

The difficulties in perceiving the meaning of text can have serious implications for the operation of electronic equipment, cause it often is necessary for the user to perceive the meaning of series of words or sentences describing the state and operation of the equipment. One example is filenames with *paths*, as used in the Dos operating system, with a format similar to *C:\alfa\bravo\Charlie.del,* another example is the texts used in some applications for guiding the user through the operation, sentences of the type: *Do you want to release the type retreat function without saving the content?*

If the sentences in addition are ambiguous or contain double negations, even attentive use is difficult. One example is the sentence: "Closing Print will cancel all printing: Press OK or press CANCEL."

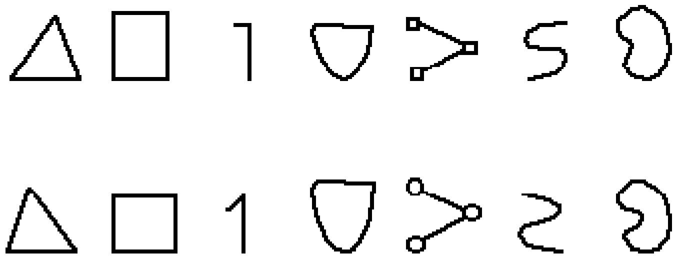
The perception of icons compared to the perception of words

Icons are, like words, symbolic representations of *some thing*. One example is an icon with a picture of a printer: It does not signify a printer but a function: *Print the document.*

Icons should in general have the same size as words: With a viewing distance of 0.5 m, they should be drawn with a line width for both black and white lines on approx. 1 mm. In many cases icons are more compact than text: It is often possible to fit an icon into the area where only two or three letters of a word will fit.

However, icons cannot be combined into sentences, and it is more difficult to perceive the meaning of icons than of printed words: We can only recognise an icon when we have seen it a number of times, and even when we can recognise it, it is quite possible that we do not have a word for it. In that case it is more difficult to discriminate between the icon and other similar icons. Besides, when we do not have a word for an icon it is impossible to find it in an ordered index: There is no equivalent to an alphabetical ordering for icons so they cannot be listed in an unambiguous order.

I made an experiment on the perception of pictures or icons [appendix b]. The experiment was made with the same 22 participants as my experiment on the perception of written texts and used the same method: The participants should look at 5 icons or small pictures on one side of a sheet of paper, turn the paper around and mark which figures on the second side that were different from the figures on the first side.



Figures used in the experiment: The first set of figures are shown on top, the second set at the bottom.

Two of the figures could be given specific names: one of them resembling a square, another the digit *1:* Respectively 88 % and 84 % of the participants could perceive differences in these figures as compared to an average of 76 % for all the figures. The difference is statistically significant with a better than 99 % probability.

The result is in good accordance with the description of the processes of thinking and conception in subchapters **7.2 The thought and its object** and **7.4 Conception**. For the conception we must have something that identifies the thing and makes it possible for us to discriminate it from others, and as described in subchapter **7.2 The thought and its object** the most compact and unambiguous type of identifier are one or more words—the name of the thing.

Consequences for the use of icons on electronic equipment

I will conclude, that icons should be drawn with a line width on approx. 1 mm for a viewing distance on 0.5 m.

Icons can be made more compact than a normal text, but it is only possible to perceive the meaning of each icon if the following are fulfilled:

- All the icons should be dissimilar. An icon with a square and another with an oblong rectangle are for instance easily confused.
- Each icon should if possible resemble an object already having a name, for instance a *printer* for the *printing function*.
- Each icon should be given a name displayed in clear text below or beside it.

Icons may sometimes be better than words for labelling the keys on a piece of electronic equipment:

- If a piece of electronic equipment is used outside the country where it is designed, it is likely that any texts or abbreviations on the keys will be meaningless for persons having a different native language, whereas it may be possible to design icons that users with different native languages can associate with a function or a meaning.
- If the keys shall be shown in the text in a user guide, any text on them may become so small when reproduced that it is unreadable, whereas icons on keys often can be reproduced in a suitable size.

The perception of tones and speech

We do not normally perceive all sounds that reach our ears. Our attention is focused on one source of sound or voice rather than another, and our attention to a voice or source of sound can to a large extent be described by the *filtering paradigm,* as described in subchapter **7.5 Attention**. Moray [1969: 46] writes:

> Frequency and loudness, then, can help in paying attention, if only by aiding the identification of a message to be received. However, the most effective dimension so far discovered along which a message may be located for selection is without doubt position in the auditory space. The most effective way in which humans handle the 'cocktail party problem' (as Cherry has called it) in which one listens to one voice out of a number which are speaking at the same time, is undoubtedly by using the fact that the different sources occupy different positions in space. [Colin Cherry was the first to investigate, in 1953, how we manage to follow one conversation when several other conversations are going on at the same time]

We focus our attention on a particular sound or voice heard through the ears in much the same manner as we focus our visual attention on something we want to see.

Perception of pure sounds

Pure sounds or tones are very often used for Audio messages from pieces of electronic equipment.

However, when the attention of the listener is shifting, or when he hears the tone without paying attention to it, his perception of the pure tone becomes very difficult.

Only a minority of people have absolute pitch, and even they may be forced to operate the electronic equipment in an environment where different pieces of equipment emit sounds with the same frequencies. Most of us find it difficult to identify a tone with a particular pitch in an environment where other pure tones may be heard, and such an environment is today the rule rather than the exception because of the widespread use of pure tones for drawing the attention to electronic equipment.

In addition, pure tones can only be used for signalling a very limited number of different messages. My own experience with radio communication equipment indicates that one piece of equipment at the most can use two pure tones intermittent for audio messages to the user. In other words, it is possible to use one tone with a high pitch and another with a low pitch, and if the tones are used as continuous and interrupted tones, and if changing high-low and low-high pitch tones are assigned specific meanings, the tones can indicate six different messages.

The user will often find it difficult to perceive the meaning of each tone combination, and only a minority of users will memorise each tone combination and its meaning. It is, however, possible to use each tone combination to indicate an event that easily can be associated with the characteristics of the tone combination. It is for instance possible by using the high—unpleasant—tone for an illegal key pressed and the low—pleasant— tone when an allowed key is pressed, and by using a low-high tone combination—indicating urgency—as an alert.

It is likely that it is easier to perceive melodies with different tones and changing pitch than to perceive pure tones with a constant pitch: At least they are easier to discriminate.

Perception of spoken words.

Eyseneck and Keane [1990: 295-96] describe the following differences between listening to speech and reading a text:

> One important difference is that in reading each word can be seen as a whole, whereas a spoken word is spread out in time. A more important difference between listening to speech and reading is that speech generally provides a much more ambiguous and unclear signal than printed text... the sound pattern for a particular speech component such as a phoneme (an identifiable unit of sound) is not invariant; rather it is affected by the sound or sounds preceding it.

This means that a spoken word only can be perceived if we are aware of it during the total interval when it is spoken. In comparison, a printed word can be perceived at any moment we look at it. It is likely that we will make more errors when hearing words than when reading them, and it is sometimes only possible to perceive the meaning of a spoken word if we have perceived the preceding words.

We can seemingly only perceive the meaning of any spoken words when we focus our attention on them for the whole period they are spoken. However, that is very often not the case, and yet we still manage to perceive the meaning. What saves us is the redundancy in our normal spoken language: We can often perceive the meaning even when we listen only part of the time.

The redundancy in speech means for instance that if we can decide when to listen and when not to, we may listen to one conversation while picking up pieces of another.

However, when someone uses a piece of electronic equipment without paying attention, it is likely that he does not benefit from any redundancy in the spoken messages:

- The verbal messages from the equipment will often have a very low redundancy—they will be generated as single words and not as total sentences.
- It is not always possible for the user to control when to focus his attention on the spoken messages and when to focus his attention on the environment, for instance on another person speaking to him.

The *filtering paradigm* for the attention, as described in subchapter **7.5 Attention**, means that very little can be perceived if we do not focus our attention on the stream of talk—if our listening is part only of an automatic process. Moray [1969: 52] writes:

> If commands such as 'Stop now' or 'Change to this ear' were inserted into the non-shadowed message [the stream of speech the listener does not pay attention to] they were neither obeyed nor heard, but if the command was prefixed by the listener's own name ('John Smith changes ears now') it was heard in about one third of the trials when listeners were not expecting it.

It seems that during an automatic process some spoken words can catch the attention of the listener as a reflex action. It is possible that single words also through habit can trigger other actions, for instance automatic processes without conscious control. The filtering effect, however, is very strong: Even the persons own name, that he through habit probably reacts most strongly to, could only cause a reaction every third time it was spoken when he did not pay attention to the voice speaking it.

Consequences for the use of audio messages in electronic equipment

It is difficult to discriminate pure tones: If any messages from the equipment shall be in the form of tones, the messages should therefore ideally consist of different tones with a changing pitch.

In most cases the meaning of an audio message cannot be perceived when the attention is shifting or as part of an automatic process, audio messages should therefore if possible only be used for drawing the attention to another message, and they should be loud or distinct in comparison with any background sounds.

If audio messages are used for giving verbal information, they should have a normal pronunciation and grammar and some degree of redundancy.

Differences in the perception

D. W. Kline and Fuchs [1993: 30] investigated the visibility of different highway signs with symbols and texts. They showed that symbolic highway signs could be perceived from about twice the distance at which highway signs with texts could be perceived. However, if it is taken into consideration, that the lettering of the texts was significantly smaller than the applied symbols and that only four different signs, or symbols, were used, the experiment seemingly shows that text and symbols normally can be perceived from approximately the same distance and therefore with the same ease.

Humphreys and Bruce [1989: 273-4] report that the duration of the fixation of the eyes during each saccade, eye movement during reading, varies between 100 ms and 500 ms with a typical value on approx. 250 ms. When that duration is compared with a length for the attentional integration between 50 and 250 ms as described in subchapter **7.3 The changing stream of thought**, it is unlikely that icons or symbols can be perceived faster than a single written word.

During inattentive use spoken words are more difficult to perceive than written words, and because they are spread out in time, it will typically take approx. 1 s to perceive a spoken word whereas a written word can be read in 200 ms.

T. J. B. Kline and Beitel [1994: 691-95] have compared the use of signs with text, with icons and with combined icons and text. They found that:

- The participants reacted equally fast on signs with text only, with icons, and with icons combined with text.
- Signs with text were perceived as more meaningful by the participants—signs with pure text were perceived as even more meaningful than some of the signs with combined icons and text.
- In a field test the participants complied best with signs showing both icons and text.

I will conclude that a user of a piece of electronic equipment in general will find icons and printed text equally easy or difficult to perceive, and that he will be capable of perceiving them with the same speed. However, unless icons are shown together with a text or already is strongly associated with a name, for instance on a letter or a geometrical figure, the user will find it difficult to associate the icon with a name and therefore also find it more difficult to perceive the meaning and to discriminate it from other icons.

The user of a piece of electronic equipment can only read a word displayed on the equipment when he is looking at the word; Apart from that, written words displayed by the equipment are faster and easier to perceive than any audio outputs from the equipment.

8.5 SENSATIONS DRAWING THE ATTENTION

Subchapter **7.5 Attention** describes how our attention as a reflex can be drawn to an intense, voluminous or sudden sensation or to something with a content of a directly exciting quality. If we hear a loud sound, we will normally turn our head and look towards its source, and if we hear someone calling our name, we will turn our head towards the caller.

Subchapter **8.1 The need of perceiving the equipment** describes how the equipment must draw the attention of the user every time he shall focus his attention on it in order to decide what to do.

This subchapter describes how it can be assured that the attention of the user is drawn to the equipment as a reflex action. The subchapter focus on sensations rather than perceptions: The perception of something also includes a fringe of farther facts, a conception and some sort of identification; when the attention is drawn towards something, the fringe of that *something* consists in the first moment it is sensed only of a habitual movement of the attention—the conception of the thing perceived is very limited.

Visual sensations drawing the attention

According to the filtering paradigm for our attention most things in the peripheral part of our field of vision are not perceived. Things in the peripheral field of our field of vision can therefore only draw the attention if they are highlighted very early in the visual process—before the filtering effect of the attention.

Bruce and Green [1990: 121] describe which elements that are grouped together when one element is not highlighted in comparison with another:

> ... pattern elements need not be identical in order to be treated together by grouping processes. Such grouping processes seem to operate between elements of similar brightness, wavelength [colour], slope and granularity. These properties corresponds to those which we know are extracted early on in visual processing.

Elements can therefore be highlighted by having lines or a pattern with a *slope* or granularity or TEXTURE that is different from the background, or they can have a distinct colour or be **brighter** or **darker** than the background.

This also means that a letter or an icon in itself does not stand out against the background: It will draw the attention only if it is highlighted, for instance with a colour that is different from the background.

Bruce and Green [1990: 123] describe also how symmetrical figures and regular geometric forms such as circles, squares or triangles are more easy to discern from the background than more irregular figures.

Jubis [1990] investigated how the addition of colours to figures reduced the search time for specific figures. He (Jubis) [1990: 291] found that figures that only could be identified by the colour and figures with a redundant colour coding—figures that could be identified by either their colour or shape—both could be found with a search time between 1800 ms and 2100 ms. Figures that could be identified only by their shape could be found only after a search time between 3600 ms and 4400 ms. The shapes of all the figures used in the experiment were very distinctive; in spite of that it was significantly easier to find figures marked with a colour than to find figures identified with a shape.

The use of figures that are identified by their colour may pose problems for colour-blind users. However, such problems can be minimised if all figures can be identified by either their colour or their shape and if no red and green figures are used at the same time: *The lack of ability to distinguish between red and green is the most common type of colour-blindness.*

The results of Jubis's [1990: 289] and Orden et al.'s [1993: 201-2] experiments describe the relationship between search times and the flashing and brightness of symbols. They found that:

- The search time for a flashing symbol is less than 60 % of the search time for a non-flashing symbol.
- The search time for a brighter symbol is less than 70 % of the search time for a symbol with the same brightness as the other symbols when the luminance of the bright symbols is improved by a factor 5; when the luminance is improved only by a factor 2, there is no significant reduction of the search time.

The experiments conducted by Jubis [1990: 289] and Orden et al. [1993: 198] were done on screens with a width that gave the participants a viewing angle significantly larger than the central part of their field of vision: The search times are therefore a good indicator for how well the different objects on the screen caught the attention.

Humphreys and Bruce [1989: 24-26] describe the function of the retinal ganglion cells, through which signals are sent from the eye to the brain. These cells maximise responses to changes in intensities of light, and does that by reacting on differences between the light intensity in the centre and the periphery of an area. His description indicates that things that are moving or showing some sort of pseudo movement may be even better than flashing symbols at catching the attention. My personal experience indicates that things seemingly moving directly towards me are the very best at catching my attention. However, the question has not yet been investigated.

It is also likely that symbols that are brighter than the background *and* flashing will be even better at catching the attention. However, that question has also not yet been investigated.

I will conclude that the attention can be drawn by symbols that are symmetrical with a distinct shape or texture. However, the attention is drawn even better to symbols of a different colour, in particular if they also appear to be flashing or moving.

Finally, it is worth bearing in mind, that the attention only can be drawn to one thing at one time: If a piece of electronic equipment at the same time displays several flashing or bright symbols, it is possible that the attention of the user is not drawn to any of them at all.

Audio sensations drawing the attention

The selectivity of our attention works in very similar ways for our vision and hearing: According to the filtering paradigm for the attention, as described in subchapter **7.5 Attention**, we exclude most of the sounds we hear, and we will therefore only react if the tone or voice has some penetrating qualities.

Even if we associate a specific word or tone with urgency or importance that is not a truly penetrating quality. As described earlier Moray [1969: 52] reports that the participant in his experiment on average heard his own name only every third time it was included in a stream of talk he did not pay attention to, and the participants own name is probably one of the most important sounds for him and the one he most habitually reacts to.

Hellier et al. [1993: 703] describe that a high pitch of a tone, fast intermittent repetitions or repetitions over a long period of time signify a sense of urgency for the listener. Such sounds will therefore have a penetrating quality. It is obvious, that loud sounds have a penetrating quality, and my own experience indicates that a human voice showing strong emotions can be very penetrating: It is more difficult to understand, but it will catch the attention.

Based on the above I can identify the following penetrating qualities of a sound:

- *It is intermittent* or with a discernible rhythm and it changes fast: For instance on/off or low/high as police sirens.
- *It is loud.* However, an experiment by A. J. Campbell [1985: E1-4] indicates that a tone should have an intensity on more than 90 dB SPL before the loudness of the tone in itself can assure that the attention is drawn.
- *It consists of penetrating or obnoxious tones*—an experiment by A. J. Campbell [1985: E1-4] shows that a tone with a frequency of 2500 Hz gives a strong reaction compared to tones with a frequency of 2000 Hz or lower.
- *It is a human voice which tone indicates strong emotions.*

A tone or voice that is repeated for a long period of time is perceived as more penetrating: It signifies an urgency and if the tone continues for a longer period of time, it is more likely that the user will focus his attention on it.

In most cases, a sound will only catch the attention if it has several penetrating qualities, for instance if it is loud, intermittent and with some high penetrating tones.

An audio sensation can only draw the attention to a piece of electronic equipment if the user senses that the sound comes from the equipment. In that case it is likely that the attention as a reflex action is drawn to the equipment.

I have myself experienced problems when I could not depend on sounds drawing my attention to the equipment I used [own observation]:

> Once I worked on a project together with two other persons; all of us were using cellular phones. When we were together and when one of our phones rang, or even sometimes when some other beeping sound was heard, we all three made a fast grab to our own belt and cellular phone.
> I was walking on a busy thoroughfare, and when I passed a parked car I suddenly heard a beeping sound. I stopped and wondered where the sound came from; it seemed to come from the car, but the car was parked with motor and lights off. The sound stopped, I moved on and the sound started again 10 s later. Then I realised that the sound came from the cellular phone I carried in a pocket in my jacket.

I have made no formal experiments, but my own experience indicates the following:

- Because of echoes, it is very difficult to determine the direction of a sound if it comes from away from the horizontal plane or close to the body.
- Determining the direction of a specific sound depends to a large extent on perceived phase shifts and interferences between different tones, I have seen that demonstrated with Hi-fi equipment being tested with music and with pure tones: It is much easier to

determine the direction of music or speech with complex wave forms than to determine the direction of pure tones.

I will conclude that any sounds drawing the attention to a piece of electronic equipment shall be loud, intermittent and either a voice or a combination of different tones. In addition, there are cases in environments with a high noise level, or when the equipment is positioned away from the horizontal plane or close to the body of the user, where sounds in general cannot be used for drawing the attention.

Adjustment of light intensity and sound levels

The intensities of light signals and the power levels of audio signals from the equipment should be within the following limits:

- They should be so powerful that the user can sense them in the environment where the equipment actually is used.
- They should not be so powerful that they give the user a shock so he cannot react or sense other events immediately after the equipment has emitted the light or sound.

The actual levels of light and audio signals should therefore fulfil the following requirements:

- The intensity of a light signal should fit the ambient light level—the intensity of the light signal should be adjusted automatically, or, if that is not possible, it should be possible to adjust the light level manually. However, the ideal intensity of light signals depends on the specific application and can therefore be determined only by experiments.
- There is no available figures on the minimally necessary sound level—my own estimate is that the power level of an audio signal ideally should be 20 dB or more above the ambient sound level. However, the user cannot close his ears, and the experiments made by A. J. Campbell [1985: E1-4] indicate that the power level of an audio signal therefore always should be below 95 dB SPL.

Tactile sensations drawing the attention

When we get any sort of tactile sensation, we will always know where it comes from. In addition, tactile sensations are better than visual or auditory sensations for drawing our attention: A tactile sensation, will, if it can be sensed, always draw the attention [own observation]:

> I have over the past years used a pager with a built in vibrator signalling an incoming call. Even though the vibration is quite small, it has always caught my attention immediately after it started to vibrate, and even though I am used to it, it can still cause me a small jolt when it starts vibrating. My experience is confirmed by other sources.

Gilliland and Schlegel [1994: 700-717] have investigated the use of tactile stimulations for giving messages to pilots. They (Gilliland and Schlegel) [1994: 707] found that when 8 points were stimulated on the top of the participants head, the participants in the experiment in 98 % of the cases could determine correctly which of the points were stimulated. Gilliland and

Schlegel [1994: 715] also found that all the participants reacted to all tactile stimulations, they did not miss one.

Tactile sensations are experienced as originating very close to the body. For that reason they tend to disrupt all other perceptions and immediately draw the attention, and they have therefore a detrimental effect on other tasks.

Gilliland and Schlegel [1994: 714] also investigated how much the tactile stimulations intruded on other tasks carried out by the participants. They found that the tactile stimulations had a significant impact on how the participants carried out other tasks: For one of the tasks the speed dropped with 50 % and the number of correct responses from 93 % to 78 %. However, they (Gilliland and Schlegel) [1994: 716] conclude that a visual or audio system presenting the same information might have the same impact.

Based on my own experience I will conclude that tactile stimulations can be very effective *and* very disruptive: They can be used when it is imperative that the user focuses his attention on the equipment, but they should not be used as indicators for the state of the equipment. The only exception might be applications where a visual feedback cannot be used, and where an audio feedback will be disruptive or a nuisance for other persons near the user.

Sensations drawing the attention during reduced conception

If the user of a piece of electronic equipment enters a state of reduced conception, the consequences can be serious because the user in that state operates the equipment without any regard to the consequences of his actions. Unless the electronic equipment is used solely for games or entertainment, the state must therefore be interrupted.

During reduced conception the user excludes all thinking about the meaning of what he is doing, and he filters out all sensations outside the narrow field where he focus his attention. His attention can therefore only be caught if sensations inside the field where he focus his attention manage to break his rhythm and concentration on not thinking. However, during a state of reduced conception his attention can only be caught by a signal that is significantly more annoying than the signal needed for drawing the attention of the user when it is shifting or during an automatic process:

- The signal can ensure, that similar actions occasionally result in different sensations or that he must read some texts or otherwise make a break before progressing in the work. Such changes in the rhythm forces the user *out* of a state of reduced conception.
- The signal can be intermittent, preferably with an irregular rhythm. Such a signal will break the concentration.

A piece of electronic equipment can be designed such that it gives the user occasional interruptions, that prevents a state of reduced conception. However, such interruptions can cause problems during the normal use of the equipment. As an alternative it may be possible to design equipment that detects when the user may be in a state of reduced conception and only in that situation generates appropriate interruptions or signals.

8.6 THE PERCEPTION OF SIMULTANEOUS PHENOMENA

Subchapter **8.4 Perception, shifting attention and automatic processes** describes the consequences if the user does not pay attention while a verbal message sounds or while a picture or a written message is displayed.

This subchapter describes the consequences if the user has more than one sensation at the same time or within a very short period of time.

If the user has more than one sensation at the same time, one of three things may happen:

- A sensation may be disregarded, it is simply not perceived.
- The sensations may be experienced one after the other, one of them is perceived later than the other.
- The two sensations may be combined into one perception.

If the user is paying attention to one source of sensations, he will not perceive sensations from other sources and will at the most be only faintly aware of them: He may have a feeling in a certain direction without being aware of its source. Eyseneck and Keane [1990: 101, 105] report that persons can have an emotional or physiological reaction to specific words, even though they are unaware of the words itself.

However, if the user shall operate a piece of electronic equipment, he must be aware of its state and indicators: It is not enough that he has a vague feeling about them.

If the users attention is divided over a larger area, the sensations may be experienced as one after the other. William James [1890: 598] writes:

> ...every act of perception of a sensorial stimulus takes an appreciable time. When two different stimuli—e.g., a sight and a sound—are given at once or nearly at once, we have difficulty in attending to both, and may wrongly judge their interval, or even invert their order.

The user of a piece of electronic equipment may therefore perceive signals from the equipment in a different order than they actually occur, or he may confuse the order between signals from the equipment and things he senses in the environment.

If an event happens immediately before or while the user does some action, he may therefore experience that the event is caused by his action.

Finally, two different sensations may be combined into one perception: If the user sees a figure displayed by the equipment and at the same time hears a sound, he may experience that the figure and the sound is one. If that happens during the users initial act of conception, it is afterwards be difficult to perceive the meaning of the figure when the sound is absent.

The perception of an inattentive user is in general limited: If he has two simultaneous or nearly simultaneous sensations, they will influence and alter each other in one way or another. The total perception can therefore be different from the perception of any of the sensations occurring alone.

I will conclude that electronic equipment to be used by inattentive users should minimise the problems caused by simultaneous perceptions by avoiding simultaneous signals of a short duration from the equipment and by avoiding signals from the equipment that can be confused with events in the environment.

8.7 PERCEPTION AND LEARNING

We learn to use our senses before we are grown up, and it is unlikely that the user of a piece of electronic equipment can improve his sensing abilities significantly by later training.

However, the user may learn to perceive what he senses in a better manner. Subchapter **7.7 The level of learning in relation to inattentive use** describes the relationship between learning something and the creation of new concepts, and subchapter **8.4 Perception, shifting attention and automatic processes** describes how the creation of new concepts makes it easier to perceive complex elements.

My own experience indicates that the creation of new concepts, for instance abstract or universal concepts, continues all the time a person uses different pieces of electronic equipment, and the person can therefore seemingly improve his sensing of signals from equipment of well-known types. If the equipment is of a new type, the situation may be different: It may be possible for the experienced user to use his concepts in the new situation, but it is also possible that his perception in the new situation is not any better than the perception of a less skilled user.

Our perception depends to a large extent on habitual movements and actions, and an experienced user will often acquire habits that improves his perception—he may for instance learn to look all over the screen before selecting the next function he wants to activate. The user can draw on such habits when he conceives of the situation as similar to one he earlier has experienced, and it is therefore possible that he can draw on his habits of perception both when he uses well-known pieces of electronic equipment and when he meets a new type of equipment.

> *In the relative sense,* then, the sense in which we contrast reality with simple *un*reality, and in which one thing is said to have *more* reality than another, and to be more believed, *reality means simply relation to our emotional and active life.* This is the only sense which the word ever has in the mouths of practical men. *In this sense, whatever excites and stimulates our interest is real;* whenever an object so appeals to us that we turn to it, accept it, fill our mind with it, or practically take account of it, so far it is real for us, and we believe it.
>
> William James [1890: 924] [W.J. italizing]

9. ASSOCIATIONS, IMPULSIVE POWER AND EFFORT

This chapter describes how the thoughts of the user are shaped from the moment he perceives something from the equipment until he does something about it.

Subchapter **6.3 The value of observations made from an information-processing viewpoint** describes how the newer cognitive psychologists and specialists working with user interfaces cannot describe the complexity and dynamics of the thoughts of the user.

One example is Gilhooly [1988] who gives a detailed description of the newer research of human thinking and decision making. He (Gilhooly) [1988: 59-90] describes the manners in which chess players, bridge and poker players, physicists, mathematicians, computer programmers, doctors and experts in political science make decisions within their own areas of experience. Gilhooly's [1988: 59-90] descriptions show that:

- The specific results cannot be generalised from one area to another, so none of the results described by Gilhooly [1988] can directly be applied to the problem of *how the user thinks while operating a piece of electronic equipment.*
- The results described by Gilhooly [1988] can all be described within the framework established by William James [1890], and such a description can often be more consistent and more precise than the description made by the experimenters themselves based on the *information-processing approach.* In particular, the *information-processing approach* as used by Gilhooly [1988] cannot describe the act of conception, the particulars in the stream of thought or any hesitation before the user initiates an action.

This chapter is therefore based almost solely on William James [1890].

The limitations of the transitive parts of the thought

The user cannot report on the transitive parts of his thoughts, the parts that brings him from a perception through maybe one or more resting places to the point when he initiates an action. William James [1890: 236] writes:

> ... it is very difficult, introspectively, to see the transitive parts for what they really are. If they are but flights to a conclusion, stopping them to look at them before the conclusion is reached is really annihilating them. Whilst if we wait till the conclusion *be* reached, it so exceeds them in vigor [sic] and stability that it quite eclipses and swallows them up in its glare.
>
> [W.J. italizing]

It is therefore not possible to describe precisely how the user gets from one point in his thoughts to the next. However, it is possible to determine whether or not it is difficult or even impossible for the thoughts of the user to reach a point where he initiates a useful action: Even though we cannot get access to the kitchen and see how the cooking is done, we can still determine if it is difficult or downright impossible to prepare an eatable meal if we are allowed to inspect the ingredients that goes into it.

That leaves some latitude for human variation. Even when the equipment is properly designed, it is by no means certain that the user actually can initiate the proper actions when operating the equipment. It is *impossible* to define a design standard and say: If such and such is done, the user can initiate the proper actions during inattentive use. It is *possible* to describe only when it is difficult or even downright impossible for the user to initiate a useful action, and when it is *likely* that the user can initiate the proper action without focusing his attention on the equipment.

9.1 THE PURPOSE OF DECISIONS

When the user has perceived the state of the equipment he must normally initiate an action that brings the equipment closer to the state he wants it to reach: A state that fulfils the goal of the task he is carrying out.

In work situations the goal is normally well defined: If the user, for instance, is operating a cellular phone, his goal may be to bring the phone into a state where he can have a conversation with another person equipped with a phone. When the user is playing with the equipment the goal is less visible, namely to give him some emotional satisfaction either as a result of the activities themselves or as a result of the state the equipment enters.

When the user has perceived the state of the equipment, he can make a multitude of different associations from that state to different actions that he might carry out, and because he cannot carry out all the actions at the same time he must choose which action to carry out first.

However, the purpose of the whole exercise is to change the external world towards a desired goal, and therefore it is not sufficient if the user *chooses* an action: He must also initiate it.

9.2 THE STRUCTURE OF DECISIONS AND ACTIONS

In order to initiate an action, the user must complete three steps, and the action he initiates depends on the results of each of these steps:

- The user makes associations to one or more possible actions.
- If the user has made associations to more than one possible action, he chooses which one he wants to carry out.
- The user initiates the action he has chosen.

The user must make an association to a possible action: If his thoughts cannot reach an action, he cannot carry it out. The actions he can make are therefore limited to the actions he can make an association to.

If the user has associated to more than one possible action, he must make a decision and select which of the actions he will carry out. His decision depends on both the goal he has set for the task he is carrying out and the dispositions that influences his selection of a single action. The user may, in addition, make a decision in different manners depending on the amount of attention he is paying to it:

- If the user is paying continuous attention to the task he currently is working on, his choice of a particular action may be influenced by a plan he has made for how to complete the task. It is for instance possible that he already has considered which steps he must complete in order to reach his goal.
- If the users actions are part of an automatic process, his next action is often determined by that process. In that case he will not make a conscious decision and his choices are limited. However, he will still end up carrying out one action instead of another. I will therefore describe his mental activity as a *de facto decision:* It serves the same purpose as a conscious decision, even though the user is unaware of making any decision.

The user shall finally initiate the action he has chosen. Whether or not he does that depends on the will and the effort he can put into his action—the actual balance between his dispositions for acting and the dispositions that hold him back.

In some cases the user initiates the action in the moment he has chosen which action to carry out, in other cases there is a period of deliberation between the choice of an action and the initiation of it. I have experienced both cases [own observation]:

> When I suddenly think about saving the document I am working on, I will do so without any hesitation. In contrast, if the computer is stuck and I know the only possible course of action is to restart it and lose the results of the last period of work, I can only press the RESTART button after some deliberation.

9.3 DIFFERENT USERS DECIDE IN DIFFERENT MANNERS

Different users have different capabilities and different dispositions, and the equipment should be adapted to a range of users with different capabilities and dispositions. This subchapter describes how different types of users may think and how they decide which action to initiate.

Different ways of thinking

All persons can think in words and recognise pictures and feelings of movement: If they could not do the first they could not express their thoughts, if they could not do the second and third, they could not find their way in the physical world. Apart from these three capabilities, the thinking of individual users may differ widely.

The following description is partly based on William James's [1890: 690-721] description of different types of imagination, but it is not limited to it.

Some people find it easier and more natural to think if their thoughts are accompanied by pictures, words or feelings of movement, and they may be more or less capable of imagining pictures or feelings of movement. The capabilities may differ widely from one person to another; however, even so-called visual or motoric types are capable of expressing at least some of their thoughts in words.

Some persons accompanies at least part of the time their thinking with pictures with all details, colours and the right spatial relationship between the different elements. In other cases the thinking includes only the different elements of the picture, maybe as representations or concepts, without the proper proportions or spatial relationships.

Even though everybody is capable of accompanying their thoughts with words, the capabilities may differ widely from person to person: Different persons are more or less apt at discriminating between the meaning of different words, they may experience a smaller or a larger fringe with each word, and they may be more or less capable of dealing with words for universals or abstractions.

It is finally necessary for some persons to accompany their thinking with some feeling of movement. When that is not possible their stream of thought is obstructed.

Dominance of emotions, reasoning or will power

I have observed that users of electronic equipment tend to choose the next possible action in one of three different manners:

- By applying intuition and emotions
- By reasoning
- By a display of will and effort.

During the testing of a financial package [own observation] the users were clearly divided into three groups seemingly choosing their actions through intuition and emotions, through reasoning or through will and effort.

The emotional type waits silently until something shows up, either a sudden inspiration or some assistance from someone else. This way of solving problems is well suited when dealing with emotional problems or problems with other people: Given time something is bound to happen. It is, however, not the best method when operating a piece of electronic equipment: When the equipment is not operated, nothing happens, and the user may be left unmoving for a very long time.

The reasoning type conducts a monologue similar to *it cannot be A, so it must be B.* Users of that type try to develop an argument for a specific type of action before it is carried out. This way of solving problems is well suited for intellectual problems, but it may cause problems when using a piece of electronic equipment where the normal laws of reason do not necessarily apply: A user of this type is prone to fall into the same trap one time after the other when his reasoning every time results in the same answer.

The user dominated by will and effort seldom lets his thoughts block an opportunity to act—he tries to do something and sees what happens. That method can be used when dealing with unbreakable mechanical things or with people that submit to his will. However, if it is possible to damage the equipment, it is likely that a user of this type will do it.

When a user gains more experience with electronic equipment in general his thinking often becomes more analytical and systematic—he has acquired some knowledge so he can reason over the function of the equipment and do an action, evaluate the result, and then do another action.

My own experience indicates that the experienced user is helped in finding the proper action by using his intuition: He has a specific feeling of the action he shall reach, his thinking becomes more focused, he may jump to a conclusion and reach the proper action by other means than reasoning or pure trial and error.

However, as I saw during the testing of the financial package [own observation], when the user works under pressure his actions are once more governed by his more basic habits.

It is likely, that the different manners in which different users choose an action are related to the different steps before the action is initiated:

- Different users may find the different steps in the process more or less difficult; it is possible that a user applying intuition and emotions finds it very difficult to associate to possible actions, it requires therefore considerable time before he makes associations to any actions he may choose between.
- A user can have a lower or higher level for accepting the result of each step before the action is initiated: One user may for instance try to make associations to a large number of possible actions before he chooses one, another user will choose the first action he makes an association to. It is possible that a reasoning user wants to be assured that he has chosen the proper action, whereas a user dominated by will and effort has a very low level for determining that he has chosen the proper action.

Impulsive and irresolute users

I have earlier described how the users action in a specific moment depends on a balance between a disposition for acting and a disposition for postponing the action. Different persons may be disposed one way or the other.

William James [1890: 1144] describes the "explosive will" where the disposition for acting is the strongest:

> There is a normal type of character, for example, in which impulses seem to discharge so promptly into movements that inhibitions gets no time to arise. These are the 'dare-devil' and 'mercurial' temperaments, overflowing with animation, and fizzling with talk...

William James [1890: 1153] later describes the type of person who postpones any action:

> Men do not differ so much in their mere feelings and conceptions ... No class of them have better sentiments or feel more constantly the difference between the higher and the lower path in life than the ... 'dead-beats,' whose life is one long contradiction between knowledge and action, and who, with full command of theory, never get to holding their limp characters erect.

William James [1890: 1137-1138] finally describes how persons are more or less disposed towards changing their minds:

> There is no more remarkable difference in human character than that between resolute and irresolute natures. Neither the physiological nor the psychical grounds of this difference have yet been analysed. Its symptom is that whereas in the irresolute all decisions are provisional and liable to be reversed, in the resolute they are settled once for all and not disturbed again.

These dispositions affect the manner in which the user operates a piece of electronic equipment: A user with an *explosive will* may initiate an operation without ascertaining that no warning signs are lighted, whereas a user that postpones any action needs more time for thinking before he initiates an action. In addition, a user of the resolute type is less willing to correct his errors, whereas the irresolute user needs more time cause he more easily is diverted from one specific line of action.

Individual reactions during inattentive use

Users may operate electronic equipment without paying attention for one of two reasons:

- As described in subchapter **7.5** the attention wanders if the user does not feel a need to pay attention to what he is doing—for instance if the task for a period of time seems routine or very little demanding.
- When the user feels he is under either external or self-induced pressure and must complete more than one task within the same period of time, he will work on a task without paying continuously attention to it.

In the first case, it is likely that the dispositions of the user will guide his actions in the same manner as when he is working and paying attention. However, in the second case—when the user feels he is under some pressure—he will act in a different manner. The user is then more inclined to act simply in order to do *something* and according to Erikson [1959: 135] he will try to protect his own feeling of self. His actions will then be less varied and dominated by a few basic dispositions.

When the user is inattentive, it is therefore possible that the emotional user lets his emotions dominate, the reasoning user only reasons and the user dominated by will cannot be stopped by neither perceptions nor reasoning.

In the same manner it is possible that the user apt to thinking in pictures lets his operation be guided by pictures, whereas other users cannot even try to visualise anything or think without touching and moving all keys and settings; finally, the irresolute becomes more irresolute and the explosive will even more explosive than usual.

Equipment for inattentive use should therefore be adapted to the different types of users. When the user pays attention it is often possible for him to overcome some of his own limitations, but—sometimes—during inattentive use he will not even try to do that.

Consequences for the design of electronic equipment

The ability to think in pictures differ widely from one person to another, the electronic equipment should therefore be designed so it fits the users that are least capable of thinking in pictures. It should for instance be possible to determine the actual state in the operation of the equipment without recalling the graphics of a particular screen picture and comparing it with the screen picture shown at the actual moment.

Words to be recognised by the users should be easily discernible: The operation must not depend on whether one word or another with an almost similar meaning is displayed, for instance on whether the equipment flashes *Danger* or *Warning*. If the user it of a type who experiences a large fringe with each word, it is more likely that he picks up associations leading in different directions. Such a user may experience problems if a text displayed by the equipment can be interpreted in ambiguous ways: It is quite possible that he will spend time considering totally irrelevant interpretations. I finally believe that most people find words for abstract or universal concepts more difficult to deal with than words that are more directly related to a sensation. The messages displayed by the equipment should therefore be as specific as possible.

The equipment should be adapted to users that *think with their fingers:* The functions in the equipment should whenever possible be reversible, so that the user can try the different functions while he is thinking. In addition, the equipment should be designed so the users habitual movements are taken into account: It should not be possible to destroy the equipment, by moving part of it back and forth or by rubbing it with a finger for a prolonged period of time.

The equipment should finally be adapted in different manners to users that are emotional or intuitive, reasoning or driven by will power: The intuitive or emotional user will need truly self-explanatory equipment and equipment that will present various stimuli if no action has occurred for a prolonged period of time, the reasoning user will benefit from a logically consistent and understandable user interface, and the user dominated by will and effort will need a piece of equipment where he cannot make any damage by accident.

It is possible that most users of electronic equipment forty years ago were reasoning persons, used to thinking in abstracts and universals and with a healthy will and resolution that made it possible for them to work in a thorough manner and gradually learn from their mistakes. Today, however, most types of electronic equipment are used by all types of persons, and it should therefore be designed for a wide range of users.

9.4 MAKING USEFUL ASSOCIATIONS

Subchapter **7.3 The changing stream of thought** described how we make associations between the most diverse objects of thoughts; we will only know afterwards whether or not the association seems meaningful or whether it brings us closer to the goal we are trying to reach.

In many cases it is therefore impossible to determine how we make an association from our perception to the specific action we want to initiate. However, it is possible to describe different lines of association or thinking leading to the action to be carried out.

Subchapter **7.7 The level of training in relation to inattentive use** described how our associations are fixed by repetition. It is therefore likely that we make the same association as we are used to—we associate to our habitual action. Such an association to a possible action happens very quickly. William James [1890: 954] writes:

> In these first and simple inferences the conclusion may follow so continuously upon the 'sign' that the latter is not discriminated or attended to as a separate object by the mind.

If we cannot associate directly to an action that may lead to the desired result, we may try to find an action by reasoning. William James [1890: 957] writes:

> *Let us make this ability to deal with* NOVEL *data the technical differentia of reasoning*. This will sufficiently mark it out from common associative thinking, and will immediately enable us to say just what peculiarity it contains.
> *It contains analysis and abstraction.* Whereas the merely empirical thinker stares at a fact in its entirety, and remains helpless, or gets 'stuck,' if it suggests no concomitant or similar, the reasoner breaks it up and notices some one of its separate attributes. This attribute he takes to be the essential part of the whole fact before him. This attribute has properties or consequences which the fact until then was not known to have, but which, now that it is noticed to contain the attribute, it must have. [W.J. italizing and capitalizing]

William James [1890: 966] describes the process of reasoning as follows:

> THUS THERE ARE TWO GREAT POINTS IN REASONING
> *First an extracted character is taken as equivalent to the entire datum from which it comes; and,*
> *Second, the character thus taken suggests a certain consequence more obviously than it was suggested by the total datum as it originally came.* Take them again, successively.
> [W.J. capitalising and italizing]

Subchapter **7.4 Conception** described how we can conceive of the same thing in many different manners depending on the situation when we conceive of it. The first step in our reasoning is therefore to conceive of the problem to be solved in a manner that highlights the features essential for finding the proper action.

If we meet a familiar problem, it is often possible immediately to conceive of it in a way where we can solve it. One example is the situation when we get an electric shock when touching the casing of an electrical appliance: Most people will immediately conceive of that problem as a short circuit or as some sort of fault in the equipment.

When we meet a more complex or an unknown problem, it is possible to conceive of it in many different manners, where only a few of them make it possible to reach a solution: If the problem is complex but of a well-known type, we can try to conceive of it in different manners, consider the results and search more or less systematically after a conception of the problem that makes it possible to find a solution.

It is quite common that we must make several attempts before we can solve a problem in that manner: I have often found that my first conception of a problem hampers its solution as much as it helps it along, and I have only gained that insight when I after my first conception of the problem have tried in numerous ways to reach a conclusion but did not succeed. When that happens my only choice has been to conceive of the problem in a novel way, and I have often tried in numerous ways to reach a conclusion. One example of that [own observation]:

> A MacIntosh computer is set so each program is allocated a certain amount of RAM memory. If the amount allocated to a program is too small, the program can suddenly be stuck, and it is not possible to operate the computer at all. The first time that happened for me, I first conceived of the problem as a fault in the keyboard—the computer did not react when I typed—and I tried to use another keyboard. I then conceived of the problem as having something to do with the program being faulty, but I could not understand why the problem suddenly had arisen. When the problem occurred again, I finally conceived of it as a problem where I had to call for assistance.

William James [1890: 553] describes our knowledge about the solution of a problem:

> ...what we are aware of in advance seems to be its relations with the items we already know. It must bear a causal relation, or it must be an effect, or it must contain an attribute common to two items, or it must be a uniform concomitant, or what not. We know, in short, a lot *about* it, whilst as yet we have no knowledge of *acquaintance* with it. [W.J. italizing]

It is therefore often possible for us to see if a train of thought brings us closer to solving a problem. That is the case when we know that we must go through a specific chain of reasoning in order to reach the solution, or when the object of each successive thought more and more resembles the solution we are looking for. If there is a possible solution, it can then always be found by reasoning.

However, in many cases we cannot see if we are getting any closer to a solution: The solution either is there, or it is not. No matter how we conceive of the problem we cannot then find the right solution by reasoning. As described in subchapter **7.3 The changing stream of thought** we will then experience a hole or a whorl in our stream of thought. We experience the absence of a solution, but cannot find one. Our thoughts are stuck: We cannot make an association from our conception of the problem to a possible solution and it is even quite possible that we cannot start over and conceive of the problem in a novel manner. I believe that such *feelings of tendency*—as William James [1890: 240] calls them—can be so strong that they block all associations that may answer them. I have experienced that such a blocking can be overcome either when an additional pressure or effort makes it possible for me to break through it, or when I can relax it slightly: If I think on something else for a moment, I can suddenly make an association to a possible solution.

In other situations the user may reach a solution by using his intuition. As described by Naur [1985] the intuition makes it possible to reach a possible solution to a problem that cannot be solved by reasoning—at least not within the same short period of time. My personal experience indicates that the intuition only works within an area where a person has substantial experience, and that it more often shows directions than specific results. It is therefore essential that the user verifies and explores the intuitive result.

However, during inattentive use the attention of the user may shift back and forth, and he can think only for a short moment about each thing. His reasoning is more limited: It is difficult for the user to reason about a problem if he cannot conceive of it immediately, he does not have time for following a train of thought through several transitive and substantive parts to a conclusion, and if the thoughts of the user makes an intuitive leap he may never get the chance of thinking about whether or not he has reached the proper solution.

During attentive use it is difficult to make an association to the proper action; during inattentive use it may be impossible.

Conception of the situation of use

Our conception of a problem depends on our conception of the situation when we experience it.

The conception of a situation was described in subchapter **7.4**: The following describes the possible conflicts between the structure of a piece of electronic equipment and the users conception of the situation when he is using it.

When we encounter a situation and try to conceive it, we can neither see what actions we can carry out nor the results they may lead to. Our conception of the situation therefore depends on two things:

- *The environment,* including persons and other things we perceive.
- *Any goal we want to reach* while being in that environment and any dispositions that influence our actions at the same moment.

We can encounter the same piece of electronic equipment in many different situations and the goal of our actions depends on our conception of the situation when we perceives it: If I am on the street and my cellular phone starts ringing, I will take it and press the Unhook key for receiving the call; if I see the phone lying on my desk at home I *may* take it and put it into the charger.

However, there is often a conflict between the situations the user conceives of and the situations a piece of electronic equipment are made for [own observation]:

> I am the lucky owner of a microwave oven with additional functions for grill and heating by warm air. I do not dry poodles in it, so my conception of using it has always something to do with preparing food, either *heating, baking* or *roasting*. However, the functions in the oven are divided into *microwave, warm air, combined microwave and warm air, grill* and finally *combined microwave and grill.* This causes some problems: When I conceive of a situation as for instance *heating*, I must consider whether it is *heating with microwave, heating with warm air* or *heating with combined microwave and warm air.*

When there is a conflict between the situations the user conceives of and the situations for which a piece of electronic equipment is made, the result is confusion and an added strain for the user. The user may feel that it is an altogether new situation, simply because the equipment forces him to conceive of it in a novel way; or the user may try to translate the situation the equipment is made for into the situation he normally conceives of. In the first case, it is much more difficult for the user to draw on his previous experiences, he has after all conceived of the situation in a novel manner; in the second case, the user must not only decide what actions to initiate, he must also find out how he can translate the elements presented by the equipment into the situation that he already knows.

In both cases, the user will experience a conflict between different sets of associations. Each action and each result of an action will have two almost equally strong associations: One pointing towards the next action given in the situation the user normally works in; and another pointing towards the state of the equipment and the next action defined by that—the association connecting the result of one action to the next is crossed by another strong association.

When the attention of the user is shifting, it is then more difficult for him to decide what action to do next, and if the user has learned to do some of the actions as part of an automatic process, the risk of errors are significantly higher than if the situations of use fit the states of the equipment.

The user must use significantly more effort when there is a conflict between the situations he conceives of and the situations a piece of electronic equipment is made for. For the—earlier mentioned—microwave oven a user guide structured according to the functions of the oven filled 16 times more than a user guide structured according to the situations encountered by the user, and the 16 times larger user guide equals 16 times more thoughts of the user when carrying out the same task. When the manual was divided according to functions, the relation between each state of the oven and the situations encountered by the user had to be described in details.

A conflict between the situations encountered by the user and the situations the equipment is made for seems to be more the rule than the exception for electronic equipment. In some cases the conflict is caused by the equipment making it possible to do new tasks or to do a well known tasks in entirely novel ways, for instance to conduct a conversation over a cellular phone while walking down the street or to correct a document on a computer instead of having to type a revised version all over on a typewriter.

However, the most common causes of such conflicts are seemingly that the equipment is not designed for the situations where it is used. It is very common that the functions in a piece of equipment are divided into states or modes, for instance one state for accessing functions by pressing keys and another for accessing more advanced or less used functions through selection in a list. It is very seldom, that the functions are divided according to the situations encountered by the user, such that the user of a microwave oven for instance can choose between *baking* and *roasting* instead of choosing between *microwaves* and *microwaves with warm air*.

Objects for inattentive use

Even when the user does not make any mistakes he may encounter something he cannot handle without paying attention. One of two may then happen: The thing may either slip from the awareness of the user or it may draw his attention.

We can only continue to be aware of something without paying attention to it, if it with very little effort can continue to be part our thoughts.

William James [1890: 930] writes:

> *Sensible vividness or pungency is then the vital factor in reality when once the conflict between objects, and the connecting of them together in the mind, has begun*. No object which neither possesses this vividness in its own right nor is able to borrow it from anything else has a chance of making headway against vivid rivals

> or of rousing in us that reaction in which belief consists. [W.J. italizing]

It is therefore easiest to stay aware of something with a sensible vividness and pungency: Something we believe is real. It is for instance, easier to stay aware of a specific thing than to stay continuously aware of a word with an abstract meaning. I encountered an example when working with a computer program with DOS-based graphic [own observation]:

> The program was intended to be used as a fairly simple sort of game. The elements in it were, however, with ragged edges and lacked details. Even though I easily could differentiate between the different figures, I could only use the program when I focused my attention on the different obstacles and the figure I was supposed to move around. Neither the obstacles nor the figure seemed real or resembled any objects in the physical world.

Subchapter **7.5** describes how the attention can be drawn to intense, voluminous or sudden stimuli or to something of a directly exciting quality: If something gives a strong stimulus or arouses strong emotions it will draw the full attention. That may happen if we suddenly see a landscape with many details, if we hear a thunderclap or when a face that we know and like for a brief moment passes our consciousness.

However, with the exception of loud noises and flashing lights, it is very seldom that a piece of electronic equipment presents the user with a strong stimulus that draws his attention. And even when that happens, it is still likely that the inattentive use will continue after the user has perceived the stimulus and found that it was of only limited importance.

Most of the things presented by the equipment are small and lacking the details the attention can be drawn to and caught by. The equipment can draw and hold the attention of the user only if the stimuli from it for some reasons excite strong emotions in the user. Such emotions can only be perceived when the elements are experienced as sensibly vivid—as real—and even in that case the emotional content shall be fairly strong before the attention of the user is held: The small sizes and lack of details and clarity in most elements presented by electronic equipment make them seem less real and therefore more difficult continuously to focus the attention on.

The state of reduced conception is only possible if the stimuli all are unreal, unclear and foggy without any emotional content; the user may be shaken into attention when something strong, clear or vivid or something with a strong emotional content is perceived.

Shifting attention or an automatic process is only possible with a vivid perception with many realities. If the perceived is unclear with fuzzy edges, it is more difficult to conceive of, and it may even be necessary for the user to focus his attention on one thing in order to discriminate it clearly. If that happens, inattentive use is no longer possible: The user will focus his attention on the one thing and the actions he is doing with it.

During shifting attention or an automatic process, it is at the same time easier for the user to handle things with visual or spatial properties than to handle things that are primarily verbal. I have an example of that [own observation]:

> When I shall find a specific document or a specific page in a document, I often recognise the look of it or blocks of paragraphs rather than the wording of the headline or the page numbers.

It is finally not possible for the user to reflect over the characteristics of a thing when he is not paying attention to it: Even when the users attention for a brief moment shifts to the thing, it is unlikely that he can complete any reflection before his attention is drawn to something else. For that reason, the things to be acted on during inattentive use should have the same characteristics as the things the user is used to—primarily things in the real world.

If something has any sort of *magical* properties, as the characters in a cartoon, the characteristics are much more difficult to discern. Unfortunately things presented by electronic equipment often has such characteristics: They obey their own laws and not necessarily the same laws as things in the physical world.

Confusing and misleading elements

It is very common that the elements presented by the equipment are confusing or even directly misleading [own observation]:

> In the word processing program where I am currently working there is a function for setting the page number on the first page of a document to another value than 1. In order to get to that function, I must pass through the menus *Format, Document* and *File series.* In a DTP program I am using, the same function is activated after passing through the menus *File* and *Page layout.* I have used the function numerous times, but I do not feel that the activations are neither obvious nor easy to remember.

Different users may find different elements confusing or difficult to understand. There is, however, some particular situations where most users find it very difficult or even downright impossible to initiate the proper action. The user may be forced to try several different actions before he has found the right one, or, in some cases, he may cause irreversible damage or give up without finding the proper action to initiate.

In the following I have divided the confusing elements into some main groups.

<u>Hidden states in the equipment</u>

If an internal state of the equipment does not affect its operation, it makes no difference whether the user can perceive it or not. However, it is essential that the user can perceive the state of the equipment *when* it affects the operation of the equipment.

The equipment may be designed so it cannot show the state it is in, or it may have *hidden states* where the user cannot perceive that the equipment after the last operation has changed to another state.

Products with hidden states are fairly common. One example is [own observation]:

> A cellular phone has a memory where a number of phone numbers can be stored. Each of these can later be called up by entering a 2-digit number, the *short number*. In order to store a phone number, the user must first enter the phone number, then a symbol (#), and finally the *short number* it shall be assigned. It is, however, not possible for the user to see if he is in the process of entering the phone number, if he has entered the symbol, or if he has started entering the *short number*.

If the state of the equipment affects the operation of the equipment, and if the state of the equipment is unknown or hidden, the user can only operate the equipment correctly if he is constantly aware of the state of the equipment.

Invisible choices

It is sometimes difficult or even impossible for the user to perceive all the available choices. Of course, if a user cannot perceive a choice, he cannot select it.

The problem appears to be a general one for graphic oriented programs for Windows and similar systems: It is often impossible to see which parts of the graphical interface that simply displays information, which parts that are pure ornaments and which parts that actually can be used for initiating some actions. I have some examples of that [own observation]:

> The frame around a field on the screen may be more than part of the graphic design of the screen picture, it may be possible for the user to move it by *pointing and dragging* it or even to do other actions after having *clicked* or *double-clicked* it.
>
> —
>
> A field displaying some information gives access to additional functions or information when the user *double-clicks* it.

Such a hidden function can only be activated if the user—in the moment he needs it—can make an association to the proper way of initiating it.

The user may find such an invisible choice by chance or he may be told about it, but he cannot find it simply by trying to use the equipment. That may cause problems if the choice is one that the user really needs [own observation]:

> I used a program, where the function to stop the program was such an invisible choice: I was left with the choice of trying to figure out if a special combination of keys could stop the program or risk ruining something by turning the computer off.

Elements that cannot be discriminated properly

It can sometimes be very difficult to discern the elements displayed by a piece of electronic equipment.

William James [1890: 499] writes:

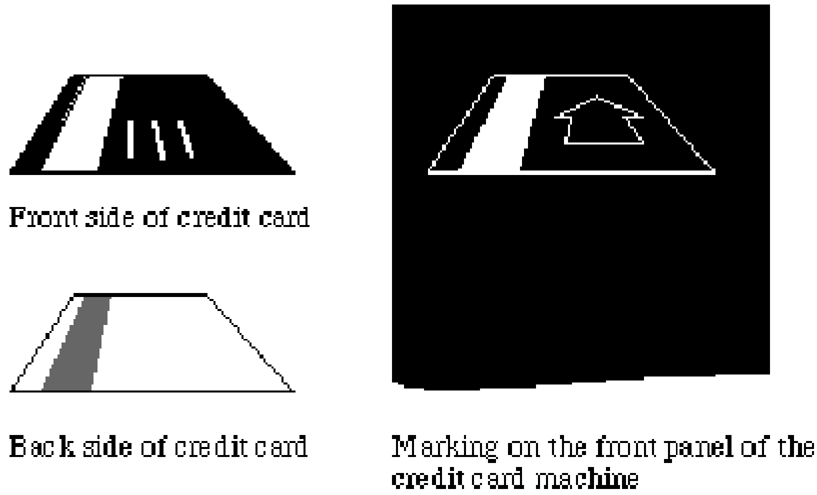
> The *same things*, then, *which arouse the perception of difference usually arouse that of resemblance also*. And the analysis of them, so as to define wherein the difference and wherein the resemblance respectively consists, is called *comparison*. [W.J. italizing]

When the user tries to discern the different elements displayed by the equipment he will therefore at the same time experience both resemblances and differences between the elements: If he feels that the resemblances dominate, he will feel the elements are identical; if the differences dominate, he will feel the elements are different.

The elements presented by a piece of electronic equipment will often resemble each other: They may all be shown on the same screen, they consist of symbols with a similar graphic design or similar types of wording. There are differences, but they are small as compared to the multitude of phenomenas the user experiences in the physical world.

In other cases, the equipment presents an element such that it resembles something else more than it resembles the thing it should symbolise. I have an example of that [own observation]:

> Last summer I had to use a credit card machine with a dark front panel. The proper direction for insertion of the credit card was marked on it. However, because the front panel of the machine was black, the marking was made as a negative of the card. I made several attempts on inserting the card, before I figured out how it should be inserted.



Credit card and marking on credit card machine

The back side of the credit card was shown on the credit card machine in such a manner that it was more similar to the front side of the credit card than to the back side of it.

Use of almost identical names for different elements

An identical name is used for different elements, or the names of two elements are almost identical as for instance *Set file* as compared to *File settings*. If the equipment in some cases also shows the *File settings* as *Settings file* the user cannot perceive the difference. In a Similar manner, it is difficult for the operator of a piece of equipment for control purposes to discriminate its parts, if every part is labelled *System-something, System-other* or *System-system.*

The user will have more and stronger associations to the more universal words as *System, File, Structure,* or *Parameter* than to the words telling specifically what system, file, structure or type of parameters they are referring to. The user will therefore find it difficult to discriminate between different elements labelled with the same universal word.

For that reason it is necessary to give the different elements names that are noticeably different.

Unusual meanings

It is of course impossible to make sure that all users understand the words and symbols in the same manner as the designer. For instance, I saw a test of a financial package [own observation] that had a field labelled "Identification":

> ...one [of the users] said immediately when he saw it: "Identification must be a number". He was employed in a bank.

The other users wrote a date or some keywords into the field, whatever they felt was necessary for identifying the entered value.

However, in many cases the designer of the electronic equipment uses familiar words in an unfamiliar way. I have some examples of that [own observations]:

> In Danish the word *File* normally means *to file,* that is to polish or scrape with a file, whereas *Save* does not mean *save* but *sawing.* The words *File* and *Save* have however been used by computer specialists in Denmark, making some novice users fear that the document would be reduced or cut in half when they chose to *Save file*.
>
> —
>
> Some users felt insulted by the error message "Invalid operator".
>
> —
>
> On a piece of communication equipment with tone signalling, the key for transmitting the calling tones were marked with a note sign, similar to the one used for marking a pitch in the scores of a piece of music: Users thought often that the key had something to do with changing the characteristics of the sound coming from the loudspeaker on the equipment.

When symbols or words are used with an unfamiliar meaning, one of two things may happen: They may be misunderstood as in the preceding examples, or the things they signify may be given wrong characteristics because these characteristics are associated with them [own example]:

> In Danish computer programs the word *Library* is used for a directory. A user explained to me that it was possible to put two libraries together into one, but it was impossible to put one library into another.

No names at all

In some cases, the elements in a piece of electronic equipment have no names at all. Subchapter **7.2 The thought and its object** and subchapter **8.4 Perception, shifting attention and automatic processes** describe briefly the importance of naming all elements.

That requirement may, at the same time, seem very obvious and slightly unnecessary: It is after all possible for us to think about something or to recognise something without having a name for it.

However, if an element in a piece of electronic equipment is given a proper name, it is easier for the user to associate it to his previous experience and to the goals he wants to reach; If the user does not know a proper name for the element in the equipment, it is more likely that he conceives of it in a manner where he cannot decide what action to initiate:

- The users label or name for a displayed element is often based purely on its physical appearance and not on the function or behaviour of it. In contrast, the first thought of the user carrying out a task is normally about the task he wants to accomplish—he makes an association from that task to the functions and behaviour of different elements in the equipment and ends up thinking about a specific action he wants to initiate. If he perceives only the *appearances* and not the *functions* of the elements, it is likely that his chain of reasoning will be broken. In a word processing program, as the one I am using, the users conception of an element may be *arrow with tail to the right* instead of *Set left tabulator*. If the users only or primary association is to *arrow with tail to the left* it is difficult for him to associate that element with the setting of a tabulator.

- The users label or name for an element may vary from one situation to another. In the same word processing program the left tabulator can variously be conceived as *arrow with a tail to the right*, or *leftmost box with arrows* or *box above number 11*. The users association to the element will therefore be more diverse and altogether weaker.

Symmetries

If two elements in the equipment are symmetrical, they are very difficult to discern. I will define symmetrical elements as elements that are identical except that one of them is *A* and another is *not A*, or that one of them is *A* and another one is *B* where *A* and *B* are similar qualities. The two elements may for instance be identical except that one of them has a black dot, *A*, on top of it, or *A* may be black or a direction to the right and *B* may be white or a direction to the left.

The user will then have many similar associations pointing to both of the two elements and the user will have many similar associations pointing to either both *A* and *not A* or to both *A* and *B*. These associations will be more numerous and probably stronger than the associations connecting *A* with the first element and not *A* or *B* with the second.

Inconsistent functions

It is very common that the functions in different states or parts of a piece of electronic equipment are inconsistent:

- *By purpose:* The designers will in some cases try to suboptimise, to improve the function in a few states or of a small part of the equipment, and they will therefore change the operation of some states or parts of the equipment.
- *By accident:* The designers of one part of the equipment do not know what the other designers are doing, the designers cannot reach an agreement on how the equipment shall be, or they have not ensured that all parts of the equipment are operated in a consistent manner.

In the first case, the use of the electronic equipment can be made easier if the special functions in a state always are in addition to the normal way of operating the equipment. If the user out of habit operates the equipment as in any other state, he will still succeed. As described in subchapter **6.1 the need of a theoretical basis** I have an example of that [own observation]:

> When a cellular phone is turned on, it is necessary to enter a Pin code and then press the key M for memory. Except when making a call, it is always necessary to press the M key after entering a number. However, out of habit I very often press the UNHOOK key after entering the Pin code.

Even though it would be an exception to the normal principles for the operation of the phone, the use of it would be easier if either the M *or* the CALL key could be pressed after entering the Pin-code.

In the second case, the use of the electronic equipment is normally more difficult—the user may out of habit repeat the same error time after time [own observation]:

> In a computer program it was in some situations possible to confirm a choice either by pressing ENTER or by clicking on the appropriate virtual key on the screen. The screen would then show a text similar to *Click OK or press Enter for confirming your choice.* In other situations it was only possible to confirm a choice by clicking on the appropriate virtual key on the screen, and the screen would show a text similar to *Click OK for confirming your choice.* I used the program frequently, but, in spite of that, I continued trying to confirm a choice by pressing ENTER when that was not possible.

Invisible or missing relations between elements

The user assumes normally that some elements are related in the equipment and that others are not. If the equipment operates in a manner that conflicts with these assumptions, inattentive use may be very difficult.

I have an example of missing relations [own observation]:

> I have used an electronic distance or step counter that registered each time I took a step when wearing it on my belt. The step counter could be reset to zero. However, the distance measured in km and the number of steps registered were reset separately. A number of times before a trip I have reset only the number of steps while forgetting also to reset the registered distance, so I after the trip could not read the distance I had walked.

In other cases, two elements are connected in the equipment even though they normally are unconnected for the user. I have an example of that [own observation]:

> On a modern programmable camera the operation of the shutter, the flash and the diaphragm are seemingly all controlled by some electronic circuits that depending on the distance to the centre of the motive and the actual lightning selects a combination of exposure time, opening of the diaphragm and use of the flash. When using such a camera the flash may go off at surprising or even awkward moments.

Confusing things and functions

There is a very basic difference between things and functions in the equipment, between items *we can manipulate* and *ways in which things can be manipulated;* they are normally two entirely different universal concepts. As described in subchapter **8.2 Perceptions, concepts, habits and expectations**, it is easier to discriminate between two different universal concepts than between two of the things one of them stands for. When the user tries to conceive of an element shown by the equipment, *his conception is therefore bound to be wrong if he is led to conceive of a thing when the element presented to him actually is a function.*

In spite of that, functions are often presented as objects in electronic equipment. That may have two consequences:

- When the user is looking for a function, it is more difficult to find if all he perceives are things.
- When a function is shown as a thing, the thing is often *what the function acts on* and the precise function cannot be discriminated.

An example of the first consequence was seen during the test of a financial package [own observation]:

> It was difficult for the users to associate a number of words in the screen pictures with other situations they had experienced or with the exercises they were supposed to solve. Examples were the words "Economy" and "Budget", where the users seemingly could not associate them with any functions.

An example of the second consequence caused some confusion [own observation]:

> An elevator on a railroad station had three keys labelled WAITING ROOM, PLATFORM and DOOR. It was of course impossible to ascertain whether the key marked DOOR opened or closed the door to the elevator and the door was in addition a bit sluggish. The result was that people entered the elevator and after a moment pressed the key marked DOOR because they wanted to close the door. I found out that the key actually opened the door or held it open for a moment longer. However, people kept pressing the DOOR key because they could not understand why the door did not close.

Keys in the elevator on railroad station

Consequences of confusing or misleading elements

If there are any confusing or misleading elements in the equipment, the user will make errors whenever he is unaware of the true meaning of the these elements, be they hidden functions or elements where the stated meaning is misleading.

The operation is, however, significantly more difficult if the user in addition must be continuously aware of the state of the equipment, either because of hidden states or because the operation of the equipment is inconsistent or differs in non-functional ways from one state to another.

If one or more of the elements presented by the equipment are misleading, the operation will be more difficult until the user has learned the proper meanings of the elements. However, even after the user has learned the proper meanings of the elements, he must still remember the proper meanings of the special elements and during use be aware of both them and the situations in which they occur.

The error rate can only be reduced when the user has learned to use the elements as part of an automatic process. As described in subchapter **7.7 The level of training in relation to inattentive use** this is achieved only when the user has operated the elements between 600 and 1500 times.

Even after such an extensive training it is by no means certain that the elements can be acted upon as part of an automatic process:

- If the users perception of the meaning of the different elements depends on his perception of the meaning of sentences or combinations of several unrelated symbols, the total meaning cannot be perceived as part of an automatic process.
- If the use of the different elements are both misleading and inconsistent—if for instance the same symbols are used to convey different meanings in different states—an automatic process cannot be learned in 1500 attempts.

If the operation of the equipment is inconsistent, it is therefore likely that the user finds it much more difficult to do some of the actions on the equipment as an automatic process.

Use of help functions and user guides

If everything else fails, try the manual is a common saying among users of electronic equipment, and most users will only as a last resort look for additional information in a manual or user guide.

During the testing of a financial package [own observation] I found that:

> ..the users ... did not try to activate the "Help" Windows of their own accord.

My own experience with other programs confirms that the use of a *Help function* does not seem very obvious when operating a piece of electronic equipment.

The user tries to make an association to the next action to initiate, his consciousness is filled with a gap that only can be filled with an appropriate action, an action he believes brings the state of the equipment closer to the goal he wants to accomplish. When the consciousness of the user is filled with such a gap—with a longing for an action—he cannot make an association to any use of a *Help function* or to any other search for information he needs for solving the problem.

Case study - kitchen timers

In order to ascertain the impact of a few confusing elements I have made a study of kitchen timers. The principles are very simple, and it is therefore possible to give a full description of the operation of the devices.

In order to fulfil its purpose, for instance the sounding of an alarm when the eggs are hard-boiled, a kitchen timer shall incorporate the following functions:

- Setting the duration of a period of time.
- A start function that makes the timer start counting downwards from the set duration of the period of time to zero.
- An alarm that sounds when the timer has counted down to zero.
- An optional acknowledgement function so that the alarm only stops after some action from the user.

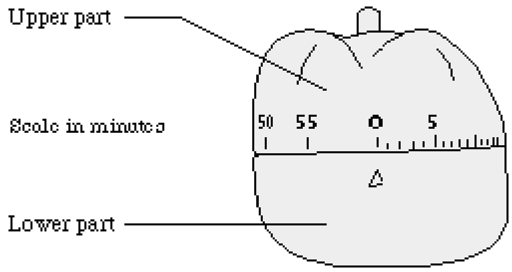
In addition to the input devices the user interface consists of some facility showing the actual value of the timer, either the duration of the set period of time or the value the timer has counted down to.

Three timers are analysed:

- *Pepper timer*, a mechanical timer of a shape as a green pepper
- *La cuisine*, an electronic timer
- *Kitchen Assistant*, an electronic timer

Pepper timer:

This timer consists of an upper and a lower part. The time is set by turning the upper part, and a marker on the lower part points to a scale on the upper part showing the actual value of the timer.



Pepper timer, close to actual size

The states and possible actions are related as follows:

States:	Actions: Rotation of the top	Time out *
Zero	Time set ->*Counting*	-
Counting	New time set ->*Counting*	->*Alarm*
Alarm	Time set ->*Counting*	->*Zero*

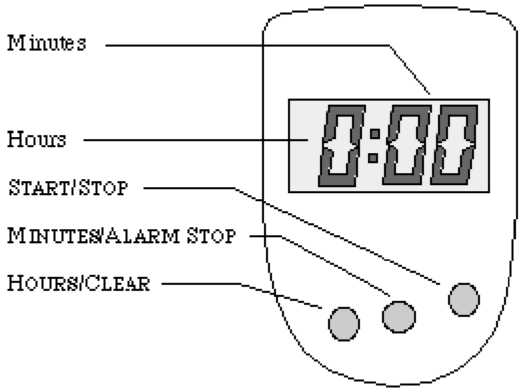
* Shows an event that happens when a timer runs out
-> Marks the state the timer progresses to after the action has been done.

The operation is very consistent: The rotation of the upper part gives the same result no matter the state of the timer. The only exception is the case when the time is set to a value smaller than approx. 2 min. In that case it is possible that the alarm does not sound when the timer reaches zero.

La cuisine:

This timer has a display showing the time in hours and minutes and three keys that are marked as follows:

- HOURS/CLEAR
- MINUTES/ALARM STOP
- START/STOP



La cuisine, close to actual size

The states and possible actions are related as follows:

States: Actions:	HOURS/CLEAR pressed	MINUTES/ALARM STOP pressed	START/STOP pressed	Time out expires*
Zero	+ 1 hour to set time ->*Time set*	+ 1 min. to set time ->*Time set*	->*Alarm*	-
Time set + 1 hour	+ 1 min. to set time	->*Counting* to set time	-	
Counting	-	-	->*Stopped*	->*Alarm*
Alarm	->*Zero*	->*Zero*	-	-
Stopped ->*Zero*	-	->*Counting*	-	

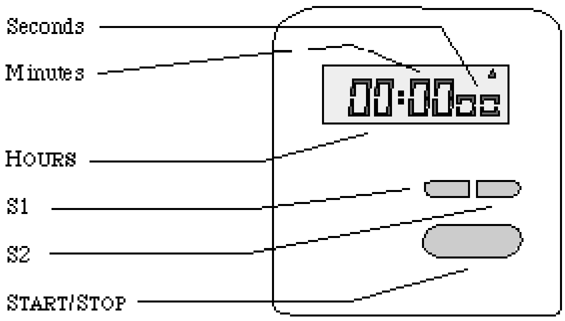
* Shows an event that happens when a timer runs out.
-> Marks the state the timer progresses to after the action has been done.

The use of different labels for the keys and two keys with a *Stop* function are confusing and the use of the START/STOP key is inconsistent: Depressing it does not stop the alarm when the kitchen timer is in the alarm state. In addition, the states *Time set* and *Stopped* are shown in precisely the same manner on the user interface.

Kitchen Assistant:

This timer has a display showing time in hours, minutes and seconds and three keys with the following labels:
- S1
- S2
- START/STOP

In addition, it is possible to access some functions by pressing S1 and S2 simultaneously. That access is shown as S1 + S2 below.



Kitchen Assistant, close to actual size

The states and possible actions are related as follows:

States: Actions:	S1 pressed	S2 pressed	S1 + S 2 pressed	START/STOP pressed	Time out * expires
Zero	+ 1 min. ** to set time ->*Time set*	+ 1 s to set time ->*Time set*	> *Alarm*	-	-
Time set	+ 1 min. ** to set time	+ 1 s to set time	->*Zero*	->*Counting*	-
Counting	-	-	->*Zero*	-	->*Alarm*
Alarm	->*Zero*	->*Zero*	->*Zero*	->*Time set*	-

* Shows an event that happens when a timer runs out.
** When scrolled above 59 minutes, the display starts showing hours: The hours are set by counting minutes up to 59 minutes and over.
-> Marks the state the timer progresses to after the action has been done.

The labelling of the keys is misleading: It is not indicated that S1 + S2 shall be pressed simultaneously in order to set the timer to zero or to stop it while it is counting. The use of the START/STOP key is in addition inconsistent, it cannot stop the timer while it is counting.

Conclusion on the operation of the timers:

I have used all three timers for a period on more than one year, making it possible to do part of the operation as an automatic process and in general using the timers without paying attention to them. The different confusing elements have had the following consequences:

- The *Pepper timer* is clearly labelled and seemingly without hidden states. I first believed it was the simplest of the kitchen timers to operate: It has only one function, the rotation of the top. I found, nevertheless, that whenever another kitchen timer was available, I did not use the *Pepper timer*. The reason was that the *Pepper timer* only could be operated when held in the hand. It therefore had a *hidden* state where it was handheld, and I actually had to perform three different operations in order to set the timer: Pick up the timer, turn the top and, finally, put the timer down again.
- Both *La cuisine* and *Kitchen Assistant* have keys that are labelled in misleading manners. In the beginning that caused problems, but it seems that habits and the gradual learning of automatic processes overcomes them.
- The operation of *La cuisine* and of *Kitchen Assistant* is inconsistent: The START/STOP keys function differently in different states. Even though the timers are very simple devices, these inconsistencies continue to cause problems, even when they are fully learned and understood and the timer is operated as an automatic process.
- On *La cuisine* the states *Time set* and *Stopped* are shown in precisely identical manners. That has, as far as I remember, not caused any problems cause the START/STOP key functions in the same manner in both states and the HOURS/CLEAR and MINUTES/ALARM STOP keys only are used very seldomly in the *Stopped* state.

I will conclude that *a misleading labelling of the functions makes the use more difficult, but the effect can be overcome with training; If the operation is inconsistent, the problems will always be the same during inattentive use, even if part of the operation can be done as an automatic process.*

Consequences for the design of electronic equipment

Before the user reaches his goal, he has often used a large number of functions and passed a significant part of the states of the equipment. This means that even if the problems only are encountered in a small part of the states of the equipment, they can still make the use of the equipment significantly more difficult.

It is difficult for the user to make an association to the proper action if his conception of the situation when he is using the equipment is wrong, and it is therefore necessary to adapt the states presented by the equipment to the situations experienced by the user, or at least to make them in a manner that does not conflict with the situations the user already has conceived of.

One example is a cellular phone. Instead of having one state for *use of a menu* and another for *entry of digits,* it may be made with one state for *carrying the phone* or for *answering a call while running*, or with one state for *searching for a channel* and another for *ongoing call*. Even though *searching for a channel* may be new for the user, it will at least not conflict with any of the situations the user already has conceived of.

If a piece of electronic equipment shall be used by users who cannot pay attention, the elements presented by the equipment should be vivid with many realities: They should look as real as possible, and they must resemble and if possible behave as things in the physical world.

It is very difficult for the user to operate the equipment if any of the states or functions are hidden, or if the names or *labels* of any elements in the equipment are misleading, if for instance almost identical names are used for different elements, or if any of the words used for names are given an unusual meaning. In particular it can cause problems if the names for functions seemingly are names for objects; the user will conceive of the element as an object instead of a function, and it will in addition often not be clear precisely what the function does, the word *door* can signify both that the function opens the door and that it closes it.

In addition, all functions should be given names that clearly describes their function—even when the icon for a specific function is easy to recognise and discriminate, it is essential that it is presented with a name describing its behaviour or characteristics.

It is difficult for the user to distinguish between two symmetrical elements, for instance elements that differ only by the absence or presence of one characteristic. It is therefore necessary to do two things:

- Avoid the use of right and left for discriminating between elements.
- Ensure that all elements differ from each other in at least two aspects.

The designer of a piece of electronic equipment has worked intensively with the different elements of the equipment and has quite likely learned to discriminate between elements that ordinary users perceive as identical or almost identical. In addition, when designing from the top down it is very tempting for the designer to make seemingly logical structures where different binary parameters with similar names show the intricate relations between both the elements they refer to and the total structure of the equipment. Unfortunately, most users can neither understand nor appreciate such structures.

The designers of electronic equipment should therefore ensure that it is easy to differentiate between the different elements in the equipment: If the user cannot discriminate between the different elements of the equipment, he cannot operate it.

It is only possible to identify all confusing elements and hidden states and actions, if a piece of electronic equipment is analysed in the actual situation where it is used. Otherwise, it is likely that some invisible states remains hidden for the designer and that the designer cannot identify the discrepancies between the situations the user experiences and the states shown by the equipment.

A built in *help function* or a written user guide cannot solve the problems caused by confusing elements in the equipment. The user may look in a user guide or use a built in *help function* for finding the meaning of a confusing element, but only when he during the actual operation of the equipment is aware of the user guide or the *help function,* or at least has a strong association from the tasks he wants to accomplish to them.

In addition, my own use of kitchen timers confirms that it is easier to learn an automatic process that overcomes the problems caused by elements that are difficult to discriminate or misleading than to learn an automatic process that overcomes the problems caused by inconsistent operation. In the first case the user should only train the process until the meaning of each element is strongly associated with it: In the second case he must train the process until he has strong associations from the element and each situation where it occurs to its meaning and behaviour in the particular situation. *It is therefore imperative that the operation of the equipment in all states are consistent.*

9.5 CHOOSING AN ACTION

The action we chose among others are influenced by:

- Our dispositions to act in one way instead of another.
- By the plans we make.
- By the amount of attention we devote to deciding upon the action.
- By the goal we are striving for.

This subchapter describes our dispositions, how we plan our actions and how the possible decisions are limited when are not paying attention.

Dispositions

The actions we chose may seem surprising, but they are never arbitrary. We are always disposed towards acting in one way rather than another. Gilbert Ryle [1949: 126] describes our tendency towards acting in one way and not in another:

> Tendencies are different from capacities and liabilities. 'would if...' differs from 'could' and 'regularly does ... when ...' differs from 'can'. Roughly, to say 'can' is to say that it is not a certainty that something will not be the case, while, to say 'tends', 'keeps on' or 'is prone', is to say that it is a good bet that it will be, or was, the case. So 'tends to' implies 'can', but it is not implied by it.

Such a disposition or tendency to act in a certain manner may consist of several different parts: Concepts influencing both thoughts and perceptions, habits as described by William James (as in subchapter **7.6 Different types of inattentive use**) and finally feelings of pleasure or pain that are associated with a specific course of action. A disposition will often consist of all three parts: A person who is disposed against use of electronic equipment may conceive of a piece of electronic equipment as something very complicated, he may out of habit give up very easily when he encounters a problem, and when he tries to use the equipment he feels an intense displeasure.

Ryle [1949: 83, 84, 114] describes that dispositions compared to emotions are comparatively permanent traits in the character of a person, and even though they influence his behaviour in a specific direction, they cannot be the cause of a specific action.

A person who is disposed towards being careful, hesitates often before he does any operation on a piece of electronic equipment; if he suddenly believes that his actions has damaged the equipment, his belief may be caused by the equipment starting to act in a peculiar manner, but it cannot be caused or triggered by his disposition in itself. In the same manner, the user is not doing a specific act of *being careful*, but he is doing all his actions in a *careful manner* because they are influenced by his disposition.

When the user tries to solve a problem his thinking is strongly influenced by his dispositions: They influence the goal he is striving for and the manner in which he tries to find a solution, and when he considers whether or not he has found a solution for the problem, his acceptance of the solution will also be influenced by his dispositions.

If a user is disposed towards being careful, he may feel that it is more important that nothing goes wrong than that he actually succeeds in the task he is carrying out, he may ask somebody else for a solution instead of trying to find one himself, and he will only try a possible solution, if he is absolutely certain that he can carry it out without making an error.

When the user is paying attention to what he is perceiving and doing, his reasoning and thinking in general are directly related to the actions he is initiating. During inattentive use, the relation is less direct:

- The user may be doing actions as part of an automatic process or in a state of reduced conception without thinking about them at all.
- The user may be thinking about what he is doing—while it is going on as an automatic process—and he may try to plan the next steps and consider what results to expect. However, it is by no means certain that his reasoning will influence the actions he is carrying out or even that the actions he is carrying out are the same as the ones he thinks about.

During inattentive use it is quite possible that the user will act without any thinking or reasoning, and even when he is thinking it is by no means certain that his thoughts will influence his actions or in fact bear any relation to them.

When the user—during inattentive use—starts thinking about what he is doing, it is likely that one of two things happens: His thought may be cut short by his inattentive actions, or his actions may be slowed down or stop when his attention is focused on his thoughts.

Making and using a plan for the actions

During inattentive use it is normally impossible for the user to *step back* and get an overview over how the work is progressing and how the next actions shall be done: When the attention is shifting, he may not have the time to consider the progress of his task and to make use of the result, before something else draws his attention; during reduced conception and during an automatic process he does not think about the actions he is initiating.

The user must also stop his inattentive actions before he can use any manuals or diagrams showing an overview over functions and states in the equipment. It is quite likely that the user during inattentive use cannot make an association to the use of a user guide or a diagram, and, as described in subchapter **8.4 Perception, shifting attention and automatic processes**, the user can only perceive the meaning of sentences in a user guide or a diagram when he focuses his attention on it. The use of a user guide or a diagram is therefore one more task that his attention shifts back and forth to, and some of his other tasks are therefore bound to suffer when he uses the user guide or a diagram.

Many current user guides are difficult to use—even for the user who is paying attention—and it is therefore possible that a user guide will occupy the full attention of the user, so he for a period of time cannot carry out any actions besides looking in the user guide, and it is of course possible that his effort with the user guide is in vain, because something draws his attention so he forgets what he found in the user guide before he initiates any action.

The thoughts of the user depend on his conception of the situation when he is operating the equipment, and during inattentive use it is very difficult for him to change that conception. The reason is, that he can transcend his concept of the situation only when he pays attention to what he is doing and the results he accomplishes; he is caught by his conception and cannot escape as long as he does not pay attention. That has some consequences:

- The user cannot perceive if his conception of the situation is wrong. He may for instance be operating a piece of equipment that is malfunctioning but conceive of operating a piece of equipment that is functioning properly, or he can have the wrong concept of the operation of part of the equipment, because it is operated in another manner than the main part of the equipment.
- The user cannot choose consciously how to conceive of the situation when he is operating the equipment; it is for instance impossible for him to realise that he must conceive of the situation in a different manner so he takes more aspects into account.

I have not found instances when the user confused his perception of the equipment and his operation of it with his perception of the physical environment and the actions he initiated in order to change it: During inattentive use the user can—seemingly without any problems—change between a conception of the situation when he is operating the equipment and a conception of the situation when he in some manner is reacting to the physical environment. It indicates that the users problem during inattentive use is not a matter of being incapable of discriminating between different concepts or of any confluence between them, but merely a matter of being incapable of finding out when his conception of the situation is wrong.

Decisions during reduced conception

As described in subchapter **7.6 Different types of inattentive use** the users conception of his experiences can be reduced, so he finds it difficult to think about what he experiences.

The user can react but can neither reason nor make any conscious decisions; he will therefore repeat the actions that give him some sort of immediate satisfaction and he will continue to do that until his rhythm of interaction with the equipment is broken.

When the users rhythm of repeated perceptions and actions is broken, he will stop his actions, drop out of the state of reduced conception and start paying attention.

The user did not decide to enter the state of reduced conception, he just happened to fall into it; in the same manner, the user cannot decide to get out of the state of reduced conception: It simply ends when the circumstances are right.

In order to reduce the risk of undesired states of reduced conception, the equipment should at irregular intervals interrupt the user if his rhythm of repeated actions becomes too regular.

Decisions during shifting attention

When the attention of the user is shifting back and forth, his thinking is often cut short.

Subchapter **7.3 The changing stream of thought** described how both the substantive and the transitive parts of a thought have a certain duration. In addition, it is often necessary for a thought to pass through several substantive and transitive parts before reaching a conclusion.

The process before the user decides which action to choose is therefore easily stopped when his attention is shifting:

- As described in subchapter **7.2 The thought and its object** a thought cannot be cut in half: If the user is interrupted before the thought is completed, it is lost and he must start his reasoning all over.
- If the users attention is drawn to something else before he has completed his chain of reasoning, he must start all over. For that reason, the user can only reach a conclusion and decide upon an action if the duration of his chain of associations from he perceives something until he decides upon an action is shorter than the time between two events that draws the attention of the user.
- Every time the user makes an association from one substantive part of his thoughts to another it is possible that the association will be away from the train of thought leading to the next action to initiate: He may make an association to an event in his physical environment or to something that has nothing to do with the problem at hand. Every time the user makes an association it is therefore possible that his attention will leave the problem he is trying to solve.

If the user shall operate the equipment without paying attention, all problems posed by the equipment should fulfil the following characteristics:

- The duration of each thought needed for solving the problem should be as short as possible, preferably less than half the average time between each time the attention is drawn to something else.
- It should only be necessary with one or two transitive parts or associations from the conception of the problem until an action can be initiated.
- It should be possible for the user to move his undivided attention between the task he is doing on the equipment and something else, for instance the environment. There must be no hidden states in the equipment, and there should not be any instances where the user has to remember any information about the equipment.

When the users attention is shifting it is seldom possible for him to make and carry out a plan covering several separate actions: In order to do that he must associate from the result of one action to the other actions in the plan and initiate all of them before his attention is drawn to something else. For that reason it should not be necessary for the user to plan several steps ahead in order to reach his goal. He cannot use any sort of map with a description of his route—he needs a road sign pointing him in the proper direction at every crossroad.

The situation for the user is very similar to the situation of a person trying to find his way from one point to another. Butler et al. [1993: 162] found that signs pointing towards the different targets were substantially faster to use than a map showing *You are here* and the position of the goal; it took 3 to 8 times more time for the participants to pass from the starting point to the goal by using a map than by following road signs.

Butler et al. [1993: 172] describe two reasons for using a map being so much slower than following the signs:

- When the participants used a map they often had to follow the simplest route, the easiest one to remember, whereas the signs could direct them along the fastest—shortest—route.
- It took more time to study and memorise a route on a map than to read a sign.

If the user all the time is pointed in the right direction, he can follow the shortest route to the goal, even though it is not the simplest one. When operating a piece of electronic equipment *the shortest route* may be the one where the user does the lowest number of activations of specific keys, whereas the simplest one is the one where the equipment passes through the lowest number of states before the goal is reached.

Decisions during an automatic process

When an automatic process is running, it is unaffected by any decisions made by the user. The automatic process will continue until it is stopped:

- If the attention of the user is drawn to the process, it will often stop.
- If the attention of the user is drawn to the process, the user may *decide* to stop it.
- The automatic process may, however, interfere with another automatic process, so one of them must stop. One example is a user, browsing through a piece of electronic equipment and doing it as an automatic process. If he feels an itch on his nose, he will normally stop his operation of the equipment in order to scratch his nose.
- The automatic process may stop because it is completed: The stopping of the process is the last step in it. That may be the case if the process consists of searching for a particular element: When it is recognised, the process stops automatically.

It is possible that the user during an automatic process is thinking about the process and even tries to plan the next steps in it, but it is not given that his thoughts in any manner will influence his actions. He will make a number of *de facto decisions*, they result in the choice of one action instead of another, but the user has not thought about their consequences, and they may be completely unrelated to his thoughts while carrying out the automatic process—the user may think about doing one thing while doing another.

In addition, it is downright impossible to read map or a diagram showing the states and functions of the equipment during an automatic process. As described in subchapter **7.5 Attention** it is impossible to perceive pictures consisting of several seemingly unrelated elements without paying attention to them, and the interpretation of a diagram requires normally the perception of several unrelated elements.

Slips and errors

We will occasionally do something foolish that cannot lead to the desired result. Reason [1979: 69] describes the proble m as follows:

> Logically, we can fail to achieve a desired outcome in at least two ways; when the actions go as planned, but the plan is inadequate; or when the plan is satisfactory, but the actions do not go as planned...

In the first case we try to carry out the planned action, but it does not lead to the desired result, in the second case we carry out the wrong action: An action that is not part of the plan and that—even if it is successful—cannot lead to the desired result. It follows from Reason's [1979: 75-76] later description that one example of such a plan is an automatic process.

I have experienced the following slips or errors while working with electronic equipment [own observations]:

> As described in subchapter **6.1 The need of a theoretical basis**, I often call two eight-digit phone numbers that have the first two digits in common. When I start entering one of the numbers, I often end up entering the last six digits of the other number.
>
> —
>
> My telephone has a Redial key, also called a *divorce button,* that activates a retransmission of the last number typed in. However, the number can only be transmitted after the handset is lifted off. I frequently forget to do that.

Reason [1979: 70] found that the participants in his study reported an average of 12 *actions not as planned* over a two week period. It is therefore likely that similar errors or slips occurs regularly during inattentive use of electronic equipment.

Reason [1979: 71-75] described the different types of *actions not as planned:*

1. 11 % of the errors were "discrimination failures", where one object was mistaken for another one that either was physically similar, functionally similar or in close proximity or where an action was done at an inappropriate moment.
2. 5 % of the errors were "program assembly failures" either so-called spoonerisms where the order of two similar actions done on two objects was reversed or errors where actions from one process was confused with actions from another one.
3. 20 % of the errors were "test failures" where the person did not verify the progress of his actions. He might "over-shoot" instead of stopping when he was finished, make a "branching error" where an initial sequence of actions were the same for two processes or be side-tracked and start doing something else when one or more minor distractions happened.
4. 18 % of the errors were "sub-routine failures" where the error involved single actions in the automatic process: An action could be omitted or added to the process or two actions could be done in the wrong order.
5. 40 % of the errors were "storage failures" where the person forgot the state he had reached in the process, forgot a single action in the process, reverted to an earlier process that had been given up or simply forgot the goal of his actions.

The 1. type of errors occur in situations where the object to be used are not discriminated from another element. The user of a piece of electronic equipment may for instance press the adjacent key instead of the one he should press.

As described in subchapter **7.6 Different types of inattentive use** each stage in the automatic process is normally closely associated to the next. However, each stage in the automatic process is also related to other actions or situations. That is the cause of the 2. and 4. types of errors.

The possible progressions of the different automatic processes are similar to a number of winding lines or arrows that may cross themselves or each other, and where we at each crossing may follow the wrong association. It is therefore possible for the user to follow an association that does not lead to the next action in the automatic process but to:

- An action later in the automatic process, in particular if the action is experienced as more important than the preceding ones.
- An action that does not fit into the automatic process. When the user makes an association to such a loose action, it can be included in the automatic process.

The 3. and 5. types of errors happen when we do not verify that an action has been done successfully or forget the state we have reached in the automatic process. That may happen if our association to an action that verifies the state of the work is weaker than our association to our next action in the process, or when we forget the stage we have reached in the process.

The user will always make mistakes

As described in subchapter **7.7 The level of training in relation to inattentive use**, inattentive use is only possible with some amount of training. Until the user has been trained he must pay attention while using the equipment.

With sufficient training, the user pays less attention while operating the equipment—when he feels that his attention is not needed, it starts to wander. However, the operation of the equipment does not demand the same level of attention at all times. If the user has gained some level of training, he will therefore occasionally focus his attention less than necessary on the equipment. That explains the common experience, that most errors seemingly are not made by people with minimal training, but by people that have gained some routine in the use of the equipment.

When the user learns to operate the equipment as part of an automatic process each association in the automatic process becomes closely associated to the next, and these associations are often stronger than the associations the user makes in his conscious thinking. Unless the user makes an effort, his habits will therefore be stronger than his conscious decisions, and he may carry out an automatic process that is inappropriate in the specific situation or he may make slips and errors in the process he is carrying out.

It is therefore necessary to minimise the consequences of all the possible mistakes the user may make.

Consequences for the design of electronic equipment

During inattentive use of electronic equipment, the user cannot *step back* and consider the progress of his task and he cannot plan several actions in advance and follow that plan. The user can only do one step at a time, and it is difficult for him to find out if his conception of the situation is wrong and to discover if he has made any mistakes.

It should therefore all the time be possible for the user to perceive the directions that the different choices may lead him to, and it should always be possible for the user to perceive the result of the last action he has done.

The decision needed for choosing one action instead of another should be simple: The consequences of each action should be immediately apparent so it is unnecessary for the user to pass through thoughts with several substantive and transitional parts before choosing the action to initiate. In addition, the length of each of the users thoughts should be shorter than the average period between each time he is interrupted. Thoughts requiring longer chains of words or reasoning should be avoided, because it is likely that thoughts about single words, pictures or symbols normally have a shorter duration that thoughts that are experienced as sentences.

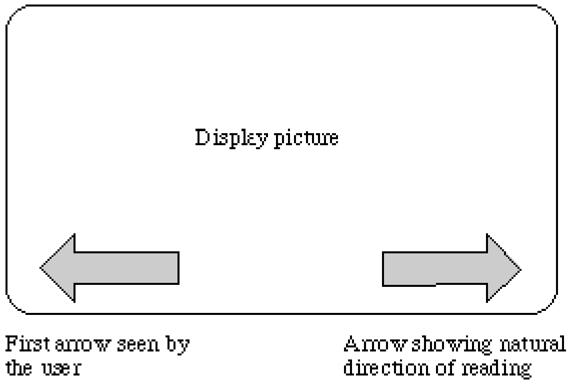
As described earlier, the inattentive user cannot use a map or diagram over the states and functions of the equipment.

What can be provided instead are signs of direction. The best directions are the ones the user easily can discern through habit:

- Up and down
- Towards the user or away from him
- Right and left

Up is normally taken as a movement towards something more general and less specific, whereas *down* is into a smaller area and more details. In addition our normal direction of reading and working is from the top downwards, so when the user is scrolling in a list he will normally perceive that the elements in the list move upwards or downwards.

Even though we always read from left to right, we can easily mistake right and left. In addition, there is a peculiar problem with right and left. The normal direction of working and moving from one element to another means that we normally work from left to right, but it also means that a user looking on the display first will perceive an arrow pointing to the state to the left of the active one cause that arrow naturally is placed in the left side of the screen. Only afterwards will the user perceive the arrow pointing to the right— the natural direction of work and reading. The horizontal direction is therefore best suited for similar and equal elements.



Screen or display with direction arrows

My personal experience indicates, that even though such a side-stepping in the structure of the elements does not significantly reduce the number of actions the user must carry out in order to find a particular element, it is experienced as a convenience by the user, because the user easily can associate the horizontal direction with access to other *similar* and *equal* elements.

The directions towards us or away from us are not used in equipment today. One reason may be the limited display quality and a need for using letters of a similar size all over the display. However, it might be possible to show a number of choices as a landscape, where the background is of a lighter colour and smaller than the foreground. As described in subchapter **8.4 Perception, shifting attention and automatic processes**, we are used to perceiving depth. A simulation of depth may therefore make it easier for the user to perceive things from the electronic equipment and to act upon them.

During inattentive use the user does not pay continuous attention to the equipment so he cannot control what elements in the equipment he is aware of. It is therefore by no means certain that he will discover that he has made an error: He may discover it later, after it has had serious consequences, or never at all.

The user will at the same time always make errors, in particular during an automatic process. The equipment should therefore be designed, so the impact of slips and errors are minimised: They should never have serious or irreversible consequences.

In addition, the equipment should be designed so the risk of the different types of slips and errors are minimised:

- *Discrimination failures* can be avoided if the elements in the equipment all are easy to discriminate: The users perception of different elements should be clearly different and the function of each element should be easily and unambiguously associated to the users perception of it. In addition, it should not at any stage be possible for the user to do irreversible damage by pressing any key adjacent to the one he is supposed to press.
- *Program assembly failures, sub-routine failures* and *test failures* are all errors involving a single step in the automatic process. However, it is possible to reduce their consequences if the equipment can discriminate between different actions, no matter the order in which they are carried out, or if the equipment either will accept that actions can be done in an arbitrary order or at least gives a suitable warning when the actions are done in the wrong order. For instance, two actions both involving the entry of a number of digits must never precede each other cause the equipment cannot register if the user enters the two numbers in the wrong order. If the second number is replaced by a selection in a list, it is possible for the equipment to handle both the number and the selection in a proper manner, no matter the order of the two entries. The consequences of errors can further be minimised by providing *milestones* where the user either is forced to check the state of the process before he can continue, or where it is impossible to continue if the preceding steps have not been done properly.
- *Storage failures* may consist of the user forgetting the process he actually is carrying out or the stage he has reached in the process. The risk of such errors can be reduced if the user always can perceive the actual stage reached in the operation from the equipment.

When an error may have serious consequences the equipment should be capable of detecting most of the errors committed by the user: Either by demanding some redundant information from the user, so that it can check the coherence of his actions, by offering some sort of feedback, or in some cases by requesting an acknowledgement from the user when an action may result in irreversible damage.

9.6 USE OF BROWSING AND TRIAL AND ERROR

When the goal is known, it is sometimes evident what action is needed for accomplishing it. One example is the situation when a computer displays *Press OK if you want to save the file.* In other situations it is less obvious what specific actions that will lead to the desired result. The user shall then find the action to be carried out.

When the user shall find the proper action, he can often get a better result by using browsing or trial and error—where the user tries the different possibilities—than by trying to determine the next course of action by pure reasoning:

- The electronic equipment may present the choices in a misleading manner or the presented information may be insufficient for determining the next action by reasoning. In these cases, the user can only find the next action by browsing or by trial and error.
- Reasoning can take more time than trying to determine the next course of action by trial and error. As described in subchapter **7.3 The changing stream of thought**, a thought has often a duration between 10 s and 15 s, whereas the perception of a thing typically takes 0.75 s. The right choice is on average found after having tried 1/2 of the total possibilities, so when some time is added for activating each choice, bringing the total time for testing each choice to 2.5 s, one right answer out of 6 possible can be found by trial and error in 7.5 s, whereas the user may need 10 to 15 s or more for getting the same result by reasoning.
- Finding an answer by browsing or trial and error can be done as an automatic process where the process will stop when the proper answer is recognised. Browsing can therefore be done during inattentive use, whereas finding the right answer by reasoning is possible only while paying attention.

Browsing can be faster than reasoning, but it does not necessarily lead to the proper result, and its speed is highly dependent on the design of the equipment.

All elements in the equipment and the structure of the equipment should therefore be adapted to browsing and trial and error:

1. All states and functions should be labelled in a clear and concise manner that cannot mislead the user.
2. It should be possible for the user to be aware of the relationship between the state he has activated in the electronic equipment and the other states of the equipment.
3. It should be possible for the user to reach any function with the lowest possible number of actions.

Subchapter **9.4 Making useful associations** described how the 1. and 2. requirements can be fulfilled; this subchapter describes how the 3. requirement can be fulfilled.

Reducing the number of choices and actions

The time it takes to find an element by browsing can be decreased by reducing the number of choices the user shall browse through before reaching the goal.

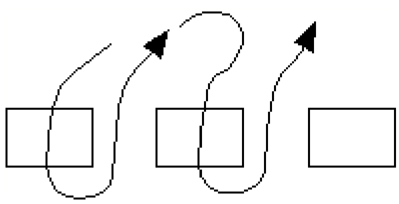
I have calculated the average number of actions necessary for finding an element in five different structures of equipment. The calculations are based on the following assumptions:

- When browsing the user looks into one element at a time: He either enters a state and sees if it contains what he is looking for, or he activates a function and sees if it gives the result he wants.
- The user can exclude a proportion of the presented elements, but he must browse through the rest of the elements until he finds what he is looking for.
- The user browses in a systematic manner—he will look into each element only once. That is not always true, but the assumption does not affect the relative differences between the different calculations.

If the user shall select one of a number of displayed elements he shall on average browse through:

$$\mathbf{B} = p + (1-p) * (n - 1)$$

where p is the proportion of choices that the user on average can recognise directly from their markings, and n is the number of choices the user cannot discard before doing any browsing. There is the probability of p for the user being capable of directly activating the desired choice, and there is a probability of $(1-p)$ for the user having to browse on average $n/2$ choices before the proper one is found. In all except the last of these, where he has made the proper choice he must backstep in order to try a new operation; the testing of $n/2$ choices therefore involves $2 * (n/2 + n/2 - 1)$ separate actions.

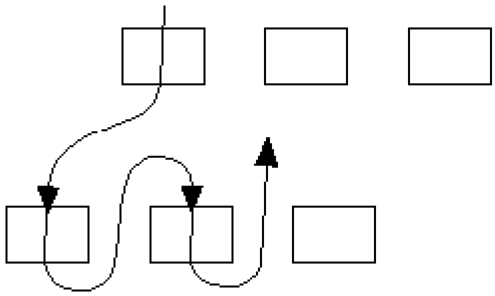


Browsing one element after the other

It is in general not possible to have a separate key for activating each function in a piece of electronic equipment. In most pieces of electronic equipment, the different choices are therefore structured, so that only some of them are accessible on each level—the user must search through the choices on the different levels in order to find what he is looking for.

If the choices include a second level similar to the first, the user must do the following number of separate actions before he has activated the proper function:

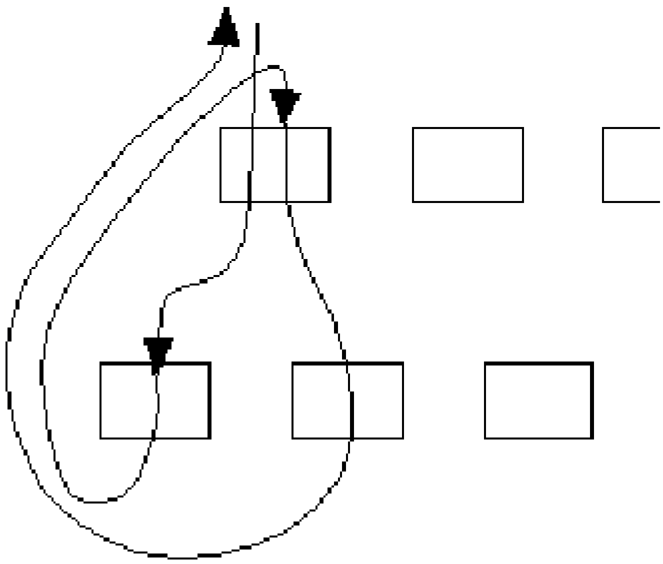
$\mathbf{B} = 2 * (p + (1-p) * (n - 1))$



Browsing one element after the other on the second level

However, electronic equipment is sometimes designed such that if the user makes a mistake, he must return to the top and start all over. In that case the total number of separate actions with two levels in the structure becomes:

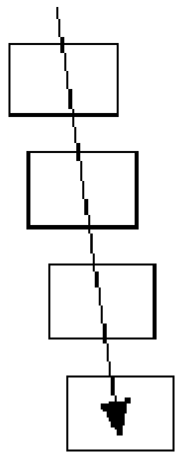
$\mathbf{B} = (p + (1-p) * (n - 1)) + (p + (1-p) * (3/2\ n - 1))$



Browsing on the second level when it is necessary to return to the top level each time an element is browsed.

In other cases the equipment uses a *scrolling menu*—actually a list the user can scroll in, so that he can see one item in the list at a time. When scrolling in such a list the user must scroll down one step at a time until he reaches the choice he wants to try. If the designer has made a function that makes it possible to go one step back without starting all over from the top level, the total number of actions becomes:

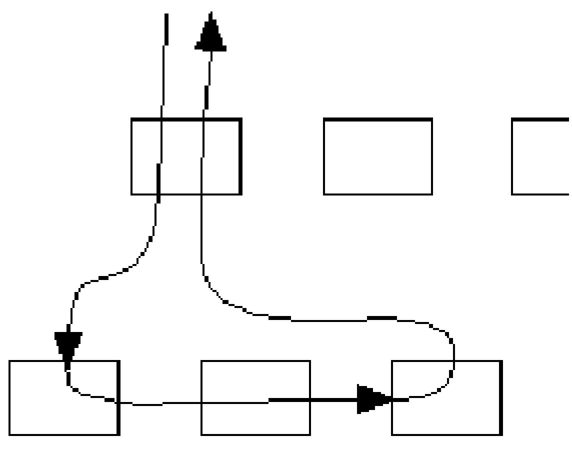
$$\mathbf{B} = 2 * n/2 * (p + (1-p) * (n - 1))$$



Scrolling or browsing in a *list*

If the user can access each choice directly without scrolling and in addition move horizontally between the choices without having to do a backstep after each browsing, the total number of actions becomes:

$$\mathbf{B} = 2 * (p + (1-p) * (n/2 + 1)) \text{ or } B = 2 * (p + (1-p) * (n - 1))$$



Browsing where it is possible to move horizontally from one element to another.

The following number of actions are on average necessary for finding a specific element in the different structures:

p	n	1 level	2 levels	Return to top	Scrolling	Move Horizontal
0.00	6	5.0	10.0	13.0	30.0	8.0
0.60	6	2.6	5.2	6.4	15.6	4.4
0.80	6	1.8	3.6	4.2	10.8	3.2
1.00	6	1.0	2.0	2.0	6.0	2.0
0.00	5	4.0	8.0	10.5	20.0	6.5
0.60	5	2.2	4.4	5.4	11.0	3.8
0.80	5	1.6	3.2	3.7	8.0	2.9
1.00	5	1.0	2.0	2.0	5.0	2.0
0.00	4	3.0	6.0	8.0	12.0	5.0
0.60	4	1.8	3.6	4.4	7.2	3.2
0.80	4	1.4	2.8	3.2	5.6	2.6
1.00	4	1.0	2.0	2.0	4.0	2.0
0.00	3	2.0	4.0	5.5	6.0	3.5
0.60	3	1.4	2.8	3.4	4.2	2.6
0.80	3	1.2	2.4	2.7	3.6	2.3
1	3	1.0	2.0	2.0	3.0	2.0

An additional number of element that shall be scrolled increases the amount of actions significantly. It is therefore essential that no states in the equipment contains superfluous elements and that the elements are presented such that the user beforehand can exclude as many elements as possible from the browsing.

It seems that the user only shall do a small additional number of actions when he must *return to the top* each time he has scrolled an item. However, such a structure cannot be recommended for inattentive use, because the consequences are more grave if the user forgets the stage he has reached in his browsing, and because such a structure becomes very ineffective when a third level is added: The user must then do 4 actions each time he browses through an element on the third level.

Designs where the user must scroll through a number of choices in a list— a *scrolling menu*—cannot be used with more than two levels with at most 3 different choices on each level. The only exceptions are situations when the user is scrolling in an alphabetical list or a list in numerical order, where the scrolling can continue automatically as long as a key is held down and where it is possible to scroll in both directions: In these cases the scrolling can be done as one fast automatic process.

Finally, structures where it is possible to go sideways without backstepping can reduce the number of separate operations somewhat, but the difference is smaller than expected: Side-stepping from one element to another can be a convenience for the user, but it does not significantly reduce the average number of actions that must be carried out during the browsing.

Use of browsing and trial and error during inattentive use

Browsing is possible as an automatic process, whereas the user only can find the proper action by reasoning when he focus his attention on the task for a period of time.

However, the browsing is easier if the user can devote some attention to it; the browsing of an inattentive user will therefore be different from the browsing made by a user that pays attention to the task:

- The inattentive user finds it more difficult to discriminate between different elements shown by the equipment and he is more easily fooled by confusing elements. If any of the presented elements can be misleading or confusing, they will affect his inattentive browsing more than an attentive browsing.
- It is likely that the inattentive user forgets the state he has reached during his browsing, and he may browse through the same elements more than once. The user will therefore do more actions during inattentive than during attentive browsing.

However, the difference between attentive and inattentive browsing is a difference of degree and not of kind, so equipment where browsing shall be possible during inattentive use shall fulfil the same requirements as equipment for *convenient* browsing by users paying attention. The inattentive user will only encounter more problems when the requirements are not fulfilled.

Adapting the equipment for browsing and trial and error

The equipment can be adapted for browsing and trial and error by minimising the number of actions the user must do before he has activated each function. That can be done by reducing:

- The number of actions needed for activating each function
- The number of choices on each level
- The distance from each state of the equipment to any other

The number of actions needed for activating each function can be reduced by placing more functions in each state. If all functions, ideally, were accessible at the same time and could be activated by pressing a single key, the user could browse through the functions with a minimal number of actions.

The number of choices in each state can be reduced by combining different functions into one, for instance by combining two functions for searching in lists into one, so that the user never shall browse between two search functions before finding the right one.

The number of choices in each state can also be eliminated by rooting out all unnecessary choices in each state. Damay and Poulain [1985: B3-7] reports that a phone with a dynamic dialogue—where only the relevant functions are shown in each state—is significantly easier to use than a phone with a permanent dialogue—a phone where all functions are shown in all states. These results support that each state should present only the choices and information that are relevant for the user in the particular state.

In particular during inattentive browsing, it is very common that the user forgets the stage he has reached in his browsing, and the equipment should therefore indicate the last element he has operated.

The distance from one state to any of the other states can finally be reduced by placing the states in a multidimensional structure. The distance between 25 different choices depends in the following manner on the structure:

Structure	Average distance between elements	No. of elements with distance 1 or 2
One-dimensional—list or scrolling menu	12	4
Tree structure—two levels	3.6	5
two-dimensional structure, matrix	2.5	11
three-dimensional structure, cube	2	18

A multi-dimensional structure reduces significantly the average distance from one state to another. In addition, not all choices are activated equally often. It is therefore advantageous if the distance from the *Stand by* state to the most used choices are reduced even more. The column showing the number of choices with a distance of only 1 and 2 grows very rapidly with the increasing number of dimensions: In a list it is only possible to have that distance to 4 of the choices, in a 3-dimensional structure it is possible for 18 of the choices.

In particular the use of a list or—as it also is called— a *scrolling menu* results in a very large distance between the different elements. Such a list is easy to implement in the equipment, but the figures show that the user may be forced to do an excessive amount of actions when he shall operate a function.

In addition, a multidimensional structure makes it possible for the user to reach the same element in different ways. It is therefore possible for the user to continue his search for a new element onward through new states, instead of going back through states he already has been through and discarded.

However, a multidimensional structure increases the risk of the user bypassing the choice he is looking for: In a list he cannot avoid passing the choice he is looking for, in the tree he will reach the bottom and be forced to move back and try another direction, whereas in a matrix or the cube he can move round and round without ever meeting the choice he is looking for. Unrestricted movement in all dimensions should therefore be avoided: The paths through the structure should be similar to roads with occasional gates and road signs making it difficult to miss the proper exit to a side road.

9.7 INITIATING THE ACTION

It is not given that the user initiates an action, even though he has identified an action that may lead to the desired result. William James [1890: 1137-8] describes how we actually decide to initiate a particular action :

> The particular reasons for or against an action are of course infinitely various in concrete cases. But certain motives are more or less constantly in play. One of these is *impatience of the deliberative state*; or to express it otherwise, proneness to act or to decide merely because action and decision are, as such, agreeable, and relieve the tension of doubt and hesitancy. Thus it comes that we will often take any course whatever happens to be most vividly before our minds, at the moment when this impulse to decisive action becomes extreme.
>
> Against this impulse we have the *dread of the irrevocable*, which often engenders a type of character incapable of prompt and vigorous resolve, except perhaps when surprised into sudden activity.
>
> These two opposing motives twine round whatever other motives may be present at the moment when decision is imminent, and tend to precipitate or retard it. The conflict of these motives so far as they alone affect the matter of decision is a conflict as to when it shall occur. One says 'now,' the other says 'not yet.'
>
> Another constant component of the web of motivation is the impulse to persist in a decision once made... How many of us persist in a precipitate course which, but for a moment of heedlessness, we might never have entered upon simply because we hate to 'change our mind.' [W.J. italizing]

Whether or not we initiate an action in a specific moment depends on the balance between three dispositions: A tendency to act, a tendency to wait and postpone the final decision and finally a tendency towards persisting in a decision that has been made. The balance between these three dispositions depends both on the person making the choice, the particular situation and the type of action that can be initiated. William James [1890: 1143] writes:

> *There is a certain normal ratio in the impulsive power of different sorts of motive, which characterises what may be called ordinary healthiness of will...* The states of mind which normally posses the most impulsive quality are either those which represents objects of passion, appetite or emotion—objects of instinctive reaction in short; or they are feelings or ideas of pleasure of pain, or ideas which for any reason we have grown accustomed to obey, so that the habit of reacting on them is ingrained; or finally, in comparison with ideas of remoter objects, they are ideas of objects present or near in space and time. Compared with these various objects, all far-off considerations, all highly abstract conceptions, unaccustomed reasons, and motives foreign to the instinctive history of the race, have little or no impulsive power. They prevail, when they do prevail, *with effort; and the normal,* as distinguished from the pathological, *sphere of effort is thus found wherever non-instinctive motives to behaviour are to rule the day.* [W.J. italizing]

In other words, the will to initiate a specific course of action may come about through some impulsive power or because we make a conscious effort.

If the will of the user in a particular situation is very strong, he may initiate an action simply because he wants something to happen; if his will is very weak, it requires a large effort to undertake any sort of action, and if the sun is shining it is even possible that daydreaming while glancing out of the window carries a strong impulsive quality that can be overcome only with a strong feeling of effort.

In addition, we may initiate a specific course of action simply because the power to act by chance dominates for a short moment. William James [1890: 1132-3] writes:

> We know what it is to get out of bed on a freezing morning in a room without a fire, and how the very vital principle within us protects against the ordeal. Probably most persons have lain on certain mornings for an hour at a time unable to brace themselves to the resolve... Now how do we *ever* get up under such circumstances? If I may generalise from my own experience, we more often than not get up without any struggle or decision at all. We suddenly find that we *have* got up. A fortunate lapse of consciousness occurs; we forget both the warmth and the cold; we fall into some revery connected with the day's life, in the course of which the idea flashes across us, "Hollo! [sic] I must lie here no longer"–an idea which at that lucky instant awakens no contradictory or paralysing suggestions, and consequently produces immediately its appropriate motor effects. [W.J. italizing]

When the user is in a situation where he must shift his attention from one thing to another, it will affect the balance between his different dispositions: The impatience of the deliberative state and the dread of the irrevocable. When the attention of the user is interrupted or when he must move his attention from one thing to another, he will feel less dread of the irrevocable and maybe more impatience: He will try to act faster before his attention once more is drawn by something else and he may even show a sort of dare-devil style where he does not consider the consequences and accepts risks that he normally would rule out.

My personal experience indicates that even normally irresolute persons can be caught by this effect: They may in fact decide to do almost any action because they cannot deliberate, so their only way away from the pain of making a decision is to make it in the shortest possible time.

In such cases, even though the user in fact is very little disposed towards acting, the impatience of the deliberative state may dominate for one brief moment, where the user initiates the action. The careful user, who otherwise could not make up his mind, may in that case initiate almost any action, simply to get over it.

However, the initiation of an action may also be postponed for too long: If the user hesitates for a longer period of time his attention may be drawn to something else before he can initiate the action. In that case it is likely that he must start all over, and try to decide which action to initiate.

The users effort and unreliable equipment

If the user experiences that his actions do not give the expected result, it weakens his will and it becomes more difficult for him to make an effort: Even if he can make an association to the proper action to initiate, he finds it more difficult to initiate it.

Such a weakening of the will may be caused by confusing elements in the equipment: The user makes more errors because of them, and he will experience that his action often does not give the expected result.

However, such a weakening of the will may also be caused by unreliable equipment. The problems caused by unreliable equipment are different from the problems caused by confusing elements in the equipment:

- When the equipment is unreliable its function will also be inconsistent—whereas it is possible for the user to learn precisely how some confusing elements of the equipment functions and thereby overcome some of the problems, it is impossible for him to learn precisely how the equipment is unreliable.
- It is my personal experience that the will of the user is more affected by unreliable equipment than by confusing elements in it: If there are confusing elements in the equipment, I may believe the designer has been stupid or sloppy, but I will trust the results shown by the equipment; if the equipment functions in an unreliable manner, I will distrust all parts of its function.
- By careful design and review of the design it is possible to reduce the number of confusing elements in the equipment. However, all equipment is to some extent unreliable, it is therefore necessary to design the equipment so it can function even when parts of it does not function properly.

The following part describes how the equipment can be designed such that any unreliable parts in it have the smallest possible impact on the use of it.

Operating the *real* equipment

It is often lamented by technicians that they do not want some sort of user interface, they want to operate the *real* equipment. Of course, that *real* equipment is a fiction: Even if they are manipulating single bytes directly in the equipment, they are perceiving them from some sort of user interface.

However, the feeling is real. It may occur if the user cannot operate all parts of the equipment or if the operation gives unpredictable results.

A good user interface will often restrict the users access to particular functions in the equipment. That is normally done because the average user can do more harm than good with some of the functions:

On older types of radio communication equipment, the user could manually set the squelch level—the power level of a received signal that opened the loudspeaker of the radio. It was told that when the adjustment of the squelch level was left out on newer types of radio equipment it drastically reduced the number of units reported for service as faulty—many of the seemingly malfunctioning units were malfunctioning because the users had turned the squelch level all the way up or down.

Some technically inclined people will of course miss functions left out in the user interface and therefore complain that they cannot operate the *real* equipment. However, as the example above shows, functions not needed by the ordinary user should be included only if:

- The access to them is restricted—they may for instance be placed in a special *Service mode* requiring a password.
- There is an easily accessible *default setting,* so that no matter how the settings are changed, they can easily be returned to the default value.

A piece of electronic equipment will always have some limitations caused by its design, functions or capacity: The information in a computer must for instance normally be stored on the harddisk or a disk in another drive, the user must wait some time before the connection to a distant location is established and the size of the RAM in a computer limits the number of programs that can be active at any one time. If the user interface hides such limitations, the equipment will react in ways the user cannot predict [own observations]:

The user interface in many computers reports a document as printed when it has been send off to the printer, no matter if the printing actually is completed or even if the printer is out of paper. Even if the computer reports that the document is printed out, the user may therefore find that it is not.

—

If a program in a computer needs more memory than is available, the computer may suddenly be stuck without any warning, and without any indication of the cause of the problem.

—

If the electronic equipment cannot react fast enough, the user may feel it is sluggish compared to a direct physical action, for instance when the line drawn with an electronic pen appears on the screen only with some delay.

It is therefore necessary for the equipment to show in full all the limitations it actually has: If that is not done, the user will experience that the equipment is unreliable, even though the equipment in fact is highly reliable.

Consequences of a single, a few and frequent breakdowns

A single or a few breakdowns are experienced in the same manner as a single or a few experiences with a new piece of equipment: the user will not conceive of a type of situation where a breakdown occurs. However, the reaction of the user will depend on the consequences of the breakdown:

- If the consequences are slight, situations when breakdowns occur will not be a part of the users concept of the situations when the equipment is used.
- If the consequences are serious, for instance if a large amount of work is lost, an accident or a breakdown will be part of his conception of the type of situations when the equipment is used. His will is reduced and he will not trust the equipment, but whether or not he adapts his operation of the equipment to its lack of reliability depends on how he thinks about the problems caused by the lack of reliability.
- If the equipment frequently breaks down or malfunctions, the user will conceive of the type of situations when breakdowns occur and may even end up solving them as part of an automatic process. That can for instance be the case if a key on the keyboard frequently is stuck *so it* does not react when pressed. However, the users will and effort will still be reduced.

Long or varying response times

The user can perceive long or varying response times in precisely the same manner as other cases where the equipment does not operate in a consistent manner.

However, if the user continuously is informed about the state of the equipment it is possible for the user to perceive long or varying response times without feeling that the equipment is unreliable. In many cases the equipment shows only that a process is going on—for instance the sounding of a ringing tone in a cellular phone or a computer showing a small clock with turning hands—but that is not sufficient: The user must not only be shown that something is going on, but also what is going on, and when he can expect it to be completed.

The need for reliable indicators

The user perceives the equipment as reliable when his actions lead to the expected results. Because it is impossible to design the equipment such that it overcomes all the physical limitations for its operation, the equipment must be designed such that the user understands and accepts these limitations. That is done by providing reliable indicators of the state of the equipment.

The user needs dependable information about the state of the equipment, for instance the amount of power available in any batteries in the equipment. The indicators of the state of the equipment should of course show the precise state in order to be of any value: An unreliable indicator can only make an unreliable piece of equipment even more unreliable [own observation]:

> Most battery powered pieces of electronic equipment are equipped with an indicator of the remaining power of the battery. However, the indicator often shows simply the voltage over the battery, and the discharge characteristics of all commercially used batteries mean that the voltage over the battery remains nearly constant until the battery is more than
> 80 % discharged. The indicator will therefore show a fully charged battery until the battery is almost empty.

Consequences for the design of the equipment

Even though the user in fact is very little disposed towards acting, the impatience of the deliberative state may dominate for one brief moment when the user initiates the action. The careful user, who otherwise could not make up his mind, may in that case initiate almost any action, simply to get it over with.

All actions that may have serious consequences or that cannot be undone should therefore be clearly marked. In some cases it is even necessary to include a separate warning or ask for an acknowledgement from the user.

In other cases the user may hesitate for too long and therefore forget which action to initiate.

It is therefore an advantage if the consequences of each action are reduced, for instance by dividing each larger action into a number of smaller actions that all—except maybe the last—can be undone.

Equipment for inattentive use must be more reliable than equipment for normal attentive use: The user will during inattentive use be less aware of the state of the equipment and will find it more difficult to predict and correct any errors in the function of the equipment.

If the user must react immediately to any problems with the equipment, the equipment should draw his attention and show him the cause of the problem. However, because the user cannot control what he at a particular time is aware of, it is possible that he does not perceive the signal from the equipment. In order to avoid that, it is necessary to provide a continuous signal or even a signal which strength increases until the user manually turns it off.

In most other cases, it is not advantageous that the equipment draws the attention of the user. It is better if the different indicators simply show the state of the equipment for a period of time, and in some cases also show a report over the last occurred events.

Long or variable response times are perceived as malfunctions during inattentive use, because the user is unaware of the time he has waited for a response from the equipment. It should therefore be possible for the user to perceive from the equipment how long time a process has taken, and how much longer he must wait for a response.

Finally, the indicators in themselves must be highly reliable: The user may perceive the setting of the indicator, but unless he pays attention to it for a period of time he cannot evaluate whether it is dependable or not, and what the consequences may be if it is not.

9.8 LEARNING AND INATTENTIVE USE

When the user uses the equipment without paying any attention, he gets more training in the automatic processes he is carrying out, and the associations he makes while operating the equipment becomes more and more fixed in his mind.

However, he will not learn anything new about the equipment he is operating. Subchapter **7.5 Attention** described how our remembering of something depends on the strength and number of associations we make to it, and subchapter **7.7 The level of training in relation to inattentive use** described how the creation of new concepts is an integral part of learning something. Both processes are hampered when the thoughts during inattentive use simply follows the deepest groves—the most fixed associations [own example]:

> I completed a three day course in a word processing system and tried during the course to use most of the functions, but had not had time for any significant training in the use of them. In the months after the course I found that I actually used less and less of the functions even though I wrote a lot and got plenty of training in use of the word processing system.

When doing a task on the word processing system, I used the functions I had the strongest associations to and where I first gained the training necessary for automatic processes, whereas I gradually forgot how to use the other functions.

During inattentive use the user will only learn something new when an accident draws his attention to the equipment and forces him to think about its function, and he may find such thinking difficult: He has trained the use of the equipment, but he lacks training in thinking about the equipment, why it behaves as it does, and what he can do about it.

10. PHYSICAL ACTIONS

I will define as physical any sort of activity that involves a contraction or relaxation of muscles in the body of the person doing the activity. In addition, I will use the words physical movement and physical action:

- *Physical movement* designates one separate act, as when we for instance is reaching out and grabbing something.
- *A physical action* may consist of several movements, as when we for instance reaches out and grabs something and then turns it around before putting it down.

In order to carry out any sort of physical movement we must activate a number of muscles with the proper timing and degree of contraction, and we must use visual, tactile and sometimes audio guidance for finding the target of the movement and for ensuring that the movement leads to the desired result.

Most physical movements are controlled by automatic processes; unless we are learning a new skill or experiencing a problem while carrying out the action, we will not pay attention to the precise way in which we are carrying out the physical movement.

Even when we are focusing our attention on what we are doing, we devotes only little attention to the control of each physical movement. No matter if we are focusing our attention on a task, shifting our attention back and forth or carrying out the task as an automatic process, our physical actions are therefore carried out in the same manner.

The only difference is that the physical movements in general are smoother and easier when they are part of an automatic process than when they are done under conscious control, cause any conscious attention may make the user hesitate and interrupt the flow of the movement.

It is therefore *not* crucial to describe the difference between the physical actions we can carry out with and without paying attention to them; the crucial question is which physical actions that in general are easy to carry out and which that are difficult to carry out.

If an inattentive user cannot make physical actions that reliably brings his task closer to its conclusion, he will either make errors without being aware of them or he will focus his attention on the equipment while operating it.

If a specific physical action is difficult to do, it will therefore disturb the inattentive use of the equipment.

10.1 THE NEED OF PHYSICAL ACTIONS

The physical actions of the user shall either give him some sort of emotional satisfaction—at least relieve his boredom or anxiety—or they shall bring the task he is doing one step closer to its conclusion. However, this chapter describes only the requirements for the second type of physical actions: Actions with some useful purpose.

When doing an action with a useful purpose, the user must carry out a physical action that changes the state of the equipment: He may move the equipment from one position to another or manipulate an element of the equipment that registers part of his action—the actions of the user must be so powerful and specific that they affect the state of the equipment.

10.2 THE USE OF VISUAL GUIDANCE

Our visual guidance of physical actions has two consequences:

- It makes it possible to perceive where the target for a movement is located before the movement starts.
- It makes it possible to guide the movement more precisely—a smaller target can be reached over a larger distance.

The use of visual guidance is therefore highly advantageous.

The relation between visual guidance and physical action

My own experience strongly indicates that most persons are habitually used to focus their visual attention on the target of any physical action done with the arms, hands or fingers; the movement of our eyes will in fact often precede even the decision to initiate any such action.

Unless the user has trained specifically *not* to use any sort of visual guidance while doing the particular action, it is likely that he before and during the physical action will look towards the target for his movement.

It is therefore often more difficult for a user *not* to look towards the key he is going to press than to look towards it.

In addition, my own experience indicates strongly that the physical action tends to follow the direction of the gaze of the person doing it: If the visual attention is drawn in a particular direction, the movement will habitually be drawn in the same direction.

One example can be experienced during the steering of a car or bicycle: We tend to turn in the direction in which we focus our visual attention.

The relations between visual perception and movements makes it easier to guide a physical action, but the users visual attention may be drawn away from something he should continue to keep his attention on, or in his physical movement being misguided when it follows the direction of his visual attention.

Finding the target of the movement

It is often necessary for the user to use some visual guidance for finding the target of the movement. That is for instance the case when the user shall reach out and press a key.

In addition, even when it is possible to find the target *without* any visual guidance, it is often much easier to find the target *with* visual guidance.

One example is Cooper [1983: 15] who describes that even though touch typists can type with the same speed without any visual feedback, they make 60 % more errors when no visual feedback is possible.

Guidance during the movement

If the users fingers must *crawl* towards the target of his action because he cannot see it, but only feel it, his movement becomes slow and uncertain. In most cases such a movement requires the continuous attention of the user.

If the movement is attempted without any visual guidance, the actual movement becomes less precise. Wallace and Newell [1983: 313, 316] conducted some experiments where the participants should move a pointer a certain distance and hit a target. They found that visual guidance significantly reduced the error rates when the user should reach a target with a diameter of 6 mm over a larger distance than 3.8 cm or a target with a diameter of 12 mm over a larger distance than 7.5 cm, whereas a target with a diameter of 2.5 cm could be reached equally well over a distance of 15 cm with or without visual guidance during the movement. Wallace and Newell [1983] had no data for larger distances.

Smyth and Silvers [1987: 61] investigated the role of visual guidance during handwriting: Their results shall be described in subchapter **10.5 Turning of knobs, adjustment of settings and handwriting**.

The visual guidance of a movement takes a certain amount of time. Keele and Posner [1968: 157] found that visual guidance of a movement was impossible if the movement took less than between 190 and 260 ms. This means that some physical movements are slowed down because they cannot be done without visual guidance.

The slowing down of movements because of the need of visual guidance can be seen when comparing the speed of entering digits on the numerical keypad with the speed of touch typing. At least two different types of numerical keypads are used on telephones and other electronic equipment, and almost nobody learns to operate a numerical keypad purely by touch without any visual guidance. I [own observation] have found that it takes at least 500 ms to enter each digit on a numerical keypad. In contrast, touch typing is possible without visual guidance of every move, and Gentner [1983: 106] reports interstroke intervals for touch typists on less than 160 ms, approx. one third of the time needed for similar movements with visual guidance.

Consequences for the design of electronic equipment

The user will in general look towards the target of his physical action. Any physical actions done on the equipment can therefore disturb the users perception of the environment or even of parts of the equipment. Since events in the environment cannot be postponed, the operation of the equipment should therefore be comparatively time-independent: It should at any time be possible for the user to stop the operation of the equipment for a short period of time without any adverse consequences.

The physical movements of the user will often be directed towards the direction in which he is looking. If that may result in any damage, it should therefore require some force or an additional movement—an unlocking—to change the direction of the operation of the equipment while it is done.

If the keys or knobs are small or their position unknown, the user must use visual guidance during the last part of his movement and he must either slow that part of the movement down or risk missing the key. If the user is operating the equipment with his hand *poised* over the keys without any support for the hand or the wrist, or if a key or switch has to be reached in a fast movement without any hesitation, the width of each key or switch should be 25 mm or more in diameter depending on the specific application. If the size of the key or handle is smaller, the movement will be delayed; the movement must then have a duration longer than approx. 200 ms in order to make visual guidance possible during the movement.

When the user is operating the equipment without paying attention to it, it is difficult for him to control whether or not he is looking on the equipment while operating it. In order not to draw his attention unnecessarily from the environment or from any indicators on the equipment, it is therefore advantageous that all keys and other actuators are made oversize—approx. 25 mm or more in diameter depending on the application. It is then possible for the user to look away from the equipment at least part of the time he reaches for a key, knob or other actuator.

10.3 THE STRUCTURE OF PHYSICAL ACTIONS

When we carry out a physical action, our movements are influenced by several different tendencies:

- We tend to position parts of our body in a certain position in relation to objects in our environment and each other. According to Rosenbaum [1991: 7] we will in particular tend not to end our movement in an awkward position where further movement is blocked.
- We tend to move as effectively as possible. Rosenbaum [1991: 7] describes that Hogan and Flash [1987] showed that the size of jerks, that is the rate of change of the acceleration in the movement, is minimised, and Rosenbaum [1991: 7] describes that Uno et al. [1989] reports that we at the same time tend to minimise changes in the muscle torque. According to Rosenbaum [1991: 7] both the minimisation of jerks and the minimisation of changes in the muscle torque minimises the energy expenditure used for the movement.
- We tend to move parts of our body with a reasonable speed to the position that is the goal of our movement.

Rosenbaum [1991: 5-8] describes these principles as ways of solving the "degrees of freedom" problem. However, that term turns the problem upside down: Our freedom of movement is no more a problem than our freedom to think about an almost unlimited amount of different topics one after the other. In the same manner as our freedom of thought makes it possible for us to find a solution to a problem our freedom of movement makes it possible to do a physical action that leads to the desired outcome.

Static use of muscles

All physical actions require some static use of muscles—some muscles that are contracted and held with the same contraction throughout the action.

Such static use of muscles can cause problems:

- Prolonged static use of a muscle may cause pain or damages.
- The user may relax the muscle at an awkward moment if he becomes unaware of the static work.

Plum and Øfeldt [1987: 93] report that prolonged static use of muscles results in an accumulation of fatigue poisons in the muscle, and these fatigue poisons may lead to temporary or even chronic pains. The pains are increased if the muscles already are under-trained or under-used—that may for instance be the case for muscles in the back that are held in the same position during most of a working day at a computer terminal.

If the user of a piece of electronic equipment are forced to hold part of his body in the same position for a longer period of time, that may result in pains or even damages to his muscular system, and—as described in subchapter **7.5 Attention**—when the attention is focused strongly on something else, we may be unaware of something causing pain, and therefore not react on it. Inattentive use increases therefore the risk of work related injuries when a muscle is held with the same degree of contraction for a period of time.

I have experienced that I often relax a muscle when I momentarily is unaware of it. If the user of a piece of electronic equipment holds the equipment in his hand and in a short moment becomes unaware of gripping it, he may therefore release his grip and drop the equipment.

The control and co-ordination of movements

The resulting movement is always the result of the activation or relaxation of a number of muscles in the proper order. Rosenbaum et al. [1983: 98] report on an experiment showing that rapid movements are controlled hierarchically; instead of one movement simply calling up another by association, we have a structure where one impulse—or idea of a movement—triggers a number of more limited impulses—or ideas of movements—that in turn trigger the specific impulses to our muscles.

The movements triggered by a signal are therefore characterised by the activation and relaxation of specific groups of muscles in a certain pattern or order.

There is, however, no simple hierarchical level where the different parts of the body are controlled in a top down fashion. According to Sternberg et. al. [1990: 5, 8, 11] it is possible for different impulses to converge on a lower level and one impulse can in addition get priority over another by being on a higher level *or* by preceding it.

Rosenbaum [1991: 243-44] describes a number of experiments showing a relation between the duration of a movement and its size: When we for instance move our hand with what we perceive as natural speed, a shorter or longer duration of the movement also will lead to a smaller or a larger movement of the hand.

This means that the units of movements we have learned, for instance pressing a key with a finger, are characterised by the activation and relaxation of certain muscles in a certain order *and* at a certain speed.

Feedback in the control of movements

There is a substantial amount of feedback from the lower to the higher levels in the hierarchy of movement. Wiesendanger [1990: 69] describes how the guidance of movement is done through a combination of higher and lower parts of the brain and different nerve centres with a substantial amount of feedback from the lower to the higher parts. The total guidance of a movement resemble therefore more a network than a purely hierarchical structure.

The ability of one impulse of movement to inhibit another is crucial for assuring a coherence of movements: When the contraction of a conflicting muscle cannot be blocked a co-ordinated movement is next to impossible.

<u>The conception of movements</u>

A specific movement—for instance reaching out and picking up something—involves the activation and relaxation of certain muscles in a certain order and at a certain speed, and it involves normally some sort of visual guidance of the movement and visual, proprioceptive and tactile feedback during the movement.

In order to select the proper interaction between sight, muscles, and feedback we must therefore recognise the type of physical movement we shall perform; we must therefore conceive of the movement in order to carry it out.

We conceive of each movement in two different manners: We conceive of the movement we do, and we conceive of the movement we have seen or believe we do: The results of these two conceptions are often different, even though we call them by the same name.

<u>Movements and emotions</u>

William James [1890: 1002] describes the relation between emotions and bodily functions as follows:

> *A process set up anywhere in the centres reverberate everywhere, and in some way or other affects the organism throughout, making its activities either greater or less.* [W.J. italizing]

However, William James [1890: 1065-66] goes one step further and describes how emotions consist of the felt changes in the body:

> *...the bodily changes follow directly the perception of the exciting fact, and that our feeling of the same changes as they occur* IS *the emotion... objects do excite bodily changes* by a preorganized mechanism, or the farther fact that *the changes are so indefinitely numerous and subtle that the entire organism may be called a sounding-board,* which every change of consciousness, however slight, may make reverberate. [W.J. italizing and capitalising]

This so-called James-Lange law is probably the most controversial parts of William James's description of human psychology. William James may have overstated his case somewhat, it is likely that emotions cannot be *fully* described as the perceived results of bodily changes. However, Rosenbaum [1991: 347-48] concludes on the experiments by Ekman et al. [1983: 1209] that the relationship described by William James and Carl Lange exists.

I will conclude on the above that very fine or precise movements always are affected significantly by our emotions or general mood; they cannot be controlled sufficiently by our conscious thoughts. Any shaking of the hand or other bodily reaction on the emotions will at the same time influence the felt emotions. If the user feels any problems while using the equipment, there will be a positive feedback between the emotions he feels and the precise control of his movements. And because that positive feedback is the result of a pure reflex and not of a conscious action it may occur during inattentive use of electronic equipment.

Movements are non-verbal

It is very common that we can recognise a specific movement and even do it, without having a name for it and without being capable of describing even its most important characteristics in words. One example is the operation of a bicycle lock that is unlocked by pushing or pulling a number of catches in a specific combination. it is common that [own experience] we can remember and operate such a lock without being able to recall the combination and tell it to somebody else.

Yamada [1983: 392] describes a number of measurements of EEG—electrical signals from the brain—done on persons doing spatial tasks as compared to persons doing touch typing. He found that touch typing in some persons primarily involved the parts of the brain used when thinking spatially or non-verbally, whereas it in other persons to a large degree involved the parts of the brain used when thinking or formulating things in words.

It is likely that the individual differences described by Yamada determine how easy it is for a person to combine an automatic process consisting of physical movements with another task requiring conscious thinking: If control of the physical action and the conscious thinking occur in different parts of the brain, their interference will be reduced. It is then, for instance, easier to operate the equipment as an automatic process while talking with other people.

Simultaneous movements

If a physical movement always is triggered by the preceding one, one movement must be completed before the next one can be started. However, in real life the physical movements can be overlapping or simultaneous. Norman and Rumelhart [1983: 54, 47] describe the movements of the fingers during touch typing as follows:

> The results of these studies show the fingers of the hand in almost constant motion, with fingers starting to move toward their destination before several preceding characters have been typed.... there seems to be a co-ordinated structure that allows the control of several fingers simultaneously ... The movement of the fingers over the keyboard reminded us of sea grass weaving in the waves, gracefully bending this way and that, all in motion at the same time.

Norman and Rumelhart [1983: 61] formulated a model of the total movement of the fingers during touch typewriting:

> ...each active schema pushes its relevant hand and finger toward its desired key at the same time, and the final overall configuration is determined by the competition among these forces. Each schema pushes with a force proportional to its activation level. As a result, the forces are weighted so as to cause the letter schema that is next in line to be typed to approach its key most quickly. [N. and R. use the word schema for the sum of past experiences and responses guiding a particular movement, for instance the touch typing of one character]

That model is in accordance with the results of the experiments made by Georgopoulos et al. [1986: 1418]. They found that the movement in a particular moment was the vector sum of a number of signals, each pointing towards a movement in a slightly different direction.

Sternberg et al. [1990: 7] describe the difference between what they call "high level" and "low level invariance" in a physical movement. The high level invariance describes how a specific physical movement each time involves the relaxation and contraction of the same muscles in a specific order, the low level invariance describes how each part of the physical movement is done in the same manner no matter the specific movement done before or after.

However, the description by Sternberg et al. [1990] is in conflict with Norman and Rumelhart's [1983] description. Sternberg et al. [1990] have only investigated comparatively simple movements and they admit that the low level invariance even then did not apply to all cases because there would be some smoothing out between one movement and the next.

Sternberg et al.'s [1990] attempt on describing physical actions as the result of a hierarchy with invariant elements therefore actually can be seen as a confirmation of Norman and Rumelhart's [1983] model where the movement in each moment is the result of several competing forces.

There is no indication of the reaction time during the automatic process being larger than the reaction time under normal circumstances. The stream of movements is, however, so fast that it takes more time to stop it than to complete one or even two separate movements in it.

Logan [1983: 205] reports on experiments where typists should stop the typing when they had made an error. In these experiments between 4 and 21 % of the typists typed one or two letters before they managed to stop the typing after having made an error. These data fit well with the reaction time being the same during an automatic process and in other situations where we do not pay particular attention.

Logan [1983: 206] found in addition that the typists could not stop, even though they knew they were about to type an error. He writes:

> ...there is evidence that typists may detect their errors before they register on the keyboard... In principle, errors may be detected any time between the initiation of the erroneous movement and the (expected) termination of the keystroke following the error (i.e., movement time for the error plus one interkeystroke interval).

These results are not quoted because electronic equipment primarily is operated through touch typing; they are quoted because touch typing is a precisely defined and very complex physical action where a large amount of experimental results are available, and because they are applicable when describing how we in general carry out physical actions.

Deecke et al. [1969: 161] found two qualitative changes in the EEG signals, and therefore in the brain activity before a movement was carried out; the changes occurred between 56 and 86 ms before the muscles were activated for the movement. These changes follow after the activity that—as described in subchapter **7.3 The changing stream of thought**—precedes the decision to make the movement. According to Rosenbaum [1991: 61], the change in the EEG 56 ms before the activation of the muscles is only associated to the centres in the brain controlling the execution of the movement. When that change happens, the movement is therefore already under way and cannot be arrested. It is even possible that the first change in the EEG already marks a point of no return; if that is true the beginning movement cannot be stopped during the last 86 ms before the muscles are activated.

Rosenbaum [1991: 130, 242-43] presents results that appear to confirm that walking and handwriting are co-ordinated in a similar manner as touch typing. I will therefore conclude that other co-ordinated movements are guided in the same manner as touch typing: Our perceptions, habits and conscious decisions result for each moment in some impulses gaining a larger *weight* or influence than others. The resulting impulses to move in different directions inhibit each other to a greater or lesser degree, and *the total movement in each moment is the result of all the simultaneous impulses to move.*

Feedback from a stream of movements

It is possible to do even highly complex movements, as for instance touch typing, without any visual or auditory feedback. However, the situation is different if the feedback is erroneous instead of lacking.

Cooper [1983:17-18] reports on a number of experiments showing that a delayed visual or auditory feedback resulted in more errors and a lower work speed for a typist. It is difficult to disregard erroneous feedback.

Cooper [1983:17] found in addition that visual or auditory feedback was important as a motivation for the person working during an automatic process: Even though the sound of the operated typewriter did not provide any useful information for the typist, the typist preferred being able to hear that the work process was going on. The sound of the typewriter serves the same purpose as the sound of a steadily humming motor: It tells in an unobtrusive manner that everything is working correctly.

Lack of feedback may finally be dangerous. When our physical actions have become part of an automatic process, we become less aware of the feedback from them, and we will then be unaware of any slow changes in the work process and its impact on our body. Therefore, there is a larger risk of work related injuries when the equipment is operated as part of an automatic process, than if we at least occasionally focus our attention on the physical actions we are doing while operating the equipment.

Combinations of movements

According to the results by Wiesendanger [1990: 69] it is not possible to discern any difference between habits or automatic processes that are learned during infancy and the habits or automatic processes that are learned later. My own experience shows, however, that it is difficult to learn a totally new type of movement and that we cannot unlearn old habits; we will therefore always base our learning of new habits or automatic processes on the habits and automatic processes we already have learned. That is a well-known experience among people learning to play an instrument; if a wrong movement is learned it cannot be unlearned.

This means that it is extremely difficult to learn and perform movements that contradicts the movements we already have learned; movements we perceive as *un-natural* or *artificial* [own observation]:

> When working on a computer I can activate functions as *Save* by a *short cut* where I press a *Function key* situated in the left side of the keyboard at the same time as I press the *S key* for *Save*. I found out that I always pressed the *Function key* with my left thumb, even though my thumb and the finger I used for pressing the *S key* then were crossed. I found that the movement caused considerable strain in my hand and tried to learn another way of pressing the keys. That was difficult: I continued trying to move my fingers as when I was touch-typing, and could then only press the *Function key* with my thumb.

<u>Movements along curved lines</u>

Abend et al. [1982: 335] found that the participants in their experiment had a tendency of moving in straight lines. Even when they tried to make a movement following a curved line, it was in reality fitted together from a number of small straight-line or only slightly curved segments.

My personal impression is that when we attempt to move along a curved path, it is very likely that the force we apply to the movement part of the time is not parallel with the intended direction of the movement. Even when we are turning a knob where any sideways forces easily are taken up by the knob, the forced curved movement means that we will use an excess of force and have a less precise control of the speed of the movement.

<u>Different movements with both hands or with different fingers</u>

In some cases, the movement of one part of the body affects always the movement of another. Smyth et al. [1994: 125] describe how it is almost impossible to tap the head with one hand while rubbing the stomach with a circular motion with the other hand. The movement almost inevitably degenerates into *tap, tap, tap, rub, rub, rub,* instead of simultaneous tapping and rubbing: *tap, rub, tap, rub, tap, rub, tap, rub.*

Rosenbaum [1991: 221-23] describes a number of experiments showing that the movement of one arm is co-ordinated with the other: If one arm moves in a specific pattern, the other arm cannot move in another pattern or with another rhythm but will tend to move in the same pattern or with the same rhythm.

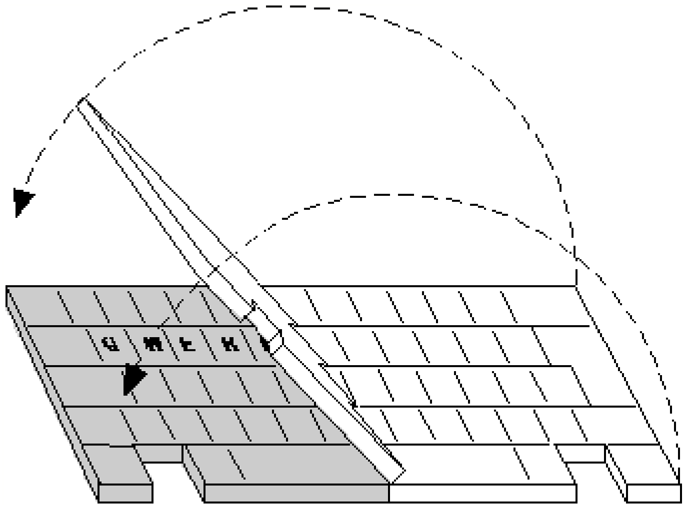
Grudin [1983: 128-29] investigated the errors made by touch typists. He found that approx. 12 % of the total number of errors involved the similar letter being typed with the opposite hand. In other words, the typist did the proper movement but with the wrong hand.

In addition, Grudin [1983: 128-29] also found that the most common types of error done during touch typing was the typing of one letter instead of the one directly adjacent to it in the same row. Excluding the cases where both letters normally are typed by the same finger, he found that the remaining letters in almost all cases were hit by the proper finger. In other words, the problem was not that the proper finger made the wrong movement and hit the wrong letter, but that the adjacent—and wrong—finger made the proper movement and hit the adjacent—and wrong—letter. More than 20 % of the total number of errors were of that type.

I will conclude that there is a relation between the movement of one arm and hand and the movement of the other arm and hand, and a similar relation between the movements of two fingers on the same hand. If we move one hand or arm the other hand or arm will partake in the same movement, and if we move one finger, the neighbouring fingers will also partake in the movement.

It is possible to utilise the relations between movements done with the different arms and hands; one example is a keyboard for touch typing using only one hand [own observation]:

> If a person has learned touch typing on a normal keyboard it is very easy to write on a keyboard where the same character is activated with the same finger but on the opposite hand. This means that with a suitable mean for shifting between the characters belonging to the left and to the right side of the normal keyboard, it is possible to do touch typing with only one hand on a keyboard resembling either the left or the right half of a normal keyboard. I have found, that most people who have learned touch typing on a normal keyboard can sit down and immediately start touch typing on such a reduced keyboard.



Principle of keyboard for touch typing using only one hand

Electronic equipment adapted to the structure of physical movements

The structure and control of our physical movements should be decisive when designing electronic equipment for inattentive use—a design that focuses on the appearance is often unsuitable for inattentive use.

The equipment should be made without any sharp edges or protruding corners that may rip clothes or hurt the user when he is unaware of the equipment—the equipment should ideally be shaped as pebbles on a beach.

In order to reduce the risk of muscular pains or damages from static use of muscles, it should be easy to vary the position of the body while operating the equipment—the equipment should ideally force the user to vary his position while operating the equipment.

The risk of the user dropping a piece of hand-portable equipment should be reduced— for instance by including a protruding rim or edge above the point where the equipment is gripped, such that the user can hold the equipment even when he relaxes his grip for a moment.

Portable equipment may also be made with a strap or handle, such that it can be carried over the shoulder or the lower part of the arm.

The equipment should be equipped with a lock or a lid such that it is impossible to activate any parts of the equipment by accident when carrying it—the users will often carry the equipment in pockets or in manners not envisaged by the designer.

If the users attention suddenly is drawn towards something else, it may affect his operation of the equipment. If that may cause any sort of adverse consequences, the equipment should have a *dead-man switch* that stops or blocks the equipment whenever the users attention is drawn towards something else. Such a *dead-man switch* may stop the equipment if the grip around the equipment is relaxed, if no operations have been detected for a period of time, or if a succession of identical entered digits are detected.

There is a direct relation between the finer details of the control of the movement and the emotions experienced by the user. This means that if the mechanical function of the equipment is unreliable the emotional reactions are part of a positive feedback loop: The users emotions makes it more difficult to operate the equipment, and the more difficult operation of the equipment affects the emotions of the user. Such a feedback is possible, even though the user is not fully aware of the details of the motions done while operating the equipment.

For a majority of people the left hand is more directly connected to the right—non-verbal—than to the left—verbal— part of the brain. It is therefore advantageous if equipment for inattentive use *can* be operated with the left hand, cause left-handed operation normally interferes less than right-handed operation with any verbal thinking done by the user while operating the equipment.

However, because a minority of users may find it very difficult to use the left instead of the right hand, equipment should normally not be made such that it only can be operated with the left hand, even though the experiments made by Hoffmann [1994: 502] show that right-handed users typically only are 6 % slower when doing a movement with the left than with the right hand.

The user can do a series of fast movements as an automatic process where several movements are in progress at the same time. This mode of working is automatic, experienced as comparatively effortless and at least twice as fast as an automatic process where a movement only can be started after the former one has been completed.

Such a series of fast movements involve the contraction and relaxation of specific muscles in a specific order and *for specific relative periods of time.* Long or varying response times on single actions should therefore be avoided. If—for instance—the response time after pressing a key is long or varying, the rhythm of movements is broken, the speed may drop to less than half of the speed of the unhampered automatic process and it might be impossible to do the task as an automatic process.

If the equipment is unreliable—for instance, if the keys do not react in precisely the same manner every time they are pressed—it is not possible to do the work as an automatic process. The flow of the automatic process will then be interrupted and the speed will drop to less than half of the speed of the unhampered automatic process.

This means that the equipment for inattentive use—in particular any keys or other mechanical parts—should operate in an easy and dependable manner without any delays; if a few percent of the responses from the equipment are delayed, or if there is a slight mechanical problem with a single key, that may reduce the work speed and make inattentive use difficult.

Even though the work can be done without any visual or audio feedback, it is essential that such feedback on each separate action is precise and immediate: If the feedback is unreliable or delayed, both the quality and the speed of the work will be degraded. Audio feedback can often motivate the user and be considered desirable by him. It may, however, block him from hearing sounds in the environment during inattentive use. For that reason, the sound level of key *clicks* and similar audio feedback on each separate action should be kept on a low level, and it should be easy to turn them off.

During an automatic process the user of the equipment is often unaware of how the use of the equipment affects his body. In order to reduce the risk for work related injuries, equipment for inattentive use should therefore be designed with special care: In some cases it is necessary to analyse in details the specific impact the use of a given piece of equipment can have on parts of the users body.

During an automatic process, a user will commonly continue and do one or two operations even after an error has been detected. This means that it should be possible to *undo* or *backtrack* the operations at least two steps back. When that in some cases is not possible, the equipment should attract the attention of the user, for instance by delaying the next step and requiring an acknowledgement from the user.

Some types of physical actions or movements are difficult to perform. That is in particular the case for physical movements that conflict with those previously learned; in particular physical movements where the first part is the same as a previously learned movements or where only one detail differs from a previously learned physical movement.

Therefore, it should be possible to operate the equipment without doing any physical actions or patterns of movements that conflict with those learned for touch typing and without any need for making a physical movement to the left in order to actuate the movement of an element in the equipment to the right or vice versa.

The equipment should be made, so it can be operated without any precise curved movements, in particular such with a small radius. When it is necessary to turn a handle it may be easier to do if the hand is not locked in the same position on the handle but can slide in relation to it—perform a movement consisting of slightly larger straight-line segments.

Finally, simultaneous but different movements with two fingers or with both hands should be avoided. In particular it should normally not be necessary to press two keys at the same time in order to activate a function. The only exception is the case when two keys are adjacent and can be pressed as one.

However, the operation of the equipment requires less attention and can be done significantly faster, if one physical action can be started before the last one is completed. Even though it should not be necessary to do simultaneous and different physical actions while operating the equipment, it should be possible.

10.4 REACHING, STOPPING OR GRASPING

A large part of the movements done during the operation of a piece of electronic equipment consists of the user reaching out with his hand and touching or grasping parts of the equipment. One example is the movement when the user reaches out and presses a key on the equipment with his finger.

The user may do similar actions with his legs and feets when he for instance is pressing a pedal. I am not describing the specifics of actions done with the legs or feets in this subchapter. However, cause they are cruder than but similar to the physical actions the user does with his arms and hands, part of the descriptions in this subchapter are valid for similar actions done with legs or feets.

A reaching or grasping movement can be divided into the following parts:

- *Aiming for the position of the target.* We will already at the beginning of the movement start positioning the hand for the action to be done, no matter if it is the picking up of something or the pressing of a key.
- *The ballistic and corrective phases* where the hand moves forward towards the target, first freely—ballistic—and during the last phase guided by visual feedback.
- *Impact on the equipment.* During the movement of the hand the maximum speed may exceed 2 m/s or 7 km/hour. Therefore *impact* is an appropriate word for the part where the hand reaches its target.

Aiming for the position of the target

When we reach out for something, we adapt the movement to the target we reach for and the operation we want to do on it, and in most cases we start to adapt the movement and the position of the hand before we even start to reach out. When we reach out to press a key, we straighten our fingers; when we reach out to grasp something and turn it around, we open our hand so it fits a grip where we can turn the thing around when we hold it.

Rosenbaum et al. [1990] investigated how the specific direction, distance and speed of our movement depend on the target we reach for as well as on the movements done before and the movements that are likely to be done afterwards. They are, however, using the expression that we are "planning" the movements.

I will instead use the expression that the movement is *varied* depending on the circumstances; *planning* might suggest some sort of conscious or rational planning of each step of the movement. That is not the case: What is going on, is part of the automatic process we use for controlling the movement.

Rosenbaum et al. [1990: 338-39] found that the movements are varied so we tend to do the following:

- To "minimise time in awkward postures". Rosenbaum et. al. [1990: 323] defines awkward postures as ones with extreme joint angles, where the joints are far from their resting position. Rosenbaum notes the length-tension properties of the muscles makes it necessary to exert an extreme force to bring a joint to such an angle.
- To "exploit awkwardness" at the beginning of the movement. The movement is varied, such that we during the movement will move from a more to a less awkward position. If we shall grab something and turn it around, we may for instance grab it with a rotated wrist or an overhand grip, so we can make the rotation towards a less awkward position.

Rosenbaum et al. [1990: 339] note finally that during a physical action we seemingly cannot vary a movement so any movements after the next one is taken into account: We can vary the movement when reaching and grabbing an object such that it is possible to turn the object we have grabbed once, but without conscious planning we cannot vary the movement so we minimise the time in awkward postures when we turn the object first in one and then in another direction, as—for instance—we shall do when we grab a bottle and pour from it in a position that is difficult to reach.

It is possible for us to vary a movement so it becomes easier to perform. In addition, it is likely that we can perform a smooth movement only if we can start varying the movement to the goal already when we start the movement. A movement will therefore be more difficult, and maybe demand our conscious attention, if we cannot see the direction of it or if it is necessary to perform a movement consisting of several parts.

In addition, Athenes and Wing [1989: 294] report on experiments by Wing and Fraser [1983] and Marteniuk et al. [1987] showing that the movement already from the outset is varied according to the expected target; the fingers are for instance spread wider when reaching for a fragile than for a more solid object of the same size.

Ballistic and corrective phases

When we reach out for something, we reach out in the proper direction and approximate distance to the target. That is the ballistic phase, where the arm moves freely. During the last part of the movement, we must in most cases correct our movement in order to reach the target precisely. That is the corrective phase.

In order to perform the ballistic phase, we must *translate* the position of the target into a set of movements to be performed by specific muscles. Soechting and Terzuolo [1990: 493] call these two types of definition of a position for *extrinsic* and *intrinsic* parameters, and they conclude on their experiments that there is at least one intermediate step in the translation: The extrinsic position is transformed into a polar position in relation to joints of the body, for instance the shoulder or elbow joints, before it is translated into intrinsic parameters—specific movements to be performed by specific muscles.

Such an intermediate step in the translation of the position of elements into specific movements means that a specific sequence of automatic movements is easier to perform, if we can position the crucial joints in a position that resembles the one used when learning the movement. In that situation the translation from extrinsic to intrinsic parameters will resemble the one we did when learning the automatic process.

Soechting and Terzuelo [1990: 486-87] found a consistent pattern of errors in the definition of the target for a movement. When the participants should reach out to the target without any visual feedback there was no non-random error in the direction in which they reached out, but they could not estimate the distance correctly. The participants in the experiment consistently overshot the distance to targets close to them and undershot the distance to targets farther away from them: When the distance to the shoulder joint was 30 cm the participants would on average overestimate the distance with 4 cm, when the distance was 45 cm they would on average estimate it correctly, and when it was 60 cm they would underestimate it with 4 cm. In addition, the participants made random errors on average on ± 4 cm on the distance. This means that when we reach for something at a distance closer than 45 cm, there is a significant risk of overestimating the distance. If we are doing a fast movement, we can then hit the thing we reach for with considerable force.

Meyer et. al. [1990: 188, 191, 202] describes Fitt's law giving a relationship between the time it takes to perform a movement and an index of its difficulty—the relationship between the length of the movement and the size of its target. They note that Fitt's law holds for a wide range of movement types including head movements, finger movements and the operation of rotary handles, a stylus or a computer mouse. They then derive their own theoretical description of a further development of Fitt's law where the movement time is defined as:

$$\mathbf{T} = A + B \log_e (D/W)$$

with **T** being the movement time, *A* a constant describing the minimal time for the movement and $B \log_e (D/W)$ the time needed for iterative corrective submovements. The difficulty of the movement is then expressed as *D/W* where *D* is the distance of the movement and *W* is the size of the target.

Meyer's law, as the relation between time and difficulty of movement sometimes is called, shows that there is no minimum or maximum size of keys on a piece of equipment: A key of a larger size will always be easier to hit.

Impact

I have calculated that during touch typing the maximum speed of the finger movements may exceed 60 cm/s; if the user is reaching out and pressing a single key, the speed of his finger may exceed 2 m/s.

These considerable speeds mean that fingers and even the hand can be damaged by consecutive impacts on elements on the equipment. That such damages actually occur is confirmed by an investigation of work related injuries by Pascaralli and Kella [1993: 529], who found that the risk of damages were increased if the user operated the equipment for prolonged periods of time and if he hit the keys of the equipment with some force.

In addition, it is likely that the risk of damages is higher during inattentive use than when the user pays attention to his actions. As described in subchapter **7.5 Attention**, a person may become unaware of something causing pain or discomfort when his attention is focused on something else. It is therefore likely that an inattentive user does not perceive any pain even though consecutive impacts on the equipment stresses or damages his hands or fingers.

Tactile feedback and the braking of the movement

The visual guidance is normally too slow and imprecise for guiding the braking of the finger or hand at the time of impact. We must therefore depend on tactile feedback for finding out when we have reached the target.

This means that the user cannot start braking the movement of the finger or hand before he senses the item he is reaching for, or—as when the user shall activate a key—senses a tactile feedback indicating that the item he is reaching for has been activated.

The acceleration during the braking is given by:

$$\mathbf{A} = 1/2 * V^2 / D$$

where **A** is the acceleration, *D* is the distance for braking and *V* is the speed before the braking.

The acceleration during the braking of the finger can be considerable: An impact speed on 60 cm/s and a braking distance on 3 mm results in an acceleration on 60 m/s^2 or 6 times the acceleration of gravity.

The formula for the acceleration means that the risk of work related injuries increases when the braking distance decreases—when the tactile feedback occurs so late that the user cannot stop his hand or finger in a smooth or gradual manner.

Electronic equipment adapted to the process of reaching, stopping and grasping

When the user does not pay attention to a movement, he cannot control it with a conscious effort. It is therefore necessary to adapt the equipment for inattentive use to the special characteristics of the reaching and stopping or grasping movement.

In order to make it possible for the user to position his hand properly when he starts the movement, it is necessary that the directions of movement to all keys and other actuators are immediately visible.

In addition, the equipment should be designed so the user easily can avoid awkward positions of any joints during the operation:

- If the user cannot directly see the direction in which he shall turn a knob, the maximum necessary rotation should be limited to 90°; if he easily can see the direction in which he has to turn a knob the maximum necessary rotation should be below 180°.
- It may be advantageous to use knobs with a triangular crosssection instead of spade shaped knobs, since the maximum angle the hand must be turned in order to get a grip is smaller for a knob with a triangular cross-section.
- The equipment should be designed in such a manner that it is unnecessary for the user to reach out in an awkward position or to reposition his grip between each part of a physical action. That requirement is normally fulfilled for the physical actions that the user does when manipulating keys and knobs. However, it should also be possible for the user to lift hand-portable equipment, exchange batteries, open or close covers or do other similar operations without doing any actions consisting of several different movements without any interruption between them. If hand-portable equipment is carried in the belt it may in particular be advantageous if the equipment can be carried with the keypad and display towards the body. The user can then lift the equipment and operate it without changing his grip on it.

It should be possible for the user to draw upon automatic processes from the operation of similar equipment:

- The different keys should if possible be positioned in the same relative positions on similar types of equipment. The experience with different types of keyboards seems to indicate that the distance between the different elements can be varied without any adverse consequences, as long as the size of the keys is within the range where a normal operation is possible and as long as the relative distances between the elements are the same, and the testing of a new keyboard for one-hand operation [own observation] indicates that the angles or orientations of the different elements are less important.

- It should be easy for the user to position the equipment in relation to his body or his body in relation to the equipment, so the distances and angles to the different elements of the equipment can be as similar as possible to situations where he formerly has used the equipment.

The actual movement is varied according to the perceived characteristics of the target. In order not to slow down the speed of operation it is therefore essential that the equipment appears to be solid and without any sharp edges or parts that may cause injuries.

In order to avoid overshooting and hard impacts on the equipment, the minimum distance from the shoulder joint to where the user shall reach out and do an operation should be at least 45 cm and preferably 60 cm.

According to Meyer's law, it is always be easier to reach out to a larger key or other actuator than to a smaller one. For that reason the largest possible size keys should be used in particular for emergency or alarm purposes; smaller keys are only advantageous on a keyboard for touch typing or similar activities, where the distance the fingers must move should be reduced.

It should be possible to get an immediate tactile feedback from the equipment indicating whether or not his movement has reached the proper point on the equipment. After that feedback it should be possible for him to reposition his hand or arrest the movement before it is completed:

- It should always be easy for the user to feel the angle of a knob to be turned, the position of a switch and the extent of a key, and it should in particular be possible for the user to feel the boundary between one key and the other.
- In addition it is possible to design the different keys on a keypad, so each key gives a different tactile feedback. One example is the small protruding point on the *K key* on a keyboard; another example is a keypad with a number of ridges in a concentric design—on such a keypad it is possible immediately to feel whether or not the finger is positioned on the proper key.

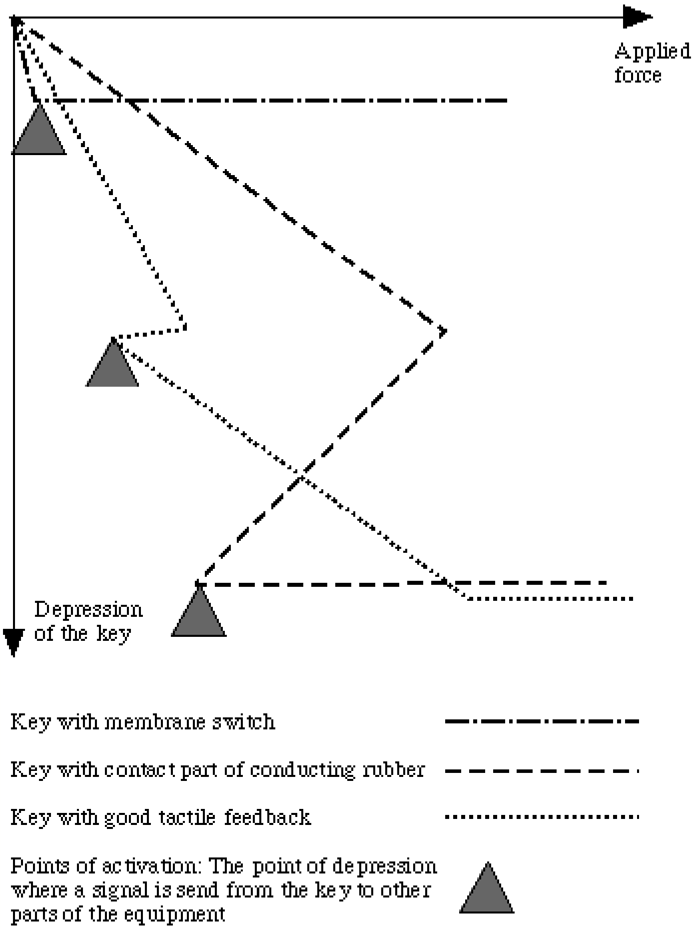
If the user overshoot the distance to a knob or key with just a fraction of a centimetre, he can hit it with considerable speed. For that reason, all keys, knobs and switches should be resilient so the movement of the hand and fingers can stop gradually after the first tactile feedback is felt from the key, knob or switch. A resilient key should be constructed so the finger of the user can stop its movement in a smooth and gradual manner whereas a knob or a switch should be made without any sharp edges and of resilient rubber or with a resilient mounting.

In addition there is some special requirements for all keys on the equipment: If the user must expend a large amount of force when activating them, the impact of the fingers of the user is similar to the cases when the user overshoots the key. For that reason the force needed to activate keys that are activated repeatedly should be minimised; my preliminary figures indicate that it should be possible to activate keys that are pressed repeatedly—for instance keys on a keyboard used for touch typing—with a force of less than 60 gr or 0.6 N, and it should be possible to activate keys that are not activated repeatedly on hand-portable equipment or on equipment for industrial applications with a force of less than 120 gr or 1.5 N.

If a key is used regularly, it should in addition give a gradually increasing resistance against the pressure from the finger, and before the key is fully pressed, there should be a *click* function with a tactile feedback indicating that the key is activated, and after that a distance of movement on at least 3 mm, or preferably up to 6 mm so that the movement can stop gradually. The need of a tactile feedback when the key is activated is confirmed by Bergman et al. [1985: C3-7] whose experiment shows that the error rates when entering phone numbers are significantly higher when only a visual or audio feedback is given than when the keys include a *click* function.

The following types of keypads and data entry devices may in particular cause problems:

- Keypads using membrane switches or virtual keys activated when a finger touches a particular spot on a screen. Such keys have no or very little movement of the key, so the movement of the finger must stop almost immediately when the finger hits the key. Kristensen [1985: C1-3] reports that 60 % of the users found a flat keyboard using membrane switches too hard to press, and 66 % found it unreliable, whereas 10 % of the users found a bubble keyboard—where the membrane switch could be depressed slightly—too hard to press and 38 % of the users found it unreliable.
  The problem may be reduced, by placing 2 or 3 mm of a flexible material beneath the active parts of the keypad, so the keypad becomes slightly yielding. However, even with such precautions it is possible that keys with membrane switches and virtual keys on finger touch screens in general should not be used for applications where the user shall press them repeatedly.
- Use of touch pads replacing the mouse or another pointing device used with a computer—the user clicking on such a pad with his finger experiences the same problems as the user of a keypad with a membrane switch.
- Keys where the connection is made by the compression of a piece of electrically conductive rubber should be designed with special care: It is quite common that such keys require the largest pressure when they are pressed halfway down even though the activation only is achieved when the key is fully pressed. In that case, the braking of the finger after the contact is made can be very sudden and cause injuries during prolonged use.
- Old or damaged keyboards, where some of the keys can be activated only with an excessive pressure. Repeated typing with such an excessive pressure can lead to work related injuries in the hand and arm, so—if feasible—the keyboard should be designed such that it becomes totally unusable if any keys are damaged. That may for instance be done by designing the keys such that a damaged key will stay locked in the depressed—conducting—position.



Characteristics of keys on electronic equipment

The tactile feedback can—in addition—be used for checking if the proper target has been reached. If the user perceives from the tactile feedback that the target does not feel right, he may arrest his movement.

For keys or actuators where the precise moment of activation is important, it is advantageous if the resistance against the depression increases sharply at the precise point before the function is activated, for instance by providing an additional *click* in that moment.

One example is the key pressed to take a picture with a camera: The force needed to depress it will typically increase sharply when it is depressed to the point where the camera measures the distance to the motive and the light level but before the picture is taken. Another example is the trigger on a gun where the force needed to pull it increases sharply at the precise point before the hammer is released and the shot fired. In these cases the tactile feedback indicates the point just before the activation of the function.

10.5 TURNING OF KNOBS, ADJUSTMENT OF SETTINGS AND HANDWRITING

This subchapter describes how the turning of a knob, the adjustment of a setting, pointing with a mouse or handwriting can be performed during inattentive use. These types of movements all require precise movements and a fast and reliable feedback on the performed movements.

Relative size of each part of the movement

Rosenbaum [1991: 243] describes how the relative distances traversed through each part of the handwriting are the same, no matter if we write in a small notebook or write large size letters on a blackboard, and he reports on a number of experiments showing that we actually use the relative time spend on each part of the action for determining the relative distance we have moved during it: We do not look and see how long a line we have made, and we do not use any proprioceptive feedback indicating the traversed distance, we stop drawing the line when we perceive we have been drawing it for an appropriate period of time.

This implies, that it is possible to do a precise movement over a short distance without any visual feedback. Actually, during normal handwriting each separate stroke is done so fast that visual guidance is impossible. The relative size of each movement can therefore only be determined by the relative time it takes to make it.

Tactile feedback

When the length of a movements is determined by the time it takes to make it, precise movements are only possible with a perceptible and stable tactile feedback. That causes problems when using handwritten inputs to a piece of electronic equipment and when adjusting the setting of a knob.

The surface of the pad used for inputs to a piece of electronic equipment is normally hard and smooth, so the friction between the pen and the pad is small and easily subject to variations because of dust or minor differences in the angle of the pen—the pen is slipping.

A similar problem may be encountered when turning a knob: The bearing of the knob gives very little friction so a very small additional force may result in a substantial change in the setting.

Finally, in order to move a pen or a knob with precision we must have a good grip on it, and such a good grip requires substantial force on a smooth surface, in particular with sweaty palms. Normally, it is therefore an advantage if the surface to be gripped is rough, even though the surface in extreme cases can be too rough. Johanson and Westling [1990: 707] report that it is difficult to release a grip on a very rough surface:

> The effort required to overcome this magnet phenomenon was especially pronounced with sandpaper as the surface structure, and became stronger the closer the grip was to the minimum grip force required to prevent slip.

However, it is likely that their results apply only to the case where the surface has sharp edges that cut slightly into the surface of the skin—whereas for instance a rough and porous rubber surface does not pose any problems.

Visual feedback

Smyth and Silver [1987: 48, 55, 57] found that persons handwriting without any visual feedback made a larger amount of errors: They omitted parts of letters, repeated some strokes or made other errors involving parts of the letters. These errors are very similar to the *slips* during an automatic process that are described in subchapter **9.5 Choosing an action**. Their results confirm therefore that the movements during handwriting are part of an automatic process.

Smyth and Silver [1987: 50, 54] found also that the visual feedback was essential for keeping each line of the handwriting horizontal. Without visual guidance the lines of handwriting tended to move upwards or downwards or even wave up and down.

These results indicate that it is impossible to keep the hand and fingers in precisely the same position without any visual feedback. In order to confirm that, I made a simple experiment [own observation]: I tried 3 times to hold my finger for 30 s over a small cross drawn on a piece of paper. In all 3 cases my finger drifted between 15 and 20 mm during the period. I will conclude, that it is impossible to hold the hand and fingers in precisely the same position without any visual or tactile feedback indicating when a movement is occurring.

Audio feedback

In some cases a setting is adjusted using audio feedback, for instance the sound volume or frequency of a receiver.

The adjustment of a setting with audio feedback will often be slower and probably more difficult than the adjustment of a setting with visual feedback, cause the sound often varies over time so the user must listen over a period of time in order to ascertain whether or not the proper setting has been found.

My experience shows that most users tend to look on the knob they are adjusting or on some visual indicator, even if the audio feedback is sufficient for making the adjustment.

Requirements for elements for setting adjustments or for handwriting on electronic equipment

The turning of knobs, adjustment of settings or handwriting can often be difficult during inattentive use. The user must do some small and precise movements; as described in subchapter **10.3 The structure of physical actions** they are therefore easily affected by emotions, and they may be difficult to perform without any firm support for the equipment and the hand used for the movements.

These problems may aggravate the general problems of using handwriting as an input for electronic equipment. The error rate for equipment that performs OCR—Optical Character Recognition—on handwriting is much higher than the error rates for typed in characters. I have tried Apple's Newton using OCR of handwriting, and even [own observation] in the best case approx. 20 % of the written words were misinterpreted by the equipment. This means that the user must control each part of the entered data and often interrupt the ongoing activity and make a correction. Handwriting can therefore only be used for data entry during inattentive use if the writing is limited to markings in boxes, or if the writing is stored as an image for later retrieval: With the present technology it is for instance not possible to enter—as normal handwriting—commands that must be entered fast with a low error rate.

During handwriting the user controls the relative size of each stroke by controlling the time spend writing it. That is only possible when each stroke can be drawn with a constant speed, and—because the force applied by the writer cannot be varied momentarily—a stable and perceptible tactile feedback or resistance against the movement is therefore necessary. Such a feedback or resistance is difficult to provide on pen-based electronic equipment: If the writing is done on a resilient surface, the surface will quickly degrade during use; if the writing is done on a hard surface, the tactile feedback will be small and unstable, and it is then impossible to write with normal speed and legibility.

The same limitation can probably be experienced during other precise movements: Without a stable and suitable friction—providing a stable and perceptible tactile feedback—the movement must be significantly slower, so that it can be guided by visual or in some cases audio feedback. Tactile feedback can be provided in several manners: Knobs to be turned can be equipped with perceptible clicks, the adjustment can be done with keys for stepping up or down on a scale, or a knob can be equipped with some sort of *brake* giving a small but stable resistance when it is turned.

Surfaces on knobs and other actuators should be neither smooth nor too rough. If they are smooth, the fingers may slip; if they are very rough—similar to sandpaper—the fingers of the user may stick to the knob or actuator and cause an unintended movement of the knob or actuator when the user releases his grip on it.

Without any visual guidance the user can do small precise movements with the same size relative to each other—whereas he needs either a visual or a tactile feedback in order to maintain the same absolute position of the finger or the element he manipulates. In addition, it is impossible for the user to remember a specific setting during inattentive use. It is therefore advantageous if all settings of a turn knob or handle either provides an immediate tactile feedback indicating the position, or if they can be done from a fixed or uniform starting position, for instance by making it necessary to move a handle back to zero in order to unlock it before it can be set to a new setting.

Audio feedback on movements are more slowly than both visual and tactile feedback. Visual or tactile feedback should therefore always be available as an alternative to audio feedback.

During inattentive use the user cannot write or adjust settings with the same precision as when he is paying attention. If the equipment demands very precise movements, the user will either make errors or focus his attention on the equipment for a prolonged period of time. The equipment for inattentive use should therefore be designed with some margin: If the user for instance should point at a bar or a field, the bar or field should be made with some width and not just as a point or a thin line that must be hit exactly before any action can be done.

10.6 SPEAKING

I have heard users of a piece of electronic equipment exclaim that if they only could tell the equipment what it should do, everything would be much easier.

It is significantly faster to speak than to touch type the same words, and it is often faster to speak one word than to press a key. In addition, speaking is one of the most automatic processes: We can even *think aloud* while being only dimly aware of it, and my own experience indicates that it is perfectly possible to speak in consistent sentences without thinking about their content.

Unfortunately, verbal inputs are not a feasible solution for equipment for inattentive use. Mayhew [1992: 405] describes two practical problems:

- There is no easy way to erase and correct a voice input: It is not possible to provide a simple UNDO key.
- Other persons may be disturbed if the user of a piece of electronic equipment is speaking out loud while operating it.

In addition, there are two other problems when the equipment is used by a user who does not pay attention:

- The voice of the user may change if the user is under stress or pressure. Such a change will degrade the performance of the voice recognition.
- The error rates for voice recognition equipment in situations resembling actual use as reported by Mayhew [1992: 406] are between 5 and 30 %. With such error rates the user must pay attention to the equipment; if the user does not pay continuous attention, some of the errors will not be corrected.

Even though equipment with voice recognition is not feasible for inattentive use, there are instances where voice operated equipment is advantageous. One example is communication equipment for voice transmission. When using such equipment it is easier for the user if the equipment starts transmitting when he starts speaking, than if he must press a key to start the transmission. However, when such equipment is intended for use without the user paying attention to it, it should either have a buffer or a very short start up time—less than 100 ms; during inattentive use the user will expect that everything he says is transmitted, and a clipped off first syllable can be crucial for the meaning of the message.

10.7 TRAINING AND PHYSICAL ACTIONS

Subchapter **7.7 The level of training in relation to inattentive use** described in general how an automatic process was trained. This subchapter describes some aspects that are specific for the training of physical actions.

We can only select and carry out a specific movement if we can conceive of it. This means that the learning of a new movement, so that we can do it without paying attention to each part of it, always involves both thinking and the training of the specific movement. It is in particular likely that thinking about the movement and any words or terms that can be used to differentiate between different types of movements will ease the learning of the movements.

Rosenbaum [1991: 148-150] reports on a number of experiments showing that the visual guidance of movements and movement in general only are developed by doing the actual movements. They are not developed simply from watching the movements or the visual feedback to be experienced during the movements. In other words: It is only possible to learn a specific set of movements by doing them a sufficient number of times.

In addition, it is not possible to unlearn wrong movements. The movements should therefore be trained slowly until they can be done almost perfect and only then should the speed gradually be increased. It may cause problems if the training of the use of a piece of electronic equipment does not progress slowly and gradually—if the emphasis for instance is on the largest possible increase in speed of operation in the shortest possible time.

Hisao [1983: 392] describes some experiments indicating that persons who have learned a motoric skill using verbal mnemonics will use the left hemisphere of the brain more than persons that have learned the same skill without any mnemonics. The use of mnemonics during the training of a skill can therefore have adverse consequences: The physical action is learned faster, but—after it is learned—it may interfere more with the users thinking than if it had been learned without any mnemonics.

The same movement must be done in different manners depending on the specific circumstances: The posture and distance to a target varies slightly so the movement must each time be done in a slightly different manner in order to succeed. This also means that only the most general parts of a movement can be put down in a description; the successful training of any set of physical movements is only possible with corrections from a *coach* or at least with some attention on the feedback from each time the movement has been tried.

I will finally note that the wrong training of physical actions can lead to work related injuries. The user may start operating the equipment in a manner that is perfectly safe and sound when the equipment is operated slowly and for short periods at a time, but precisely the same manner of operation may prove detrimental when the equipment is operated at high speed for prolonged periods of time. It is therefore essential that the user not only trains the physical actions *necessary* for operating the equipment, but also learns the *proper* physical actions to use when operating the equipment.

> For years I have been familiar, during the act of gaping, with a large, round, smooth sensation in the region of the throat, a sensation characteristic of gaping and nothing else, but which, although I had often wondered about it, never suggested to my mind the motion of anything. The reader probably knows from his own experience exactly what feeling I mean. It was not till one of my students told me, that I learned its objective cause. If we look into the mirror while gaping, we see that at the moment we have this feeling the hanging palate *rises* by the contraction of its intrinsic muscles. The contraction of these muscles and the compression of the palatine mucous membrane are what occasion the feeling; and I was at first astonished that, coming from so small an organ, it could appear so voluminous. Now the curious point is this—that no sooner had I learned by the eye its objective space-significance, than I found myself enabled mentally to *feel* it as a movement upwards of a body in the situation of the uvula.
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> William James [1890: 835] [W.J. italizing]