11. THE ENVIRONMENT AND THE WORK PROCESS

This chapter describes briefly the relation between the users perception of the environment and the actions he does in it, and his perception of the equipment and his operation of it.

As described in subchapter **7.6 Different types of inattentive use** it is not possible to pay attention to two things at the same time. I will therefore define parallel activities as activities where one activity is undertaken before the other one is completed; one or both of the activities may be done as an automatic process or the attention may shift back and forth between the activities.

The parallel activities are influenced by two factors beyond what is described in subchapter **7.6 Different types of inattentive use**:

- One activity can interfere with another. Even if one of the activities are done as an automatic process it can interfere with the other, increase the error rate or slow down the other process.
- The user tries to cope with the situation when he must do two parallel activities. He may try to postpone one of the activities or he may try to adapt the situation of use so the interference between the two tasks are minimised.

It is inevitable that two activities will interfere when they are done by the same person, but the person will normally try to cope with the situation and get the—for him—best possible result.

11.1 THE NEED OF PARALLEL ACTIVITIES

There are three possible reasons for operating electronic equipment intermittently or in parallel with other activities:

- Both the operation of the equipment and the other activities are urgent; neither the operation of the equipment nor the other activities can be postponed. That may be the case if the user must observe what is going on in the environment while he is operating the equipment, or if he must answer a call while driving a car.
- The operation of the electronic equipment and the activities done on the environment are interdependent; one of them needs information from the other. That may be the case, if the user is entering the information he receives from another person, or if the user shall read a dispatch message in order to find out where his next destination is.
- The user may start doing two activities in parallel out of sheer boredom; he is waiting for some result to happen or he is bored by the activity he currently is carrying out, and he will then start to think about something else or to do something else. That may be the case, if the user must wait for a prolonged period of time without anything happening, if the operation of the equipment happens in a state with reduced conception as described in subchapter **7.6 Different types of inattentive use**, or if an activity—as for

instance touch typing from a concept—becomes an automatic process.

In the first two cases, the user is forced by external circumstances to do two or more activities in parallel; in the third case the reason is internal, the user undertakes a parallel activity in order to satisfy an inner urge.

11.2 ONE ACTIVITY INTERFERING WITH ANOTHER

This subchapter describes the manners in which one activity may interfere with another.

Two activities may interfere because:

- Their need of perceptions—information about the state of the activities in progress—interferes.
- The actions required for each of them interferes.
- The mental activity required for each of them interferes.

Conflicts between stimuli from the equipment and the environment

In general, stimuli from the equipment are much more limited than stimuli from the environment.

Most electronic equipment consists of an oblong box with a display and some keys to push. In comparison, the user may use the electronic equipment in many different environments: At home, in the office, in the open air, in an environment with distractions or in an environment he feels is threatening, and the user may during the use be alone or together with other persons.

The user can perceive a small field of visual information from the equipment. He may in addition hear some sounds from the equipment, they are in general of a short duration and the user can sometimes adjust them or turn them down or off. If the user is touching the equipment he will feel its surface, texture, a tactile feedback when he exerts some force and occasionally some vibrations.

The user can and often must perceive visual information from a wide field in the environment, and he may hear sounds that continues for prolonged periods of time and quite often cannot be stopped or turned down. Other persons may speak to the user, he must reply without too much delay, and the user may, finally, perceive smells, vibrations or tactile stimuli from the environment.

This means that the users stimuli from the equipment are limited and often can be controlled, whereas the perception from the environment often appear to be unlimited and cannot be controlled.

The stimuli from the equipment and from the environment can block or disturb each other: It is impossible for the user to perceive visual stimuli clearly from the equipment *and* the environment, and it is sometimes impossible for the user to differentiate between sounds from the equipment and from the environment, in particular if the sounds are in the form of tones rather than speech. In contrast, it is very seldom that tactile stimuli conflicts: As described in subchapter **8.5 Sensations drawing the attention** it is very easy to localise their source.

Conflicts between physical actions carried out on the equipment and in the environment

I am using the terms *on* the equipment, and *in* the environment to classify the physical actions the user is doing: He may do something *on* the equipment, but everything he does is *in* the environment.

Even though the user normally uses his fingers and his arm when operating the equipment, the physical actions he does on the equipment quite often involves a movement of his whole body, in particular if a movement requires some strength or must be very precise. The user may for instance tense his whole body when he shall make a precise adjustment of a knob.

The user must, in addition, use his hands and arms for manipulating the environment or moving himself around—he may for instance move or carry things or walk around.

Some of these movements will interfere with his operation of the equipment.

My own experience indicate that it normally is difficult to combine different and unrelated physical actions. The user of a piece of electronic equipment may in some cases hold the equipment between his arm and his body or press a key with his elbow, but because the details of each movement are automatic and because many movements influences most of the body, the user must normally postpone one physical action until another one is completed.

In contrast, normal physical actions and the movement of the attention interfere only to a limited extent. Pashler [1991: 1038] found that saccades—movements of the eyes during reading—were possible without the normal refractory period between the saccade and another physical action. However, Pashler et al. [1993: 57, 78] made an experiment showing that the saccades in some cases were slowed down by another physical action. In other words: A physical action can interfere with the movement of the visual attention, but the interference is much weaker than normally between physical actions.

Conflicts related to the mental processes of the user

Even if the user can sense both the equipment and the environment and carry out the necessary actions without any conflict, there may still be an interference between the actions he shall carry out in parallel.

Greenwald and Shulman [1973: 71, 75] found that the interference between the tasks depended very much on the type of the task: Tasks that were, what they called, "ideomotor compatible" did not interfere with each other. If for instance the perception of <- should result in a movement to the left or the perception of *A* should result in the user saying *A*, the impulses and responses were ideomotor compatible. If on the other hand the perception of *Left* should result in a movement to the left or if the perception of *A* should result in the user saying *One* the impulses and responses were ideomotor incompatible. In other words: If the user directly can see the direction of a physical movement or directly see or hear the verbal information he shall reproduce, the selection of the proper task will not interfere with another task.

Incidentally, Greenwald and Shulman [1973: 71] did not investigate whether the participants in their experiment could carry out two simultaneous tasks: They determined the interference between the tasks by measuring the time from the completion of one task before the other one could be started, what they (Greenwald and Shulman) [1973: 70] called the "refractory period".

Wickens [1984:83]] reports in addition that tasks of the same modality—two tasks that are both either visual or verbal—will interfere, and that a task that involves visual or spatial perception will interfere with another task that requires a spatial—as opposed to a verbal—response.

Interference between attentive actions and automatic processes

There is occasional interference between attentive actions and automatic processes, such that the automatic process for instance stops while the attentive action is done.

If both the attentive action and the automatic process need visual guidance or both the attentive action and the automatic process involve movements of the hands, only one of the actions can progress at a time—either the attentive action or the automatic process must wait.

In Subchapter **7.6 Different types of inattentive use** it is described how Shiffrin and Schneider [1977: 160] found that automatic processes could be done in parallel, with none or very little interference. However, their results were based on very simple processes, and the experiments on automatic processes reported by Kahneman and Treisman [1984: 33-37] indicate that automatic processes can interfere with each other in a manner similar to the manner in which attentive actions interfere.

An action that is part of an automatic process can therefore interfere with attentive actions or with actions that are part of another automatic process:

- If both actions both depend on visual or verbal perceptions.

- If the physical actions necessary for one action interferes with the physical actions needed for another.
- If the actions are ideomotor incompatible, for instance if both involves the handling of verbal or spatial objects.

Electronic equipment where the consequences of interference is reduced

When the user tries to combine conflicting physical actions, he will often overestimate his own capabilities. For that reason, the equipment should be made such that it can withstand small impacts or that the user drops it. In addition, the equipment can be made with some suitable carrying strap or clip for carrying it.

It is also advantageous if the user at least part of the time can operate the equipment without any visual guidance.

The description of ideomotor incompatibility means that it in general is better to show than to tell: If a movement shall be done in a specific direction, it should be shown; if something shall be typed on a keyboard, it should be spelled out.

The user will use words or even think out loud when planning the task he is carrying out. It should therefore be possible for the user to experience an automatic process visually *or* spatially, so that its interference with the attentive thoughts of the user is minimised.

In addition it should be possible for the user to think about the proper response either directly in movements or in words, so he can choose the modality that interferes the least with another ongoing activity:

- If the user during the task shall observe some movements it should be easy for him to describe his action in words, for instance by using the texts on keys and a display as objects of his thought.
- If the user during the task shall communicate verbally with other persons, it should be easy for him to describe his actions in a spatial manner, for instance as the pointing on specific buttons or symbols on a screen.

The user must often perceive verbal messages or other sounds from the environment, and—as described in subchapter **8.4 Perception, shifting attention and automatic processes**—he can only perceive them in the moment they occur: It is therefore advantageous if audio signals from the equipment are used only sparingly.

11.3 COPING WITH TWO PARALLEL ACTIVITIES

When the perception, thinking and actions of the user is described, he may appear as half a victim and half a clown: He must within his limitations try to operate the equipment with almost no choice as to the manner of operating it, and he will make mistakes we may find it hard to believe any human being can do by accident.

In reality, most users are pretty smart: They try one way or another to cope with the equipment and the task they are carrying out.

It is likely, for instance from the description given by Dixon [1976: 27-31] that the user in particular will try to prevent that the stream of thought becomes a bottleneck while a task is carried out.

I have seen that the following methods of coping with two parallel activities are used [own observations]:

- *Substituting* automatic processes for attentive actions and thereby freeing the attention. My own experiences during word processing seem to indicate, that up to 5 or 6 separate steps that can be done as part of an automatic process are preferable as compared to one action that demands the attention.
- *Move the attention consciously* between the equipment and the environment. If something demands the attention, it will be observed at a moment when the work process already is interrupted; it is then less likely that a single action will be interrupted by a sudden sensation that draws the attention.
- *Try to exclude perceptions*, for instance by closing the eyes while listening or by holding a hand for one ear.
- Try to operate the equipment without any visual feedback
- *Place the equipment in the line of sight* or beneath something that the user wants to *keep an eye on* in the environment.
- *Try to postpone actions*, instead of attempting to do two actions at once
- *Try to plan actions* ahead or to anticipate problems.

The user may finally disregard one of the activities and any perceptions coming from things associated with it. Whereas the other ways of coping can be rational in different situations, total disregard of one of the activities is the users last almost instinctual way of protecting his stream of thought against an overwhelming situation.

Finally, it is my personal impression that inattentive use becomes easier when the user feels he has a choice; even if he operates the equipment in the normal manner, he perceives the operation as easier when he believes that he can adapt the equipment to his own liking. This also means, that *if the user feels he has a choice it is less likely that he totally will disregard one of the activities in a situation where such a disregard can have adverse consequences.*

Consequences for the design of electronic equipment

It should be easy for the user to adapt the equipment so he minimises any conflicts between the activities he is doing in parallel. The equipment should therefore be easy to move and position and it should be easy to adjust the lightning and sound levels.

The user can cope with the equipment only if the functions of the equipment in one way or another are apparent and easy to evaluate. It should be possible for the user to find the best way for to operate the equipment and the operation of the equipment should be consistent over time: If it is inconsistent, the best way of operating the equipment may vary from one moment to another.

It is finally necessary to provide a user friendly labelling and user guide for the equipment, the user guide should be structured after the situations of use experienced and known by the user, and it should be easy for the user to find the function he is looking for, even though he does not know the name of it.

Such a labelling and user guide is sometimes seen as a panacea that solves all problems, in reality it is of very limited use if the other requirements are not fulfilled.

11.4 TRAINING AND PARALLEL ACTIVITIES

The training necessary for doing several parallel activities in a maybe distracting or hostile environment consists of three parts:

- Familiarisation with the environment and the tasks to be done in it. Without such a training, it is almost impossible for the user to take on an additional activity while being in the environment.
- Training in the automatic processes that are necessary for operating the equipment. As described in subchapter **7.7 The level of training in relation to inattentive use**, it is only possible to do part of the operation as an automatic process if it already has been trained.
- Learning to cope with the equipment in the environment, including how to adapt the equipment to the particular needs, how to solve any problems that may occur, and finally the training of sound habits for use of the equipment.

Training of the operation of electronic equipment for inattentive use should therefore be done in situations similar to the ones where the user shall operate the equipment. The operation of the equipment cannot be trained as a separate and isolated activity.

> Habit is thus the enormous fly-wheel of society, its most precious conservative agent. It alone is what keeps all within the bounds of ordinance, and saves the children of fortune from the envious uprisings of the poor. It alone prevents the hardest and most repulsive walks of life from being deserted by those brought up to tread therein. It keeps the fisher-man and the deck-hand at sea through the winter; it holds the miner in his darkness, and nails the countryman to his log-cabin and his lonely farm through all the months of snow; it protects us from invasion of the natives of the desert and the frozen zone. It dooms us all to fight out the battle of life upon the lines of our nurture or our early choice, and to make the best of a pursuit that disagrees, because there is no other for which we are fitted, and it is too late to begin again.
>
> William James [1890: 125]

12. UNRELIABLE USE OF COMMUNICATION EQUIPMENT

This chapter describes how communication equipment is used and why it is essential that it is easier to operate than most equipment for information processing.

Communication equipment is defined as equipment that:

- Makes it possible for the user to perceive some information or some expressions made by another person over a distance where his normal senses are insufficient. That information or collage of expressions will in the following be called a *message*.
- Makes it possible for the user to transmit a suitable message to one or more selected receivers—the message may consist of information entered into the equipment or sound or pictures that are picked up by a microphone or camera.

The definition covers the types of communication equipment in normal use, for instance telephones, two-way radio equipment or computers with facilities for E-mail, electronic mail.

The communication equipment may consist of a single terminal close to the transmitting user and another terminal close to the receiving user and of no other units. One example is the type of two-way radio equipment where one radio transmits directly to another. In other cases the communication equipment consists of a larger number of units connected with cables or through relay stations. The definition of communication equipment includes also paging systems: They can be considered parts of a phone system that is used for transmitting a message to the person who has called the pager.

However, the user does not see the true extent of the total communication system, he sees only the terminal or terminals close to him that he uses for transmitting and receiving messages.

The terminals used for communication may be operated in a number of different manners: The user may speak into a microphone, make gestures in front of a camera, enter characters on a keyboard, draw with a pen that picks up the movements of the hand or make a drawing on a piece of paper that is inserted into a scanner.

The definition of communication equipment includes therefore equipment that transmits or receives a file the user already has stored in the computer or a fax machine that receives or transmits the signal resulting from the scanning of a drawing.

The definition excludes, however, three types of electronic equipment:

- Equipment for the transmission of signals from one piece of electronic equipment to another, for instance from a sensor to a recording device.
- Equipment for *information processing*—generation of files with certain information, where the users perception of that information is not the final purpose of the activity but only necessary for managing the proper processing of it. A computer used for word processing is an example of that.
- Equipment for transmitting a message to a mass audience where the equipment cannot be used for returning a reply to a received message, for instance television and other electronic equipment used for entertainment.

Normally, communication equipment includes some facilities for automatic transmission and reception of information, for instance signalling used for controlling the transfer of messages from the transmitting part of the equipment to the receiving part of the equipment.

In some cases the same terminals can be used for both communication and information processing: A computer used for information processing may for instance be equipped with a modem and suitable software for E-mail.

However, a number of characteristics of communication equipment are always the same; they are described in the following.

12.1 BEING UNAWARE OF INCOMING INFORMATION

Information processing equipment will normally present the same information for a comparatively long period of time, and the user can therefore look for a specific piece of information when he needs it.

In comparison, the information presented by a piece of communication equipment changes every time a new message arrives.

The communication equipment should therefore draw the attention of the user when a new message arrives, and the communication equipment should then present some information, so that the user can decide whether or not the incoming message is relevant for him in the specific situation. That may for instance be done by presenting the name of the person who has send the message.

12.2 THE RISK AND CONSEQUENCES OF MISDIRECTED MESSAGES

The user of a piece of communication equipment can send a message either to another user or in some cases to a previously defined group of users.

However, the user can also *inadvertently* send a message to someone the message was not intended for.

When that happens, it has two consequences:

- The intended receivers of the message will not receive it.
- The message is received and possibly perceived by someone it was not intended for.

The first consequence can sometimes be remedied: The message can be resent, and in most cases the delay will not be crucial.

However, it is in general not possible to remedy the second consequence: When a message is perceived by someone it was not intended for, it cannot in any possible way be *unperceived*. In other words, it is impossible to *Undo* the error.

Communication equipment is therefore crucially different from equipment for information processing. Unless a file is totally deleted by accident, it is normally possible to correct any error made when operating equipment for information processing: If the error cannot be corrected by using a single *undo command,* it may be possible to correct the error by entering a number of commands or by careful manual corrections to the information being processed.

Causes of a misdirected message

A message can be send to a receiver it was not intended for when:

- The user selects the wrong remote terminal—when entering a phone number the user may for instance enter the digit *3* instead of *4*.
- An error occurs in the communication equipment: A mechanical problem in a key on the telephone may for instance result in a digit being send twice, even though the user only pressed the key once.
- The communication system redirects the message to another remote terminal than the one selected by the user. That is for instance the case when a telephone system includes *automatic call transfer*, where calls to a given phone temporarily are redirected to another phone.

User errors seem to be by far more common than errors in the communication equipment.

I asked 10 persons of different age and sex to note down, during a period of one week, when they made an error when entering a phone number. The participants registered a total of 181 phone number to be called, and they reported a total of 6 errors during the calls, equalling an error rate of 3.3 %.

However, the error rate may in some cases be higher than the 3.3 % found in the experiment. It is in particular possible that persons making many phone calls, or persons entering a phone number as part of an automatic process have a higher error rate than indicated by the experiment:

- The results indicate a relation between the number of phone calls a participant has made and his error rate when making them: The more phone calls, the higher error rate, with correlation = 0.75.
- As described in subchapter **6.1 The need of a theoretical basis**, I often call two phone numbers where the first two digits are identical. When I think about one of them and starts to enter it, it happens fairly often that I end up entering the last digits of the other number. That type of error is similar to the *test failures* that may occur during an automatic process, as described in subchapter **9.5 Choosing an action**. However, even though I specifically asked for such errors to be registered, no errors of that type was reported by the participants in the experiment.

When I had received the notes from the other participants, I registered my own phone calls over a one week period. I registered a total of 22 calls, and made 4 errors of which one were of a type that is typical for an automatic process. The result was an error rate of 18%. This means, that the participants in the experiment either underreported the number of errors they made, or that the error rate may vary significantly from one user to another.

Telecommunication authorities and other companies responsible for communication equipment show a natural reluctance when asked about cases when a message has reached the wrong receiver. However, it happens.

Fraase [1993: 52] reports a case where a letter sent as E-mail to a friend by accident was send to every user connected to the system, and he advises users of electronic mail: "Don't send anything via E-mail that you wouldn't want to read in your hometown newspaper."

In addition, my own experience seems to indicate that cross talk between two telephone lines can be fairly common: It is likely that 1 out of every 1000 phone conversations by accident may be overheard by other users.

Finally, the communication equipment may redirect the message to another remote terminal than the one the user tried to send the message to. Phone systems include very often *automatic call transfer*—a *follow me* function or a function that switches a call on to another phone, if the first phone has not been answered within a given period of time. However, such functions are in general not used for faxes or E-mail systems where the user does not expect an immediate reply.

Misdirected written messages

According to my information, nobody has investigated the reactions of the typical user to any misdirected messages. My own experience is [own observation] that even if a letter contains no confidential or incriminating information, the situation is always awkward and annoying.

In addition, I have experienced that a measurable amount of paper-based communication is misdirected [own observation]:

- I have over the last 5 years probably send more than 1000 letters, and I have twice over that period mixed up addressed envelopes and letters so two letters each time were send to someone that were not supposed to receive them.
- I receive each year approx. 500 letters including junk mail describing me as an "influential decision maker". Of these 500 letters, perhaps 1 or 2 are addressed to someone else and delivered to me by accident. It is therefore likely that 1 or 2 letters addressed to me each year ends up in other persons mailboxes.

This indicates that approx. 0.4 % of all paper-based letters normally are misdirected.

Misdirected messages when using a telephone

The preceding figures indicate that the error rate when entering a phone number is 10 times or more higher than the risk of a paper-based written message reaching another receiver than the intended one.

In spite of that, most people are still comparatively satisfied with the use of telephones.

The reason is that the telephone makes it possible to check whether or not the intended receiver has been reached: It is then possible to discontinue the conversation after appropriate apologies but before any real harm has been done.

Even then, the message may sometimes reach the wrong receiver by accident:

- The calling user may start talking after having overheard the answer from the remote user.
- A third person may overhear part of the conversation because of cross-talk or interference between different phone lines.
- A third person may deliberately eavesdrop on the conversation through the use of special electronic equipment.

If the calling person is in a hurry and does not wait for a reply, an error may have adverse consequences:

> A person in my family had a phone number differing by only one digit from the phone number of the harbour office in the city where he lived. Persons trying to call the harbour office therefore often called him by accident, in particular very early in the morning. When the telephone rang one morning at 5 AM, and a voice without waiting for a reply asked if there was any work that day, the person receiving the call replied *no* and went back to bed.

My own experience indicate that crosstalk may happen once for every 1000 phone calls. That is significantly more than the risk of a message reaching a third party by other means, for instance by a document flying out of the window.

I have found no reports on the likelihood of anyone deliberately eavesdropping on phone conversations.

The consequences of a third person overhearing the conversation can be serious, the users cannot ascertain whether or not a third person listens to the conversation, and my own experience [own observation] indicates that even very security conscious persons discussing highly delicate matters over a phone line often during their conversation stop being aware that a third person may listen to their conversation. It seems that when no third person is apparent, the user habitually tend to feel that the conversation is private.

The risk of any message transmitted over the phone system reaching a third person should therefore be minimised: It should not be higher than the risk of the message reaching a third person by other means.

Reducing the risk of misdirected messages

The equipment should always ask for an acknowledgement, before any message is transmitted to a selected receiver; a telephone system offers that facility in a natural manner: The calling user can hear the reply when someone picks up the phone and replies. However, a separate acknowledgement function is essential for calls to pagers, and for the transmission of E-mail and fax messages.

It is easier to discriminate immediately between names than between numbers, because names are more visually different: They consist of different numbers of words with different lengths and different distributions of letters of different sizes. The request for acknowledgement should therefore ideally present not only the dialled number but the name of the receiver, and because the message may be misdirected by the communication equipment the name of the receiver presented in the request for acknowledgement should be transmitted from the receiving piece of communication equipment, or at least generated from a number returned from the called terminal.

Such a facility is not available in most of the communication equipment used today. Even most fax machines, receiving an acknowledgement from the

remote fax machine, shows only the phone number used by the receiving fax machine—the name of the receiver is not shown.

The communication equipment should in addition reduce the risk of any third person picking up a transmitted message. It should:

- Use digital transmission methods where the risk of crosstalk or eavesdropping even without any sort of encryption is sufficiently reduced.
- Limit the access to equipment in the communication system and to messages being transmitted. In particular when the message passes through several private service providers these precautions are essential for ensuring the privacy

12.3 THE LOW RELIABILITY OF COMMUNICATION SYSTEMS

A message transmitted through communication equipment will—before it reaches the receiver—normally travel some distance and perhaps pass different units that amplify, convert and retransmit it.

It is therefore common that the transmission of the message is interrupted or delayed, and it will normally be impossible for the user to predict the time it takes for a message to pass from the transmitter to the receiver.

Telecom Denmark [1994] describes an area as covered by the cellular GSM system, even though it is impossible to make calls from as much as 25 % of that area, and the (Danish) National Telecom Agency [1995: 37] reports that 1.1 % of the attempted test calls made in the fixed phone system in Denmark in 1994 were unsuccessful. Incidentally, these figures are pretty good: I have been told that in other parts of the world more than 20 % of the attempted calls are unsuccessful.

In comparison, information processing equipment tend to be much more reliable: if, for instance, the entering of the command for opening a file does not give the expected result 25 % or even just 1.1 % of the times it is attempted, most users will consider the equipment extremely unreliable.

It is to some extent possible to compensate for unreliable communication channels. However, in order to carry out a compensating action the user must be aware of the state of the communication equipment.

The equipment should therefore continuously indicate the state of the connections used for transmitting and receiving messages, so that the user can adapt his actions to the limitations of the equipment.

12.4 INTERMITTENT USE OF COMMUNICATION EQUIPMENT

The transmission of a message from one person to another is normally done with some purpose in mind, and that purpose is often related to some other activity that the person is doing at the same moment.

A user must therefore often move his attention away from the other activity for a moment while transmitting a message to another person. It is possible that he continues the other activity as an automatic process, or it is possible that he initiates the transmission of the message as an automatic process. When communication equipment is used outside an office environment, the user is often forced to do one of the two, because he must remain continuously aware of his environment.

One example is a person making a call on a cellular phone while walking down the street. He has just experienced something, makes an association to a phone call and decides to make it. He may interrupt his walking and stand still while making the call, or he may continue walking as an automatic process; if he often has called the particular phone number, he may even make the call as part of an automatic process while thinking about the view of the street. However, it will be awkward or even dangerous if he is not aware of what is happening on the street while he is making the call.

The user receiving the call is in a similar situation. It is likely that he is involved in some other activity when the equipment draws his attention because of an incoming call, and he must then interrupt the other activity and react to the call while he continues to be aware of his environment.

In some cases the user may feel it is necessary immediately to consider the message and compose a suitable reply, in other cases he will acknowledge that the message has arrived as part of an automatic process.

Depending on the circumstances the called person may move his attention away from the activity he currently is doing, or he may reply *I am busy* as part of an automatic process.

The user will therefore often shift his attention between the equipment and other things and he will often operate the equipment as part of an automatic process.

By contrast, it is normally possible for users of information processing equipment to operate the equipment without interruptions for a period of time, and if the user is interrupted he can decide to stop the information processing totally while taking care of the interruption.

The user of information processing equipment can therefore normally pay attention to the equipment throughout the time he operates it, while the user of communication equipment often must focus his attention on something else at least part of the time he is using the equipment.

12.5 LOW LEVEL LEARNING OF THE USE OF COMMUNICATION EQUIPMENT

Communication equipment is in general much simpler to operate than information processing equipment: A cellular phone for the GSM system, which probably is the most complex single piece of communication equipment, offers approx. 50 different functions, whereas a modern word processing program offers more than 500 different functions.

This means, that it in general is easier to learn to use communication equipment than information processing equipment.

However, most users expect to be capable of using communication equipment with virtually no training and no instruction.

I have seen [own observation] that most users of communication equipment only spend time learning to use an absolute minimal amount of functions, whereas users of information processing equipment often spend hours learning to perform actions with very little useful value, for instance functions that easier could be done manually.

It is likely that the differences between learning to use communication and information processing equipment are caused by different attitudes towards the two types of equipment: Most persons have already used an ordinary telephone, they compare therefore the operation of other communication equipment with the operation of an ordinary phone and will spend only a minimal amount of time learning how to use it; they have at the same time been told that the operation of computers and other information processing equipment is a difficult skill, and that the learning of that skill is a slow but worthwhile activity, and they will therefore spend the necessary time learning it.

Even though a user often is forced to use communication equipment while being inattentive, he will not spend any large amount of time learning how to use it. The communication equipment should therefore be designed so it feels intuitively right: *When a user without any training does a particular operation, it should give the result he expects.*

12.6 INATTENTIVE USE OF COMMUNICATION EQUIPMENT

Communication equipment is often used intermittently with other activities or while the user focuses his attention on something else, and most users will spend only a minimal amount of time on learning how to use it.

At the same time, inattentive use of communication equipment poses more problems than inattentive use of information processing equipment:

- It is essential that the users attention is drawn to the arrival of a new message.
- It must be ensured that all transmitted messages reach the intended receiver, since it in general is impossible to withdraw or *unsend* a message that has been send.
- Most communication equipment is much more unreliable than information processing equipment: The transmission of a message may be delayed or disrupted, and the attention of the user is drawn to any irregularities in the function of the communication equipment.

It is therefore imperative that communication equipment is well adapted to inattentive use, and that it in general is much easier to use than information processing equipment.

13. EVALUATION OF ELECTRONIC EQUIPMENT FOR INATTENTIVE USE

This chapter describes how to evaluate whether or not a given piece of electronic equipment is adapted to inattentive use.

The evaluation methods described in this chapter can be used when comparing the operation of different pieces of already produced electronic equipment, or they can be used during the design of new electronic equipment.

The evaluation methods are different from the ones described by for instance Hix and Hartson [1993: 6-9], who evaluates the inclusion of all necessary functions *and* the ease of use at the same time.

Such a one-step evaluation may cause problems:

- If the equipment cannot be used for the stated purpose, it makes little sense to spend time and money on evaluating how easy it is to use the equipment. It is therefore advantageous that the inclusion of all necessary functions is evaluated before the evaluation of the usability.
- If the inclusion of the necessary functions is evaluated at the same time as the usability, the usability will often be given a lower priority: The necessary functions may simply be ticked off without any discussion of their usability.

A two-step evaluation is therefore better: The first step consists of verifying that all necessary functions are included; the second step consists of evaluating whether the equipment can be operated by the users and in the situations it is intended for.

If the requirements have been described precisely before the start of the design it is easy during the development to determine whether or not all the necessary functions have been included. In most cases the functions can simply be ticked off on a list.

When it has been verified that all necessary functions are included in the equipment, the methods described in this chapter can be used for evaluating the ease of use of a given piece of equipment, in particular how well suited it is for inattentive use.

The methods are demonstrated through the evaluation of the usability of two pieces of communication equipment: *Pot1,* a combined phone and fax terminal and *GSM1,* a cellular phone for the European GSM system.

13.1 EVALUATION METHODS AND CRITERIAS

This subchapter describes how the adaptation of a piece of electronic equipment to inattentive use can be evaluated. Three different evaluation methods are described:

- *Reviews* where the designer and other persons analyse and discuss each part of the design.
- *Quantitative methods* where a number of indicators are counted.
- *Usability tests* where a number of users operate the equipment.

In most cases it is necessary to use all 3 methods:

- The reviews make it possible to give a more detailed description of specific problems in the design than the quantitative methods. It is, however, seldom possible to compare the results of different reviews.
- The quantitative methods make it possible to describe the occurrence of a number of frequent problems in the design, and it is possible to compare the user interfaces of two pieces of equipment that are used for the same purpose. However, the information about each problem will be very brief and the gravity of each specific problem is not described.
- The usability tests make it possible to observe the precise situations in which the user finds it difficult to operate the equipment, and it is possible to observe the cumulative effect of different problems in the design. The usability tests can, however, be expensive, and unless a large number of them are carried out, it is unlikely that they will identify all the problems that can be found through a review or quantitative methods.

In addition a usability classification of electronic equipment is proposed. Such a classification can in a standardised and very brief manner present the results of the review and the quantitative methods.

Reviews

The formal evaluation of the design of a piece of electronic equipment is normally called a review, whereas the evaluation of a computer program often is called a walkthrough. For instance Hix and Hartson [1993: 8] use the term "walkthrough".

I will in the following only use the term *review*.

The purpose of a review is to identify problems in the design of the user interface. Hix and Hartson [1993: 8-9] describe a number of investigations of the effectiveness of reviews, and conclude that they should be supplemented by usability tests because the results are not always reliable.

My personal experience indicates that if a review fails to identify the problems in the user interface, it may be because [own observations]:

- The review is made in a manner where potential problems are hidden rather than brought out: It is assumed that the designer should have the benefit of doubt, and even pertinent errors can be omitted from the report if the designer argues loudly or simply because the review should not be *all negative*.
- The reviewers do not know what they should look for. If the knowledge of the reviewers is on the level described in subchapter **6.2 Use of computer inspired models of the users mental processes**, their review cannot be based on any theoretical knowledge about the limitations of the users but only on their empirical knowledge about designs that has worked in the past; and if they in addition, as described in **1.2 The frustration of design**, do not get any reliable feedback from actual users, their comments during the review can only be based on guesswork about what good and bad design seem to be.

However, if the review is conducted in the proper manner, it is possible to solve these problems.

In a proper review the designer or manufacturer of the equipment should have the burden of proof: Any part of the design should be considered a potential problem unless the designer or manufacturer can offer satisfactory arguments for each decision made during the design of the user interface.

Before the review, the designer or manufacturer of the equipment should ideally make a description of the design stating the reasons for making each part of the design in the described manner. It is then easier to focus the review on the specific parts of the user interface where there might be problems.

The reviewers should, in addition, have a good general knowledge of the cognitive capabilities of persons in general and a detailed knowledge of the capabilities and limitations of the potential users of the equipment and of the tasks the equipment shall be used for carrying out. It is not sufficient that the reviewers are development managers or represent potential users of the equipment.

Quantitative methods

The quantitative methods make it possible to describe problems in the design of the equipment in a standardised manner. They are based on the requirements described in preceding parts of this project:

1. The equipment should present all elements in a manner where they can be perceived by the user and they should draw the attention of the user when and only when it is necessary. These requirements are described in more details in chapter **8. Perception during inattentive use**.
2. It should be possible for the user to select and initiate the proper actions without paying continuous attention to the equipment as

described in chapter **9. Associations, impulsive power and effort**.

3. It should be possible for the user with a minimum of attention to do all the physical actions that are necessary for operating the equipment as described in chapter **10. Physical actions**.
4. The interference between the operation of the equipment and the perception of messages or other activities should be as small as possible as described in chapter **11. The environment and the work process**.

A large part of the derived requirements can be described by counting the cases where the requirements are not fulfilled. The result is a number of problem points where *a higher value indicate more problems with the design.*

Problem points describing how the equipment presents itself to the user:

1.1 Ratio between the number of elements presented from right to left or from bottom to top and the total number of presented elements

1.2 Blurring, jagged edges or parallax of elements shown on a display or any distracting patterns on a display

1.3 Ratio between the number of elements higher or wider than 4 cm and the total number of presented elements

1.4 Ratio between 11 mm and the height of the presented text in mm

1.5 Ratio between 1 mm and the line width of the presented elements or icons in mm

1.6 Number of elements without textures or colours that distinguish them from the background

1.7 Number of elements whose meaning depend on the perception of combinations of two or more unrelated parameters, for instance the shape and colour of an element

1.8 Ratio between the number of elements whose meaning cannot be discriminated from the meaning of other elements after the reading of only a single word and the total number of elements presented in verbal form

1.9 Ratio between the number of icons the user cannot easily associate with one word describing their meaning and the total number of presented elements

1.10 Use of spoken messages

1.11 Number of states where the equipment does not draw the attention of the user when the user should pay attention to it

1.12 Number of states where the equipment draws the attention of the user when it is unnecessary for the user to pay attention to it

Problem points describing how the user must decide upon an action and initiate it:

2.1 Number of states
2.2 Ratio between the number of hidden states and the total number of states
2.3 Ratio between the number of states and the total number of connections between the states
2.4 Average distance between the states
2.5 Ratio between the number of invisible choices and the total number of choices
2.6 Ratio between elements with misleading labelling and the total number of elements
2.7 Total number of functions
2.8 Average number of separate actions needed for activating each function
2.9 Average number of actions that shall be done in order to complete a task
2.10 Average number of functions making use of each actuator
2.11 Ratio between the number of actions in each task that has to be done in a specific order and the total number of actions necessary for each task
2.12 Ratio between the number of choices that cannot be undone in one operation and the total number of choices
2.13 Number of choices that cannot be undone and where no request for acknowledgement is made
2.14 Ratio between the number of cases where the next action in a task is not clearly indicated and the total number of states

Problem points describing the physical actions the user must make when operating the equipment:

3.1 The number of sharp edges or protruding parts on the equipment
3.2 The number of situations where the user cannot change his position or must grip the equipment with a constant muscular force while using or carrying it
3.3 The number of actuators that can be activated by accident while the equipment is not used, for instance while it is carried
3.4 The ratio between the number of physical actions where continuous visual guidance is necessary and the total number of physical actions
3.5 The ratio between the number of physical actions where continuous visual guidance is impossible and the total number of physical actions
3.6 Number of actions that cannot easily be done with either the left or the right hand
3.7 Number of patterns of movements that interferes with previously learned patterns of movement, for instance patterns of movements for touch typing
3.8 The ratio between the number of physical actions where it is necessary to make precise curved movements or to move both hands or two fingers simultaneously and the total number of physical actions

3.9 The ratio between the number of consecutive physical actions blocking for each other, where part of the movements of one cannot be done simultaneously with part of the movement of another and the total number of physical actions
3.10 Number of knobs where the user can see the direction it shall be turned and where the turning angle is larger than 180° or where the user cannot see the direction it shall be turned and where the turning angle is larger than 90°
3.11 Number of knobs that are not resilient
3.12 The ratio between 18 mm and the average of height and width of the keys in mm
3.13 Number of keys without tactile feedback at the depression where they are activated
3.14 The ratio between 3 mm and the distance from the depth of depression in mm where the keys are activated to the lowest position of them
3.15 Number of keys without a resilient bottom
3.16 The ratio between the number of fine adjustments or data entry using handwriting and the total number of physical actions

Problem point describing the risk of interference between different actions :

4.1 The ratio between actions that cannot be described in both a verbal and a spatial manner and the total number of actions

The precise value of the quantitative measurements depends on the manner in which the analysis of the user interface is done. I will therefore recommend that the following guidelines are followed when making the quantitative evaluation:

- A slight blurring, slightly jagged edges or distracting patterns in the background should only be registered when the intensity of the disturbances is at least 20 % of the intensity of the elements on the screen or when the disturbances from the edge of the element protrude more than 20 % into the element.
- Two states of the equipment should be said to differ only when they are labelled differently in the display or when the same action gives different results in the two states.
- When counting the number of actions that are needed for activating a function, the most normal way of operating the function should be considered, and all methods of operating a function that cannot be seen by the user or found in the user guide should be disregarded. That includes the use of special commands or codes when a function can be operated in another manner.
- When counting the number of actions that are needed in order to complete a task, overly complex ways of completing the task should be disregarded.
- Knobs or keys should only be considered resilient if the user after reaching the surface of a knob or the point where a keys is activated can move his finger at least 2 mm more.

It is, of course, possible to make one quantitative evaluation covering all parts of the equipment. However, it is often advantageous if the parts of the equipment that must be operated in order to use the equipment for its

purpose is evaluated separately and not together with the more complex functions or with the programming and adjustment of the equipment. If the most basic use of the equipment is difficult, it is of course more serious than if the user finds some advanced functions difficult to operate.

Usability tests

Such tests can be done in two different ways:

- By using the introspective method where the designer or someone else uses the equipment for a prolonged period of time and notes down his thoughts and impressions while using it.
- By observed experiments where a group of users operate the equipment while being observed.

Use of the introspective method

In subchapter **6.5 The description of the human mind made by William James** the value of the introspective method is described. William James [1890: 185] describes the introspective method as "looking into our own minds and reporting what we there discover".

The introspective method can be used when evaluating the usability of a piece of equipment, and, as described in details in subchapter **6.5 The description of the human mind made by William James**, it offers the following advantages:

- It is possible to assure that the results are valid for at least one person.
- The method is very cost-effective.

My own experience indicates that the designer of a piece of equipment can use the introspective method and obtain valuable results if [own observation]:

- The equipment is used for actual tasks for prolonged period of time, and it is used intermittently over a period of several days or weeks. It is not sufficient that the designer once tries all the functions.
- The person using the introspective method should take careful notes every time a new phenomena is experienced during the operation of the equipment. Ideally the persons doing the evaluation should also note down the situations when he almost made a mistake or the situations when he felt some vague discomfort even though he managed to complete the operation.
- The person evaluating the equipment has some introspective talent. It is quite possible that some persons could use the equipment for a prolonged period of time, and even make a substantial amount of errors during the operation, without experiencing anything they found worthwhile to report.

If the designer experiences a problem when operating one part of the equipment, it is likely that other users will experience similar problems. However, even if the designer of a piece of electronic equipment can operate the equipment without experiencing any problems, other users may still have problems when operating the equipment.

One example was a development engineer and designer of electronic equipment I once met [own observation]:

> The development engineer was used to 16-base, hexadecimal, numbers, and found it difficult to believe that some users could not easily determine the parity of 16-base numbers before entering them.

The designer of the equipment should therefore state clearly that even though he has not experienced any problems when operating a particular part of the equipment, it is still possible for other users to experience problems when operating the same part of the equipment.

I have found that the introspective method can give results of the same quality as experiments where a group of users are observed: The introspective method can identify small infrequent problems in the operation of the equipment, whereas the experiments can give a more reliable description of the general usability of the equipment.

Use of experiments

The use of experiments where a number of users try the equipment is described in some detail by Hix and Hartson [1993: 11-18]. They describe how each of the stages of an experiment can be conducted:

- Selecting the participants to perform the tasks
- Developing usability goals and experimental tasks
- Directing the experimental session
- Data generation and collection

However, the evaluation of the equipments suitability for inattentive use raises some problems:

- It is in general not possible to let the participants use the equipment for a prolonged period of time before the experiment is made. The test will therefore normally be made with users without any training in the use of the particular equipment, and even outside a laboratory setting it is unlikely that the users will use the equipment while focusing their attention on something else.
- It is necessary to let the user *think aloud* in order to know his reasoning when operating the equipment. However, when the user talks while doing the operations, inattentive use is very unlikely.
- Unless the experimental tasks are comparatively small and clearly defined, it is very difficult to set up an experiment in such a manner that the participants in it will use all parts of the equipment. The experimental situation will therefore often be somewhat artificial: In a normal situation of use the user must solve comparatively large and less well defined tasks, whereas he in the experimental situation is requested to solve small and well defined tasks presented in writing.
- It is difficult to identify situations where the user infrequently makes an error during inattentive use even though such situations may make inattentive use significantly more difficult.

In addition, an experiment with a group of users is very time consuming. My own estimate is that an experiment where 5 users each operates the

equipment for 40 min requires more than 8 days of work for all preparations, conduct of the experiment and processing of the results; and because the results to a large extent depend on the quality of the preparations and processing of the results a test where less time is used may be completely worthless.

This means that experiments with a number of users best are used for measuring the level of usability *after* most of the problems has been found and eliminated from the design by use of reviews, quantitative methods and introspection.

Report of the evaluation

My own experience shows that it is quite common that a review or analysis of a user interface or a usability test produces a number of results that are not included in the report of the evaluation. That is unfortunate, because the evaluation of the design never can be better than the report made of it.

In some cases it is advantageous if the report is divided into two parts in the same manner as the results of the quantitative evaluation:

- One part of the report describes the usability of the parts of the equipment that must be operated in order to use the equipment for its stated purpose.
- Another part of the report describes the usability of the more complex functions or programming and adjustment of the equipment.

The report may describe different aspects of the usability of the equipment:

- If the evaluation is made before the design is completed, the report may describe all the problems that should be corrected.
- If the design is completed, for instance when the report is made for an organisation contemplating the acquisition of the equipment, the report can describe how easy or how difficult it is to use the particular piece of equipment.

However, no matter the purpose of the report, all identified potential problems should be listed in the report, in some cases with a classification according to seriousness:

- *Serious problems,* for instance cases where nothing is done for reducing the risk of an error made by the user having serious consequences. Such problems are in general unacceptable.
- *Significant problems,* for instance misleading elements which lead even trained users to making mistakes. Such problems are undesirable.
- *Minor problems,* for instance cases where the amount of physical actions needed for activating a function should or could be reduced.

The participants in a review may in some cases fear that such a detailed report may convey a very negative impression of the designers or manufacturers of the equipment. When that is the case, the report can be divided into two parts: a *main report* giving the results of the review in general and a *technical report* listing the different problems in detail.

Usability classification

In some cases it is desirable to describe the usability of a given piece of equipment very briefly.

The following scale can be used for making a brief description or classification of the usability of equipment:

1. The equipment is as usable as possible.
2. Elementary use is easy, though other use, programming or adjustment is cumbersome.
3. Elementary use is cumbersome, or other use, programming or adjustment is very difficult.
4. Elementary use is very difficult.
5. The equipment is ill suited for the state purpose.

The words *elementary use* refers to the most basic use of the equipment for the stated purpose. For a cellular phone such *elementary use* may consist of turning the phone on and making an ordinary call

The word *cumbersome* describes equipment where the operation is difficult, but where it is possible to learn to use the equipment without making any errors.

The words *very difficult* cover a number of different cases:

- When the user must learn and recall some codes or commands in order to operate the equipment.
- The equipment contains some misleading or confusing elements.
- The physical actions necessary for operating the equipment cannot be done without making errors in the actual situations of use.

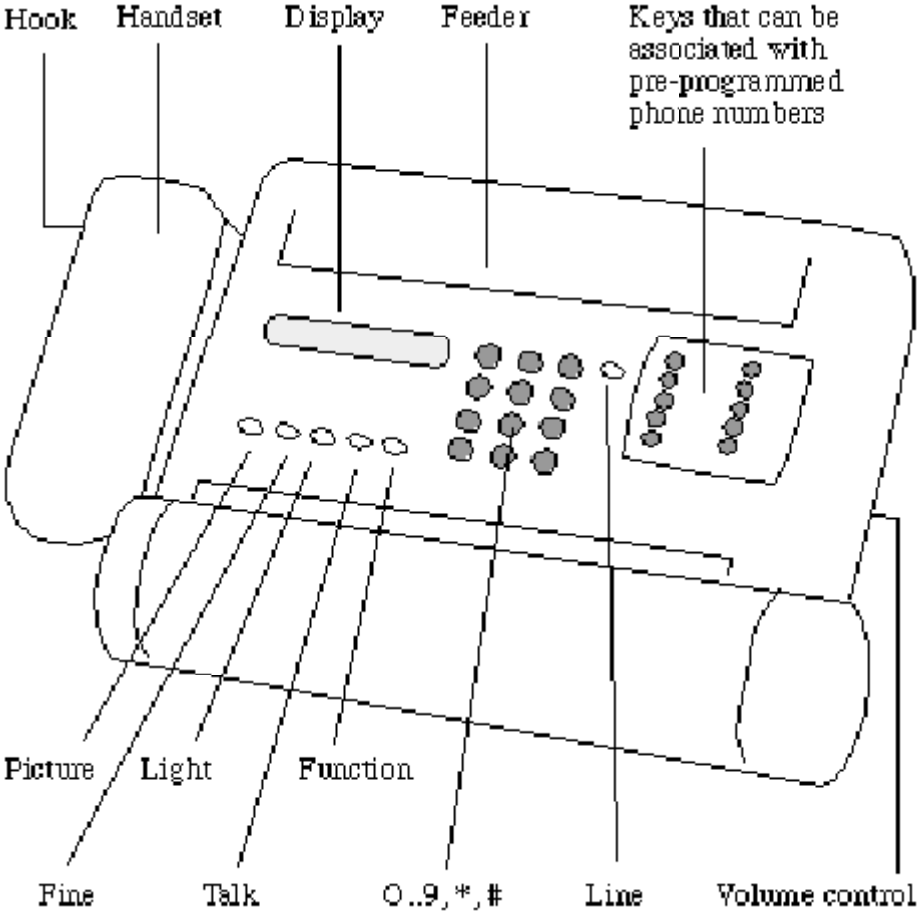
13.2 *POT1:* USABILITY OF A COMBINED PHONE AND FAX TERMINAL

The *Pot1* is a stationary terminal that combines functions for making ordinary voice calls and for receiving and transmitting faxes. It uses a *Plain Old Telephone* line and not an ISDN, Integrated Services Digital Network, connection.

It was originally envisaged that a terminal offering telephone and fax connection only could be made for the so-called ISDN connection. However, terminals as the *Pot1* offer today almost the same facilities as envisaged for the ISDN terminal on a less expensive analogue phone line, so the ISDN connection can with some justice be described with the acronym well known among telecommunication engineers: "Inventions the Subscribers Don't Need".

In addition the prices for combined telephone and fax machines, such as the *Pot1*, have decreased, and they are today often bought for private households.

The user guide indicates that the *Pot1* was first sold in 1993. However, it may still be considered state of the art and typical for the small and comparatively inexpensive private or personal fax units that are produced in the far east.



The *Pot1* combined phone and fax machine

The evaluation of the *Pot1* consists of a review divided according to the functions in the terminal and the results of a quantitative evaluation.

The evaluation is comparatively brief and it is therefore not divided into one part describing the evaluation of the elementary functions and another describing the evaluation of the more advanced functions.

The description of each function is written with normal letters whereas the evaluation of each function is written with *italics*.

Keys and actuators on the user interface

The keys on the *Pot1* are all placed with a centre-centre distance on 15 mm or more, and they are all resilient so the finger of the user can be stopped gradually.

However, five of the keys are labelled in a manner that does not refer to any function in a meaningful manner: they are labelled "Picture", "Fine", "Light", "Talk" and "Function".

It is possible to press the keys with only a minimal amount of visual guidance, but it may be impossible for an inattentive user to associate the name of each key with the precise function it activates.

Changing the volume of the loudspeaker

The volume control is placed on the right side of the *Pot1*.

The user shall in most cases bend over the Pot1 *in order to adjust the volume, and it is difficult to adjust the volume without paying attention to it.*

Selection of the number to be called

The operation is very similar to the operation of an ordinary phone: The handset is unhooked or the LINE key pressed, and when the *Dial tone* is heard the user can select the number to be called in one of two ways:

- Entering the number through the keypad
- Pressing one of 10 keys with a pre-coded phone number (if the user earlier has entered the pre-coded numbers)

Two details make the operation less suited for inattentive use:

- *If the user cannot recall the number, but has to look it up, it is very difficult to make the call as an automatic process. The user of a normal phone can experience precisely the same problem.*
- *The user shall press the LINE key before he can enter a phone number he wants to address a fax to. However, the user will often associate directly to the number he wants to send the fax to and therefore start entering the number without pressing the LINE key. It should therefore not be necessary to press that key before starting to enter the number.*

Making a voice call

The voice call can either be incoming or outgoing:

- If the *Pot1* rings with an incoming call, the *Pot1* draws the attention of the user, and the user can initiate the call by picking up the handset.
- If the call is outgoing, the user shall select the number to be called and wait until the remote phone is picked up—the voice sounding from the *Pot1* draws then his attention.

When the call is completed the user can terminate the call by putting down the handset. That can be done either before or after the remote user has put down his handset.

The Pot1 *draws the attention of the user when either an incoming call arrives or when an outgoing call is answered, and the user can then initiate the call as part of an automatic process.*

When the user wants to terminate the call, he can put down the handset and terminate the call while focusing his attention elsewhere.

The functions for making a voice call are in general well adapted to inattentive use.

Making a conference call or transferring a call

The set-up of a conference call or the transfer of a call can only be done by entering predefined codes of a format similar to ** number * number * number #.*

These facilities can in general only be used if the user pays attention and has access to a list over the precise codes to be used.

Transmission of a fax

The first page of the document to be transmitted are placed in the *Feeder* on top of the *Pot1,* and the fax number to be called is then selected. If the user has unhooked the handset, he shall replace it when a fax tone is heard from the receiving fax.

The *Feeder* can only take one or two pages at a time. It is therefore necessary for the user to supervise the operation of the fax machine and continuously feed the machine with pages.

The transmission of faxes cannot be done without paying continuous attention: If more than two pages are inserted in the Feeder *at a time they may jam, and if the* Feeder *becomes empty for even a brief moment, the transmission is stopped.*

Receiving a fax

A fax can be received in one or two possible ways:

- The *Pot1* can be set to receive a fax. In that case, the *Pot1* will automatically receive the fax when the fax tone is detected.
- The user can change the setting from speech to fax reception by "slightly pressing the hook several times" as described in the user guide.

The function of the Pot1 *is somewhat unreliable—if the* Pot1 *is set such that it can receive faxes it is likely that any incoming ordinary phone calls will be disrupted by a fax tone. It is therefore necessary for the user to set the telephone to receive faxes immediately before a fax is expected. As an alternative the user can change the setting when the fax tone is heard; however, that facility is not apparent for the user.*

The reception of a fax therefore often requires that the user pays attention to it.

Changing the settings of the Pot1

The user can change a number of settings in the *Pot1* by pressing the FUNCTION key and entering a number between *0* and *9* indicating the setting he wants to change.

When the setting is selected, the user must normally enter some additional data, he cannot simply *undo* the choice.

The user must either recall the number referring to the setting he wants to change or have access to a list over the different settings and the numbers related to them.

It is therefore not possible to change the settings without paying attention. That is, however, acceptable, because the user normally will think consciously about the settings he wants to change. The only exception is the enabling and disabling of the reception of faxes: The user may find it necessary to change that setting in a hurry while his attention is focused elsewhere.

Quantitative evaluation of the *Pot1*

In this quantitative evaluation, only the points with larger than ideal values are listed (the ideal values are shown in brackets):

Problem points describing how the equipment presents itself to the user:

1.1	Ratio between the number of elements presented from right to left or from bottom to top and the total number of presented elements	1	(0)
1.4	Ratio between 11 mm and the height of the presented text in mm	1.8	(1)
1.7	Number of elements whose meaning depend on the perception of combinations of two or more unrelated parameters, for instance the shape and colour of an element	4	(0)

1.9	Ratio between the number of icons the user cannot easily associate with one word describing their meaning and the total number of presented elements	0.16	(0)
1.12	Number of states where the equipment draws the attention of the user when it is unnecessary for the user to pay attention to it	2	(0)

Problem points describing how the user must decide upon an action and initiate it:

2.1	Number of states	24	(-)
2.2	Ratio between the number of hidden states and the total number of states	0.17	(0)
2.3	Ratio between the number of states and the total number of connections between the states	0.2	(-)
2.4	Average distance between the states	2.4	(1)
2.6	Ratio between elements with misleading labelling and the total number of elements	4	(0)
2.7	Total number of functions	26	(-)
2.8	Average number of separate actions needed for activating each function	1.8	(1)
2.9	Average number of actions that shall be done in order to complete a task	7	(1)
2.10	Average number of functions making use of each actuator	1.8	(1)
2.11	Ratio between the number of actions in each task that has to be done in a specific order and the total number of actions necessary for each task	1	(0)
2.12	Ratio between the number of choices that cannot be undone in one operation and the total number of choices	0.30	(0)
2.13	Choices that cannot be undone and where no request for acknowledgement is made	9	(0)
2.14	Ratio between the number of cases where the next action in a task is not clearly indicated and the total number of states	0.08	(0)

Problem points describing the physical actions the user must make when operating the equipment:

3.2	The number of situations where the user cannot change his position or must grip the equipment with a constant muscular force while using or carrying it	-	(0)
3.3	The number of actuators that can be activated by accident while the equipment is not used, for instance while it is carried	-	(0)
3.4	The ratio between the number of physical actions where continuous visual guidance is necessary and the total number of physical actions	0.5	(0)
3.12	The ratio between 18 mm and the average of height and width of the keys	1.2	(0)
3.13	Number of keys without tactile feedback at the depression where they are activated	All	(0)
3.14	The ratio between 3 mm and the distance from the depth of depression in mm where the keys are activated to the lowest position of them	3	(1)

Comments to the quantitative evaluation.

The misleading labelling and the hidden states are in parts of the equipment that are not used during elementary use or even most of the times the settings of the *Pot1* are changed. The most serious problems appear therefore to be the choices that cannot be undone and where no request for acknowledgement is made, in particular because these choices are made by entering a single digit that are not directly associated with the function selected. It is therefore likely that the user at that point will make errors during the operation and cannot easily correct them.

Classification of the usability of the *Pot1*

The user interface of the *Pot1* contains a number of significant problems. However, none of the problems are so serious that they make the use of some functions impossible or may create any health hazards.

If the transmission and reception of faxes are considered elementary use, the usability of the *Pot1* must be classified as:

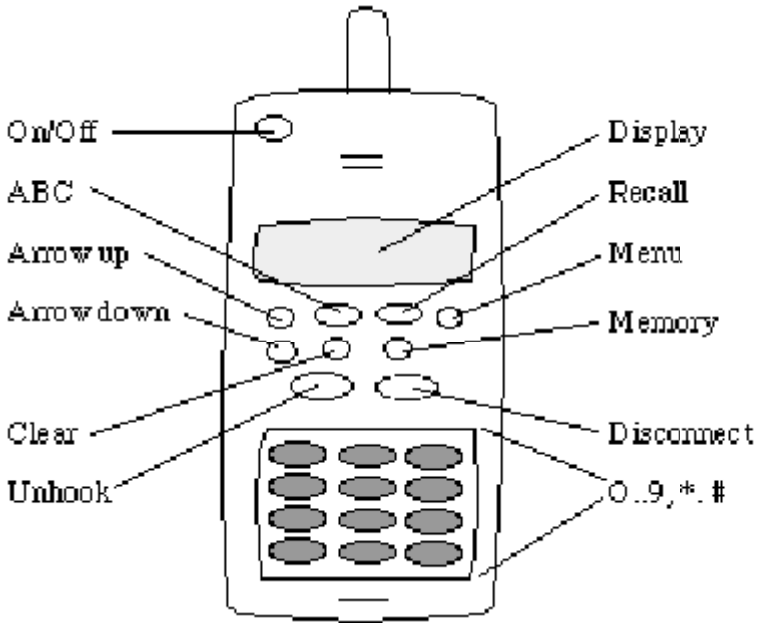
> *3.: Elementary use is cumbersome, or other use, programming or adjustment is very difficult.*

However, if only ordinary phone calls are considered elementary use, it is possible to raise the classification to:

> *2.: Elementary use is easy, though other use, programming or adjustment is cumbersome.*

13.3 *GSM1:* USABILITY OF A GSM CELLULAR MOBILE PHONE

The cellular phone is made for the GSM system phase 1. It is a hand-portable phone weighing approx. 350 gr and with a front approx. 150 mm high.



The GSM1 cellular phone for the GSM system

According to my information the *GSM1* cellular phone was first sold in 1993. However, it is still sold and its operation may be considered typical for the cellular phones that currently are sold in Europe.

The evaluation of the *GSM1* is structured in the same manner as the evaluation of the *Pot1:* It consists of a review divided according to the functions in the terminal and the results of the quantitative evaluation written with *italics.* The *GSM1* includes, however, a large number of parameters that can be set by the user, and the setting of all these parameters is only described in general: The definition and specific setting of each parameter is not described.

In the same manner as for the *Pot1*, the evaluation is comparatively brief and not divided into one part describing the evaluation of the elementary functions and another describing the more advanced functions.

Keys and actuators on the user interface

The keys do not give any tactile feedback when they are activated, and the keys shall be depressed almost to the bottom position before they are activated, and if the *GSM1* is used in the standard carrying case where a piece of clear plastic covers all the keys the user cannot even feel when the key is fully depressed.

Two of the keys are labelled with single letters whose meaning is not immediately apparent, and one of the keys is labelled with an icon where the meaning is not apparent.

The user will often during inattentive use press a key without activating it, and the keys can only be operated if the user has continuous visual feedback.

It is, however, possible for the user to learn the meaning of the 3 keys labelled with icons so he can use them in the proper manner during inattentive use of the GSM1.

Turning the *GSM1* on and off

The *GSM1* is turned on by pressing the ON/OFF key, entering the requested Pin code and pressing the MEMORY key.

The *GSM1* is turned off by pressing the ON/OFF key.

In most cases a number entered in the GSM1 *is followed by the depression of the UNHOOK key. When the* GSM1 *is turned on as part of an automatic process, the user will therefore often press the UNHOOK key instead of the MEMORY key. It would be preferable if the entering of the Pin code could be completed by pressing any key or at least either the MEMORY or the UNHOOK key.*

The ON/OFF key is set so deeply that the risk of the cellular phone being turned off by accident is negligible.

Changing the volume of the loudspeaker

The volume control is operated by pressing the ARROW UP and ARROW DOWN keys: The ARROW UP key is pressed for increasing the volume and the ARROW DOWN key for decreasing the volume. It is only possible to change the volume when a call is in progress or during an active call—it is not possible to change the volume while the *GSM1* is in standby.

The user will therefore perceive that the volume control functions in an unreliable manner: A depression of one of the keys will not always give the expected result.

Selection of the number to be called

The number to be called can be selected in the five following manners:

- By entering the number to be called on the numerical keypad. When a number is entered in that manner, it is possible to delete the last entered digit by pressing the CLEAR key.
- By pressing the UNHOOK key. The last entered number or a precoded number is then shown in the display and can be called.
- By using the *Short number facility,* where a two-digit number referring to the number to be called is entered.
- By searching in an internal list for a name linked to a phone number. The user shall press the ABC key and then, by activating a special procedure on the numerical keypad, enter the first letters of the name. The special procedure consists of the user pressing the key with short intervals if he wants to scroll between three letters linked to the key, and of making a longer interval when he has selected the proper letter and before he starts the selection of the next letter.

Compared to a normal phone it is a definite advantage that the user can delete a wrongly entered digit, so he can correct an error without having to enter the whole number once more. It is easier for the user to enter a number when the consequences of an error are smaller.

However, most of the methods for selecting the number to be called are not well suited for inattentive use:

- *If the user cannot recall the number, but has to look it up, it is very difficult to make the call as an automatic process, in particular because the hand-portable* GSM1 *often is used where it is difficult to handle a phone book while entering the number.*
- *When using the* Shortnumber facility, *the user must recall a two-digit number associated to the number he wants to call.*
- *The procedure for entering letters is slow and can be used only if the user has continuous visual feedback. In addition it can be used only if the user can recall the precise name connected with the number he wants to call.*

Making a voice call

The voice call can either be incoming or outgoing:

- If the *GSM1* rings with an incoming call, the user initiates the call by pressing the UNHOOK key.
- If the call is outgoing the user initiates the call by pressing the UNHOOK key after he has selected the number to be called.

When the call is completed the user can terminate the call by pressing the DISCONNECT key.

If the called number is occupied the user can activate an automatic redial at a later time by entering a special command sequence or by selecting the automatic redial in one of the menus or lists that are used for changing the settings of the *GSM1*.

The GSM1 *draws the attention of the user when either an incoming call arrives or when an outgoing call is answered, and the user can then initiate the call as part of an automatic process.*

In addition the user can terminate a call while focusing his attention elsewhere.

In contrast, the automatic redial is difficult to use even when the user pays attention to it.

Transmission of DTMF tones

If a key with a digit is pressed during an active call, the corresponding DTMF (Dual Tone Multiple Frequency) tone is sent. A number sent in that manner can for instance be used for selecting an extension or for entering a number to be sent to a pager.

This function is well suited for inattentive use: It is simple and operated in precisely the same manner as on an ordinary phone.

Use of a Notepad function

This function is used for storing a phone number during an active call, for instance if the remote user suggests that the user of the GSM1 calls a certain number.

When using the function the user has to enter the number to be stored and then depress the keys MEMORY, # and MEMORY.

When the user later wants to recall the number he has to press the keys # and RECALL.

The Notepad function is used during an active call and it is therefore essential that it is well suited to inattentive use. In spite of that, it can only be used if the user can recall a particular command.

Call waiting

The call waiting function is described in the GSM specifications, but its operation is not described in the user guide for the *GSM1*.

The call waiting function is therefore not in general available for the user.

Making a conference call or transferring a call

The set-up of a conference call or the transfer of a call can only be done by entering predefined codes of the format * *number* * *number* * *number* #.

Facilities for conference calls or transfer of calls can in general only be used if the user pays attention and has access to a list over the precise codes to be used.

Showing the duration and price of the last call

The *GSM1* will show the price and duration of the last call if the user presses the MENU key and uses the arrow keys for scrolling down to *Time counter*.

As an alternative the user can see the price and duration of the last call if he presses the MENU key and enters the digit *8*.

None of these methods for presenting the price and duration of the call are suitable for inattentive use.

Changing the settings of the GSM1

The user can access a number of settings in the *GSM1* by pressing the MENU key and then use the arrow keys for stepping down through lists over parameters stored in the *GSM1*. These parameters include for instance the Pin code, precoded numbers for the *Short number facility*, enabling of *automatic call transfer*, the phone number of the particular *GSM1* and the recall of any received short messages. The parameters in the *GSM1* are divided into one main list with 11 positions and 4 sublists with a total of 32 positions. When a sublist or a subsublist is selected it is only possible to return to the previous list by going to *Standby* and then moving down once more in the lists.

As an alternative it is possible to select a position in the lists by pressing the MENU key and entering a 2 or 3 digit number associated to the position in the list.

It is not possible to access the different positions in the lists without paying attention. The user must either recall in which sublist a particular setting is available or the number associated to the particular position in the list. That would only be a slight problem if the user only had to change settings when sitting in peace and quiet and never should change any settings while using the phone. However, during the use of

the GSM1 *the user may find it necessary to change the type of automatic call transfer, to view the phone number of the* GSM1 *he currently is using or to read received short messages. The difficult access to the different positions in the lists therefore restricts the use of the* GSM1 *significantly.*

Quantitative evaluation of the *GSM1*

In this quantitative evaluation, only the points with larger than ideal values are listed (the ideal values are shown in brackets):

Problem points describing how the equipment presents itself to the user

1.4	Ratio between 11 mm and the height of the presented text in mm	2.8	(1)	
1.5	Ratio between 1 mm and the line width of the presented elements or icons in mm		2	(1)
1.9	Ratio between the number of icons the user cannot easily associate with one word describing their meaning and the total number of presented elements		0.4	(0)
1.11	Number of states where the equipment does not draw the attention of the user when the user should pay attention to it		1	(0)

Problem points describing how the user must decide upon an action and initiate it:

2.1	Number of states		39	(-)
2.2	Ratio between the number of hidden states and the total number of states		0.08	(0)
2.3	Ratio between the number of states and the total number of connections between the states		0.9	(-)
2.4	Average distance between the states		6.5	(1)
2.6	Ratio between elements with misleading labelling and the total number of elements		2	(0)
2.7	Total number of functions		41	(-)
2.8	Average number of separate actions needed for activating each function		8.8	(1)
2.9	Average number of actions that shall be done in order to complete a task	8.9	(1)	
2.10	Average number of functions making use of each actuator		1.8	(1)
2.11	Ratio between the number of actions in each task that has to be done in a specific order and the total number of actions necessary for each task		1	(0)
2.12	Ratio between the number of choices that cannot be undone in one operation and the total number of choices	0.2	(0)	
2.13	Number of choices that cannot be undone and where no request for acknowledgement is made		14	(0)
2.14	Ratio between the number of cases where the next action in a task is not clearly indicated and the total number of states		0.3	(0)

Problem points describing the physical actions the user must make when operating the equipment:

3.2	The number of situations where the user cannot change his position or must grip the equipment with a constant muscular force while using or carrying it	1	(0)
3.3	The number of actuators that can be activated by accident while the equipment is not used, for instance while it is carried	8	(0)
3.4	The ratio between the number of physical actions where continuous visual guidance is necessary and the total number of physical actions	1	(0)
3.12	The ratio between 18 mm and the average of height and width of keys in mm	1.3	(0)
3.13	Number of keys without tactile feedback at the depression where they are activated	All	(0)
3.14	The ratio between 3 mm and the distance from the depth of depression in mm where the keys are activated to the lowest position of them	0.3	(1)
3.15	Number of keys without a resilient bottom	All	(0)

Comments to the quantitative evaluation.

The most serious problems identified during the quantitative evaluation are:

- The comparatively large number of separate actions that are necessary for completing a specific function or task. The main reason is the use of lists where the user often must scroll through a large number of positions in the list before he reaches the one he needs.
- The number of hidden choices, when the user cannot see that one position in a list gives access to an additional list.
- The instances when the user cannot *undo* a choice he has made while scrolling in the list.

Classification of the usability of the GSM1

The user interface of the *GSM1* contains a number of significant problems. The making of a normal call is very simple, however, and even in emergency situations it is therefore unlikely that the operation of the *GSM1* may create serious problems or any health hazards.

The *GSM1* can be classified as:

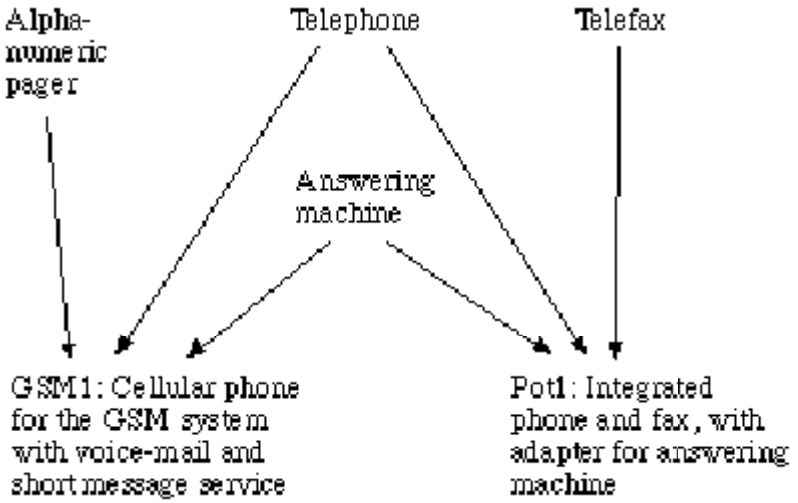
> *3. Elementary use is cumbersome, or other use, programming or adjustment are very difficult.*

That classification will be the same whether the *reading of received written messages* and use of the *Shortnumber facility* and Notepad are described as *elementary use* or whether these functions are described as *other use*.

13.4 THE DEVELOPMENT OF COMMUNICATION EQUIPMENT

Comparing the two units, the Pot1 and the GSM1, two common characteristics are apparent:

- The most basic function, the entering of a phone number and making of an ordinary call, is fairly easy to do, whereas all functions and tasks that are slightly more complex are very difficult to operate and in general not suited for inattentive use.
- The different functions are activated in different manners; these manners can be classified according to the "dialogue styles" described by Mayhew [1992: 113]: the user of the *Pot1* can for instance recall a number in the *Short number facility* by pressing a function key, whereas the user of the *GSM1* can enter a command including the initials of the user. Six of the 25 functions that are implemented in both the *Pot1* and the *GSM1* make use of different *dialogue styles*, and 11 of the functions are only implemented in either the *Pot1* or the *GSM1*. The dialogue styles used for each function and the inclusion or exclusion of a function in the two terminals appear to be arbitrary.



Possible evolution leading to the GSM1 and the Pot1

The characteristics and differences between the *Pot1* and the *GSM1* do not fit any analysis of the usability or the functions required by the users.

However, it is possible to explain both the similarities and the differences between the *Pot1* and the *GSM1* if it is assumed that they both are evolved from a simple voice only telephone, and that the different additional functions and features gradually has been added to the two terminals without being integrated with the basic functions used for making an ordinary phone call.

14. COMMUNICATION EQUIPMENT FOR INATTENTIVE USE

This chapter gives an example of the functions that are provided in communication equipment, and it describes two different pieces of communication equipment for inattentive use:

- The *Pot+* is an integrated multimedia terminal with simultaneous access to voice- and text communication and the transmission of faxes. It can use an ordinary phone line in the same manner as the *Pot1* terminal described in subchapter **13.2 *Pot1:* Usability of a combined phone and fax terminal**.
- The *GEOSM*, or GEOrg Stroem's Mobile Telephone, is a hand portable terminal for use in the GSM system. It provides essentially the same functions as the *GSM1* terminal described in **13.3 *GSM1:* Usability of a GSM cellular mobile phone**.

Both the *Pot+* and the *GEOSM* are fully specified. However, in this chapter only the operation of the different functions are described—the list over parameters implemented in each terminal and the detailed descriptions of the relations between states, functions and tasks are omitted.

14.1 AN EXAMPLE OF OFFICIAL REQUIREMENTS FOR COMMUNICATION EQUIPMENT

Communication equipment shall often fulfil requirements that are more stringent than the requirements stated for other electronic equipment.

Not only the formats and protocols, but also the specific features and functions of communication equipment are to a large extent decided by international organisations, and the equipment cannot be sold unless an independent agency verifies that it fulfils the detailed specifications. These international organisations want to ensure that:

- All communication equipment designed for a specific communication system actually can be used in it.
- All communication equipment for a specific communication system are operated in a similar manner, so that the user of one brand of communication equipment for the system can operate another brand of equipment for the same system.

As illustration, the features and functions of the GSM system are described in the following. They are the latest and most elaborately defined features and functions for a public communication system.

The features and functions of the GSM system are defined by ETSI, an international organisation financed by the EU, manufacturers of telecommunication equipment and providers of telecommunication services. It is likely that features and functions supported by the EU for other electronic equipment will show some of the same characteristics as the features and functions defined for the GSM system.

Services provided by the GSM system

ETSI [1994a: 13] defines two types of services in the GSM system:

- "*Bearer services*, which are telecommunication services providing the capability of transmission of signals between access points (called user-network interfaces in ISDN)." [such a service is defined for the interface between the network and the terminal] [present author's italizing]
- "*Teleservices*, which are telecommunication services providing the complete capability, including terminal equipment functions, for communication between users according to protocols established by agreement between network operators." [such a service is defined for the interface between the terminal and the user] [present author's italizing]

The available teleservices normally determine which types of messages the user can receive and transmit.

The following teleservices are described for the GSM system by ETSI [1994b: 12, 14, 20, 21]:

- Telephony, speech only
- Short messages consisting of up to 160 alphanumeric characters
- Alternating speech and facsimile [fax] group 3 transmission
- Automatic facsimile [fax] group 3 transmission

Even when the 3.1 kHz bandwidth is not exceeded, the speech coding prohibits the transmission of arbitrary sounds over the speech services; it is for instance not possible to transmit modem signals or group 4 fax.

ETSI has not defined any teleservices for data transmission, but it is possible to transmit information about formats used for data transfer from one terminal to another. This means that it is difficult, but not impossible, to mix speech and data transmission during one call.

Compared to the multitude of services and standards supported in other communication systems the GSM system appears to be very restricted, and most of the digital messages that can be sent from one terminal to another have no space allocated for additional information. My own experience indicates that there are two reasons for that [own observation]:

- The time from the definition of a communication system as the GSM system starts until it is operational is very long: For the GSM system it was approx. 8 years. It is therefore likely that a number of other services evolve in parallel with the definition of such a communication system.
- The definition of a system as the GSM system is normally not done by experts in the design of user interfaces or new products, and the persons defining the system do not try to invent or define new applications but define only the most basic applications.

Features defined for the GSM system

ETSI [1994c: 9, 10, 14, 15, 17] lists the following "features" for the "Mobile Station (MS)" or terminal:

Basic MS features:

1.1	Display of called number		M *
1.2	Indication of call in progress signals	M *	
1.3	Country/PLMN [Public Land Mobile Network] indication	M *	
1.4	Country/PLMN selection		M
1.5	Keypad		O
1.6	IMEI, Short message indication and acknowledgement	M	
1.7	Short message	M	
1.8	Short message overflow indication		M
1.9	FTE/DCE interface: standard connector for data services		O
1.10	ISDN 'S' interface		O
1.11	International access function		O
1.12	Service indicator [also described as signal strength indicator]		M *
1.13	Autocalling restriction capabilities		-
1.14	Emergency call capabilities		M
1.15	Dual Tone Multiple Frequency function (DTMF)		M
1.16	Subscription Identity Management, [terminates all calls if the card with the subscribers identity is removed from the mobile station]		M
1.17	On/off Switch	O	
1.18	Subaddress, for instance to the local extension of a dialled number	O	
1.19	Support of encryption A5/1 and A5/2	M	
1.20	Short message service cell broadcast [so the Mobile Stations immediately can discard some of the short messages addressed to other stations and thereby save power]	O	

-

Supplementary MS features:

2.1	Control of supplementary services		O

-

M * Mandatory if the Mobile Station is operated manually

M Mandatory

O Optional

Additional MS features:			
3.1	Abbreviated dialling		O
3.2	Fixed number dialling	O	
3.3	Barring of outgoing calls		O
3.4	DTMF control digits separator [inserts a 3 s break between the transmission of the directory number and the transmission of precoded DTMF digits]	O	
3.5	Selection of directory number in short message providing easy access to the calling number sent in a short message	O	
3.6	Last number dialled		O

M * Mandatory if the Mobile Station is operated manually
M Mandatory
O Optional

In addition ETSI [1995: 9, 11, 12, 14, 17, 18] describes how it shall be possible to operate some of the features:

- A keypad with the keys 0-9, *, # and +, or similar functions implemented with other actuators, for instance voice activated
- Call charge unit meter showing the price of a call
- Selection of language of announcements for instance for written texts
- Supervisory tones, for instance ringing tone when the remote terminal is ringing
- Support of the special codes used for operating services in a public phone system with formats similar to ** Service Code * Supplementary Information #*
- Dedicated codes with formats similar to *digit #* for operating *Call Waiting, Call hold* and *MultiParty call* (*conference call* or *3-party call*) (It shall in particular be possible to put one call on hold while making another call, and to accept a *call waiting* even though there already is one *call waiting* and one active call.)
- Changing the Pin code and unblocking (opening) of the phone by entering the Pin code
- Use of abbreviated dialling to precoded numbers using access codes with the format *Digit (Digit) (Digit) #*
- An optional dedicated key for the transmission of emergency calls

Two other features or functions are finally used in the GSM system:

- The setting up of an ordinary phone call (ETSI describes [1992: 26] how that is supported.)
- *Automatic Call forwarding* (transfer) (for instance if nobody picks up the phone and answers it within a certain period of time.)

ETSI requires that a large number of functions in the GSM terminal can be operated through special command codes and sequences that the user has to learn and recall before he can use them. That method of operation is taken from a much older standard, and it is therefore made for a much lower technical level—it is for instance made for terminals without a display.

ETSI uses the term "features" for everything that they require is implemented in a terminal for the GSM system: They do not distinguish between actuators, functions or special procedures that are used for operating the functions. That is probably the result of the manner in which the list over features are made [own observation]: The requirements are the results of a negotiation between approx. 30 representatives of regulators and manufacturers, and they may therefore be inconsistent.

In addition the features and ways of operating them tend to lag behind the development of technologies and electronic equipment. The main reason is that the requirements for a system as the GSM system is written over a period of up to 10 years—when the requirements are completed, it is therefore likely that the use of electronic equipment in other areas has moved far beyond the features originally defined for the system.

The requirements for different pieces of electronic equipment are defined in a manner similar to the one used for the GSM system: In particular ETSI produces requirements for a large range of electronic equipment. The problems identified in the requirements for the GSM terminal can therefore also be found in public requirements for other electronic equipment.

Consequences for the design of equipment for inattentive use

The design of a user interface that fulfils the requirements stated for a GSM terminal poses special problems for the designer:

- The different services have very limited capabilities: It is therefore difficult to integrate new services, for instance such that provide for alternating speech and data transmission.
- The different requirements for the user interface are presented in an arbitrary order, some of them are mandatory, other optional and some of them are apparently contradictory.
- The mandatory ways of operating the different functions are very primitive, and can in general not be used for their stated purpose.

In these cases the designer must overcome the problems found in the requirements:

- The designer should identify if the services defined in the requirements are sufficient for the tasks that the user shall do with the equipment and if necessary find ways of emulating additional services. It may, for instance, be possible in the GSM system to emulate alternating speech and data transmission by a creative use of the already defined control messages or by changing between very brief voice and data calls.
- It is in general not possible to base the design of the user interface directly on the features described for the equipment.

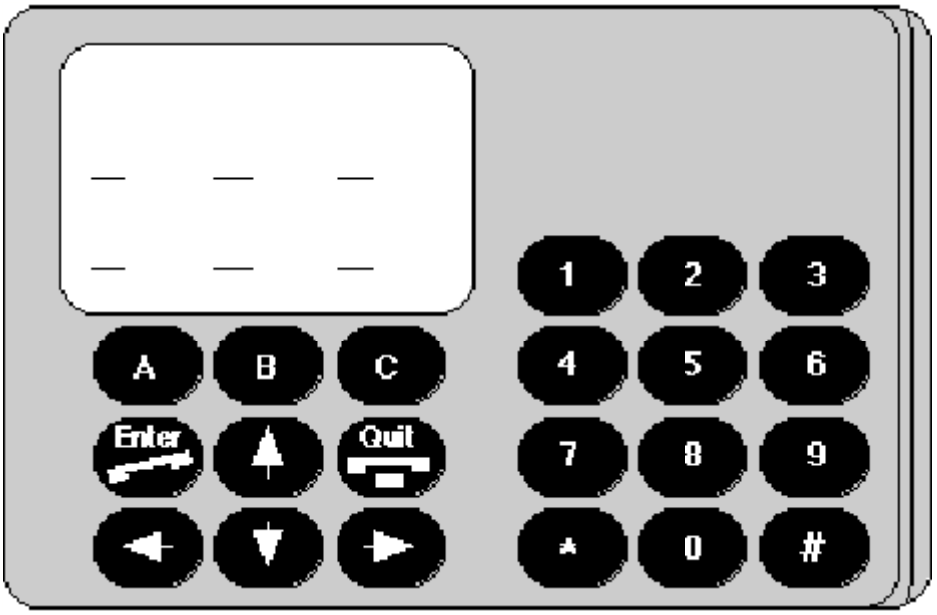
The designer should therefore independently define a suitable set of functions for the equipment or at least try to reorganise the different features.

- The designer finally has to find ways to implement dysfunctional but mandatory ways of operating the different functions, such that the user cannot activate them by accident.

My own experience indicates that the designer during the first part of the design should lend more weight to the tasks and requirements of the user than to the requirements stated in official standards for the particular type of equipment.

14.2 *POT+:* AN INTEGRATED MULTIMEDIA TERMINAL

The *Pot+* terminal is developed on the basis of the *Pot1* terminal described in subchapter **13.2 *Pot1:* Usability of a combined phone and fax terminal**.



User interface (front) of the *Pot+* multimedia terminal

The *Pot+* terminal is adapted to inattentive use and it includes some additional facilities that in the future may be necessary in a multimedia terminal:

- In addition to voice calls and the transmission and reception of faxes it includes facilities for E-mail and for file transfer.
- It is possible to mix the different types of communication, for instance to send a file while having an active call.
- It is possible to make calls or sent messages to a group of persons and to make an additional call without disconnecting the currently active call.

The goal was to make a multimedia terminal that was as easy to use as an ordinary phone.

In the *Pot1* terminal the set up of calls and the transmission of faxes were operated in different manners, whereas in the *Pot+* terminal they are operated in precisely the same manner. All services in the *Pot+* terminal are characterised by the following two parameters:

- *Type:* Voice, fax, E-mail or file transfer
- *Mode of transfer:* Real time or stored

The *Pot+* terminal can support services equalling all eight combinations of types and modes of transfer, for instance real time transfer of E-mail (teletype), or transfer of stored voice messages (voice-mail).

In addition, it is possible for the user to select the receiver of a message before *or* after the service and the particular message is selected. The user may for instance first compose a message and then decide who to sent it to, or the user may decide who he wants to communicate with and then decide if he wants to make a phone call or to sent an E-mail.

The user interface of the *Pot+* terminal has been implemented in Hypercard on a Macintosh computer. Even though the implementation does not include facilities for making an actual call, the implementation makes it possible to review the usability in details.

In the following the description of each function is written with normal letters, whereas the arguments for each part of the design are written with *italics.*

Keys and actuators on the user interface

The keys on the *Pot1* are all placed with a centre to centre distance of 15 mm and include:

- An ENTER/UNHOOK key labelled with *Enter* and an *Unhook* symbol.
- A QUIT/DISCONNECT key labelled with Quit and a Disconnect symbol.
- 3 function keys labelled A, B and C. These function keys are used as so-called soft keys: The function of each key in the actual state is written in the display directly above the key.
- 2 keys with vertical arrows and 2 keys with horizontal arrows used for adjusting the volume setting and for scrolling.

The ENTER/UNHOOK and QUIT/DISCONNECT keys are labelled so they are associated both to the communication functions used on a computer and to the communication functions used on a phone.

The soft keys are very well adapted to inattentive use and the use of browsing and trial and error:

- *The user shall only recognise the texts shown above each soft key, it is not necessary to recall any of the available functions.*
- *Soft keys can easily be used in a multidimensional structure, and as described in* ***9.6 Use of browsing and trial and error****,*

such a structure reduces the number of separate actions the user must do in order to operate the equipment.

- *The user does not have to recall the function of different function keys when the function depends on the specific state of the terminal.*
- *In each state only the information needed by the user in the actual moment is shown, making it easier for the user to select the proper action.*

Changing the volume setting

The *Pot+* is equipped with two keys with vertical arrows. These keys are used for changing the volume setting.

The two vertical arrow keys are also used for scrolling in lists, for instance the list over names and addresses of other subscribers. It is therefore not possible to change the volume setting while scrolling in a list.

The slightly inconsistent manner of operation of the volume setting may result in the user scrolling in a list by accident when he wants to change the volume. However, the risk of such an error and its consequences are slight.

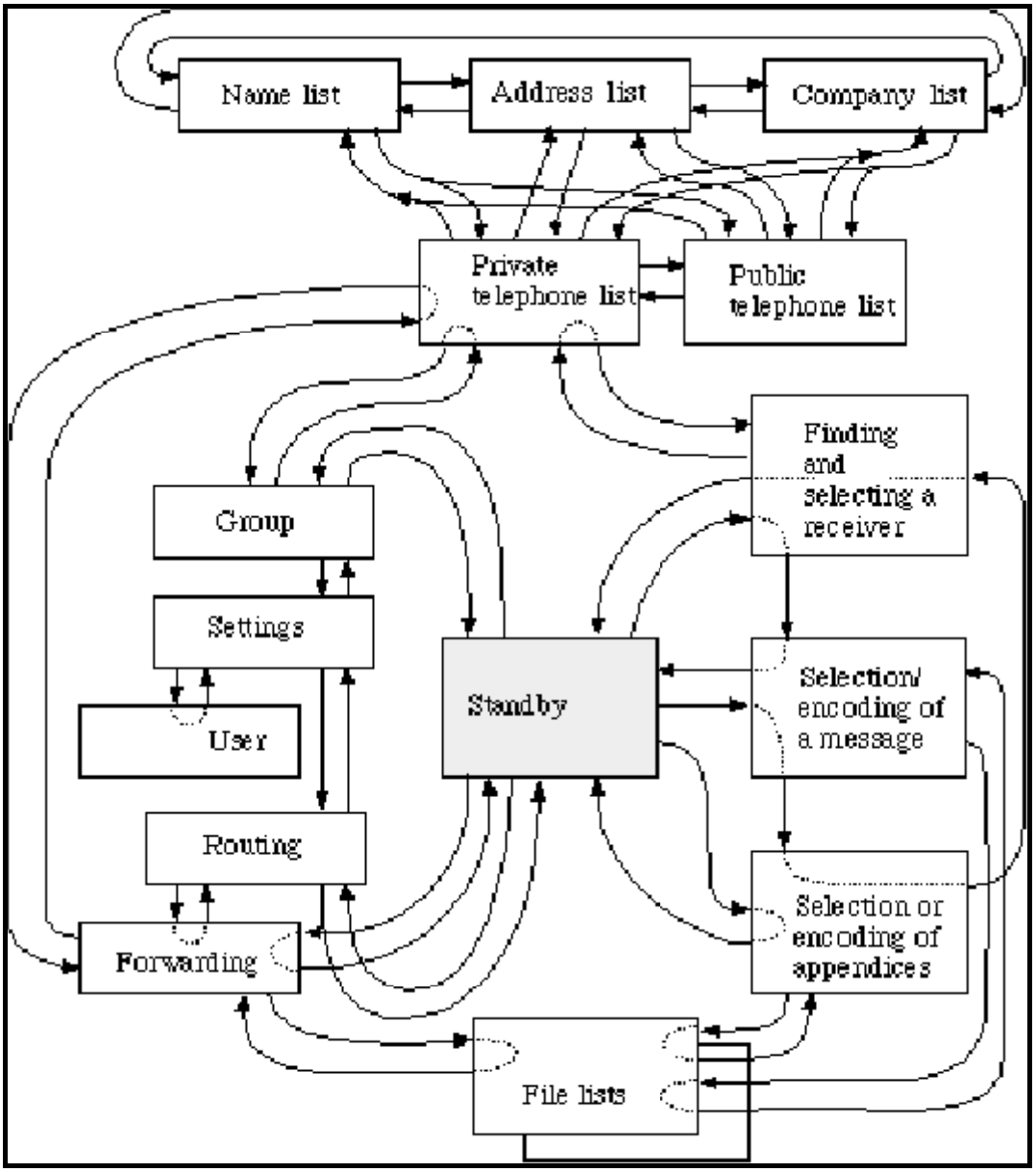
Selection of the number to be called

The number to be called can be selected in two different ways:

- *The number can be entered through the keypad* as an ordinary phone number.
- The receiver of the call or the message can be selected in one of three *private lists* showing names, addressees or companies of other subscribers, and where the user can change from one list to another by using the two keys with horizontal arrows. These private lists contain information about the subscribers the user earlier has called: The information about a person is downloaded from the public database of subscribers to the private lists when a call to the person is made for the first time.
- If the user cannot find the person he wants to call in the private lists, he can switch to the three *public list* showing names, addressees and companies of all subscribers in the system; the user can change from one list to another by using the two keys with horizontal arrows. The information in these lists are downloaded from the public database of subscribers.

The public lists are very long and resemble a normal phone book. When the user wants to scroll for a subscriber in the lists, the private lists are therefore selected by default.

If the user cannot recall the number of the person he wants to call, it is possible for the user to scroll for any known information about the person he wants to call. However, no further search facilities are included. It may therefore, for instance, be difficult for the user to find the number to be called, if he only can recall the first name of the person he wants to call.



State transition diagram for the *Pot+*. The diagram shows that the structure is non-hierarchical with a maximum number of paths between the different states

Making a voice call

The *Pot+* can be used for incoming and outgoing calls in the same manner as a normal telephone:

- If the *Pot+* rings with an incoming call, the name of the calling person will be shown if available, and the user can initiate the call by pressing the ENTER/UNHOOK key.
- If the user wants to make an outgoing call he shall simply press the ENTER/UNHOOK key after having selected the person or number to be called. If the user has not selected another service type, an ordinary voice call is default.

When the call is completed the user can terminate the call by pressing the QUIT/DISCONNECT key.

The Pot+ *draws the attention of the user when an incoming call arrives, and he can then initiate the call as part of an automatic process.*

If the user is inattentive and does not consider which type of service he wants, he will get an ordinary voice call by default. The Pot+ *will then function as an ordinary phone, and the operation will be supported by the habits of the user.*

When the user wants to terminate the call, he can press the QUIT/DISCONNECT key and terminate the call while focusing his attention elsewhere.

Making multiple calls

The user can make multiple calls in precisely the same manner as an ordinary call to a single subscriber:

- The user can define a group in the private lists. When the name of that group is selected and the ENTER/UNHOOK key pressed a conference call will be made with the members of that group.
- The user can make an additional call while having an active call, and after the second call is completed return to the first call.

In both cases the user will make the calls in precisely the same manner as when making a normal call while the Pot+ *is in standby.*

The Pot+ *is made for users that often work together in the same groups, for instance in a company. The* Pot+ *is therefore made such that it is easy to make a call to a group of users, but it is not made such that it is easy to include additional persons in a currently active call.*

Incidentally, groups of users are defined either by entering their phone numbers or by selecting them in the lists that are used for selecting the persons to be called. The definition of a group of users are therefore supported by the same habits as the making of an ordinary call.

Transmission of faxes, E-mail or voice-mail

The service type, for instance the transmission of a fax or an E-mail, can be selected either before or after the receivers of the message have been selected, and the fax or E-mail will normally be transmitted immediately after it has been composed or selected.

Any incoming faxes, E-mails or transferred files are announced to the user, and if he sends an immediate reply to the person who has sent the message the result will resemble the conversation during a normal voice call. It is possible to do something resembling a conversation in real time, even though the use of stored messages are default for faxes, E-mail and file transfers.

As earlier described, real time conversation is default for voice messages: If the user tries to make a normal voice call but does not get any answer within

a pre-set period of time, the call is automatically changed into a voice-mail message.

It is possible for the user to change between all the possible services while focusing a minimal amount of attention on the selection of the service to be used.

The reception of incoming faxes, E-mail or faxes is made as a compromise between two conflicting requirements: The Pot+ *shall announce for the user when a fax, E-mail or file arrives so he can take appropriate action, but the* Pot+ *shall not disturb the user so he cannot complete the task he is carrying out. The conflict is solved by making the* Pot+ *announce twice with a proper sound signal that a new message has arrived and showing the arrival of a message in the display, but with no request for acknowledgement from the user.*

Changing the settings of the *Pot+*

The user can by using the two keys with horizontal arrows scroll through the functions used for changing the different settings, use the soft keys for selecting functions and the vertical arrow keys for scrolling between different choices, and he can undo any choice by pressing the QUIT/DISCONNECT key.

Such a scrolling can be done when the *Pot+* is in standby or during an active call, but it cannot be done when the keys with horizontal arrows are used for moving from one list to another during the selection of the receiver of a call, a service type or message to be sent.

The user can scroll through three groups of settings, where each group gives direct access to three soft keys that each can change a setting. It is therefore possible to reach up to nine different settings by doing on the average two physical actions, and to reach 27 different settings by doing on the average three physical actions.

When one of the horizontal arrows or one of the soft keys has been pressed, it is always possible to undo *the choice by pressing just one key, and it is in addition possible at each level to move sideways to the neighbouring settings: If the user for instance has pressed the soft key that opens the settings of an* automatic call transfer, *he can use the horizontal keys for moving over where he can change the* blocking of calls. *This means that the user can browse downwards and upwards or sideways in the different settings.*

The result is a multi-dimensional structure that is well suited for browsing or trial and error as described in subchapter ***9.6 Use of browsing and trial and error****.*

Quantitative evaluation of the *Pot+*

In this quantitative evaluation, only the points with larger than ideal values are listed (the values for the Pot1 are shown in brackets):

Problem points describing how the equipment presents itself to the user:

1.1	Ratio between the number of elements presented from right to left or from bottom to top and the total number of presented elements	0	(1)	
1.2	Blurring, jagged edges or parallax of elements shown on a used screen or any distracting patterns from drivers or others on a display	- *	(0)	
1.4	Ratio between 11 mm and the height of the presented text in mm	4	(1.8)	
1.5	Ratio between 1 mm and the line width of the presented elements or icons in mm		2	(-)
1.9	Ratio between the number of icons the user cannot easily associate with one word describing their meaning and the total number of presented elements		0	(0.16)
1.11	Number of states where the equipment does not draw the attention of the user when the user should pay attention to it		-*	(0)
1.12	Number of states where the equipment draws the attention of the user when it is unnecessary for the user to pay attention to it		1? **	(0)

Problem points describing how the user must decide upon an action and initiate it:

2.1	Number of states		14	(24)
2.2	Ratio between the number of hidden states and the total number of states		0	(0.17)
2.3	Ratio between the number of states and the total number of connections between the states		0.3	(0.2)
2.4	Average distance between the states	1.9	(2.4)	
2.7	Total number of functions		11	(26)
2.8	Average number of separate actions needed for activating each function		3.6	(1.8)
2.9	Average number of actions that shall be done in order to complete a task		5.0	(7)
2.10	Average number of functions making use of each actuator		1.2	(1.8)

* These values cannot be determined for a simulated prototype.

** It can be discussed whether or not the terminal shall draw the attention of the user when an E-mail, fax or file arrives.

2.12	Ratio between the number of choices that cannot be undone in one operation and the total number of choices	0.17	(0.30)	
2.13	Number of choices that cannot be undone and where no request for acknowledgement is made		8	(9)
2.14	Ratio between the number of cases where the next action in a task is not clearly indicated and the total number of states		0	(0.08)

Problem points describing the physical actions the user must make when operating the equipment:

3.1	The number of sharp edges or protruding parts on the equipment	-*	(0)	
3.2	The number of situations where the user cannot change his position or must grip the equipment with a constant muscular force while using or carrying it		-*	(0)

3.3	The number of actuators that can be activated by accident while the equipment is not used, for instance while it is carried	-*	(0)
3.4	The ratio between the number of physical actions where continuous visual guidance is necessary and the total number of physical actions	0.5	(0.5)
3.11	Number of knobs that are not resilient - *	(0)	
3.12	The ratio between 18 mm and the average of height and width of keys in mm	1.2	(1.2)
3.13	Number of keys without tactile feedback at the depression where they are activated - *	(All)	
3.14	The ratio between 3 mm and the distance from the depth of depression in mm where the keys are activated to the lowest position of them - *	(3)	
3.15	Number of keys without a resilient bottom	- *	(0)

* These values cannot be determined for a simulated prototype.

Comments to the quantitative evaluation.

Even though the *Pot+* contains more functions than the *Pot1,* the structure of it is simpler and it is much better adapted to inattentive use.

The quantitative evaluation shows that the values are better than the ones determined for the *Pot1* terminal. The only exceptions are the figures for letter size and widths of the lines used in icons, and a slightly lower figure for the number of connections between the states/number of states.

The quantitative evaluation shows also that the largest remaining problem is the large number of choices that request no acknowledgement from the user and that cannot easily be undone.

Classification of the usability of the *Pot+*

If ordinary phone calls and the transmission and reception of faxes, E-mail and files all are considered elementary use, the Pot+ can be classified as:

> *2.: Elementary use is easy, though other use, programming or adjustment is cumbersome.*

A higher classification is primarily not given because *groups of receivers of calls* cannot easily be defined in the *Pot+*.

It is, however, shown that a new multimedia terminal can be made that is easier to use and better adapted to inattentive use than the *Pot1* terminal described in **13.2 *Pot1:* Usability of a combined phone and fax terminal**, even though the new terminal offers more functions than the *Pot1* terminal.

14.3 *GEOSM:* A COMMUNICATION TERMINAL FOR INATTENTIVE USE

As the name suggest the *GEOSM* terminal is made for the GSM cellular phone system. It fulfils the requirements described in subchapter **14.1 An example of official requirements for communication equipment**

including the reception of short written messages, and in addition it may offer access to *manual call transfer*. That function is currently not implemented in the GSM system, but it can be implemented in local cordless systems based on the same principles as the GSM system.

The functions offered by the *GEOSM* are very similar to the functions offered by the *GSM1*. There are, however, a number of significant differences:

- The functions of the *GEOSM* are more consistent than the functions of the *GSM1:* It is for instance possible to adjust the volume in the same manner in most of the states of the *GEOSM*.
- The *GEOSM* is only made with one list for numbers to be called. The user can therefore scroll between the last numbers called or entered on the notepad and any numbers or names that are precoded in the number list.
- The different functions are much more integrated in the *GEOSM*. The functions for *call waiting* and for making a *conference call* are for instance integrated with the functions used for making an ordinary call.

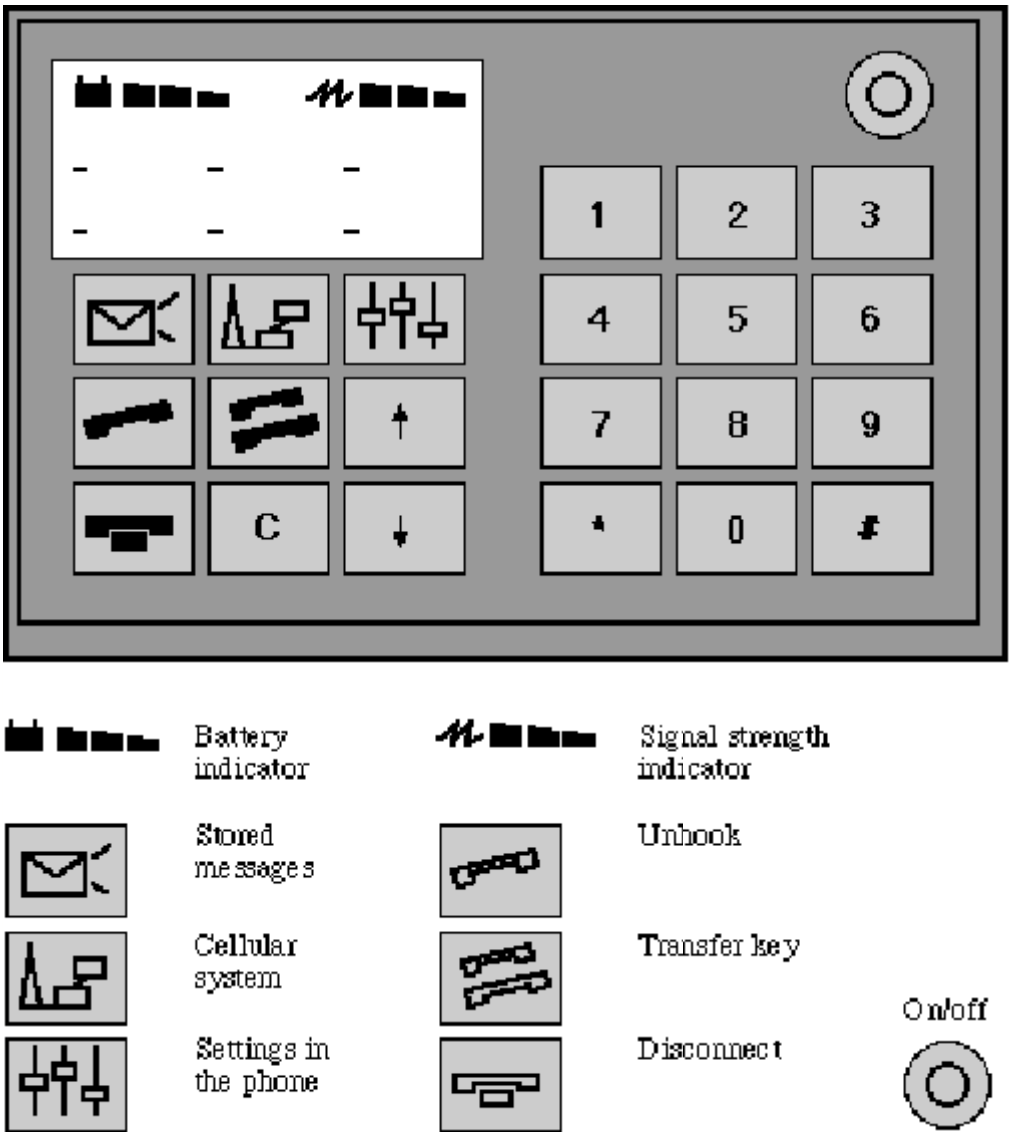
The user interface of the *GEOSM* terminal has been implemented in Hypercard on a Macintosh computer in the same manner as the user interface of the *Pot+*. Even though the implementation does not include the functions for making an actual call, the implementation makes it possible to review the usability in detail.

In the same manner as for the *Pot+* the description of each function is written with normal letters, whereas the arguments for its design are written with *italics.*

Keys and actuators of the user interface

The keys on the *GEOSM* are all placed with a centre-centre distance of 15 mm and include:

- An UNHOOK key labelled with an *Unhook* symbol.
- A DISCONNECT key labelled with a *Disconnect* symbol.
- A TRANSFER key labelled with the *Transfer* symbol.
- A C key used for clearing the last entered digit or for returning to the former state or standby.
- An ARROW UP key and an ARROW DOWN key labelled with arrows up and down.
- 3 function keys labelled with icons for *Stored messages, Cellular system* and *Settings*. These function keys are used as so-called soft keys where the function of each key in the actual state is written above the key. When no function is written in the display above the keys, their functions are given by the icons on them.



User interface (front) of the GEOSM

The keys show all icons without any text, because there is not sufficient space for a meaningful text on each key. The icons are not immediately understandable, but when their meaning is learned, it is easy to make an association from each icon to the function of the key.

The three function keys are used as soft keys and offer the same advantages as described for the Pot+ *in subchapter* ***14.2* POT+: *an integrated multimedia terminal****. During standby the three function keys have the functions that are indicated by the icons on the keys themselves. It is therefore not necessary during standby to use a line in the display for indicating the functions of the keys—the full display can be used for showing pertinent information.*

Turning the *GEOSM* on and off

The *GEOSM* is turned on by pressing the ON/OFF key, entering the requested Pin code and pressing the UNHOOK key.

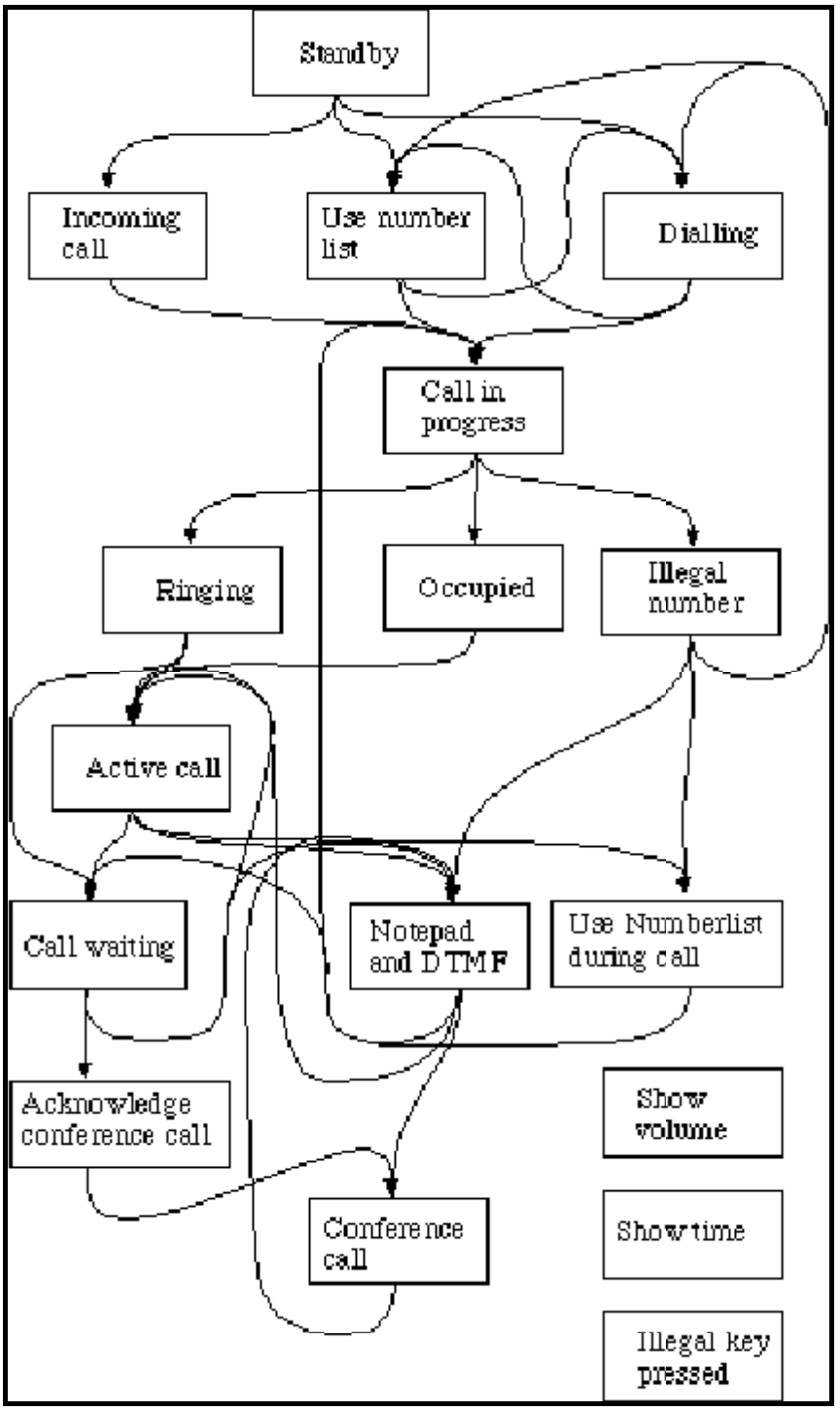
The *GEOSM* is turned off by pressing the ON/OFF key.

In most cases a number entered in the GEOSM *is followed by the depression of the UNHOOK key. When the* GEOSM *is turned on as part of an automatic process, the user will therefore by habit press the UNHOOK key.*

Changing the volume setting

The volume control is operated by pressing the ARROW UP and ARROW DOWN keys: The ARROW UP key is pressed for increasing the volume and the ARROW DOWN key for decreasing the volume. The arrow keys can be used for changing the volume in all states except when the user is scrolling in a list: The arrow keys are then used for scrolling up and down in the list, and an arrow icon, signifying scrolling up and down, is at the same time shown in the display.

The slightly inconsistent manner of operation of the volume setting may result in the user scrolling in a list by accident when he wants to change the volume. However, the risk of such an error and its consequences are slight.



State transition diagram for the GEOSM. The diagram shows only the paths related to the making of a call, not the paths related to the STORED MESSAGES, CELLULAR SYSTEM and SETTINGS keys. The diagram shows in particular the many states of an ordinary phone call.

In addition to the paths between the states shown on the diagram, it is always possible to return to the Standby state by pressing the DISCONNECT key one or more times.

Selection of the number to be called

The number to be called can be selected in the three following manners:

- Pressing the UNHOOK key opens the number list containing the last three numbers that have been entered and in addition up to 10 precoded numbers or names that each are linked to a number. It is then possible to scroll up and down in the list by using the ARROW UP and ARROW DOWN keys.
- Pressing the TRANSFER key recalls a precoded number or prefix.
- By entering the number to be called on the numerical keypad. When a number is entered in that manner, it is possible to delete the last entered digit by pressing the C key. In addition it is possible to recall the proper prefix for making an international call by entering * *. If a precoded number already has been selected in the number list or by pressing the TRANSFER key, the entered digits will be appended to the selected number.

While a number is selected in the number list it is not possible to adjust the volume: The ARROW UP and ARROW DOWN keys are used for scrolling in the list. However, while a number is entered on the numerical keypad it is still possible to use the arrow keys for changing the volume setting.

Changing between the two different ways of entering a number, between scrolling in the number list and entering a number on the numerical keypad, is done as follows:

- The user can change from selecting a number in the number list to entering a number on the numeric keypad simply by entering one digit.
- The user can change from using the keypad to selecting a number in the number list by returning the GEOSM to standby by pressing the C key repeatedly or by pressing the DISCONNECT key, and then pressing the UNHOOK key.

All stored numbers are stored in the same list, it is therefore not necessary for the user to recall in which list a particular number is stored: He can simply scroll down in the one list until he finds the number. It is therefore easier for the user to find a sought for number without focusing his attention on the actions done for finding it.

Pressing the TRANSFER key recalls a precoded number: Either a number for emergency calls or an often used prefix can be recalled in that manner while focusing only a minimal attention on the operation.

Similar to the Pot+ *it is a definite advantage that the user can delete a wrongly entered digit, so that he can correct an error without entering the whole number all over. It is easier for the user to enter a number when the consequences of an error are smaller.*

When changing from using the number list to entering a number on the numerical keypad, the user must press the C or the DISCONNECT key before he enters the first digit. The user cannot simply start entering the number while he is using the number list.

However, the method used for changing from scrolling in the number list and entering a number on the keypad makes it possible for the user to store parts of numbers, making it unnecessary to enter all digits in all cases.

The use of the arrow keys for setting the volume during the entry of a number on the keypad makes it impossible to change from entering of a number through the keypad to scrolling in the number list simply by pressing a single key: The user can only make the change by pressing the C key repeatedly or the DISCONNECT key and when the GEOSM *returns to standby press the Unhook key and open the number list in the normal manner.*

However, the ARROW UP and ARROW DOWN keys had to function in the same manner when the user entered a number to be called and when he entered DTMF digits or a number to the Notepad during a call, and it was essential that the user at any time during an active call could adjust the volume setting. In order to accomplish that it was accepted to make the change from entering a number on the keypad to scrolling in the number list a little bit more difficult.

Making a voice call

The voice call can either be incoming or outgoing:

- If the *GEOSM* rings with an incoming call, the user normally initiates the call by pressing the UNHOOK key. However, if the *Auto answer function* is enabled the *GEOSM* will automatically unhook after approx. 4 s.
- If the call is outgoing, the user initiates the call by pressing the UNHOOK key when he has selected the number to be called. If the call is selected by entering a number, and the name of the called person is stored in the number list, the name of the called person will be shown in the display of the *GEOSM* as an additional confirmation.

In addition it is possible to make automatic outgoing calls:

- The *GEOSM* can optionally make a call to a number recalled by pressing the TRANSFER key. Such a call is made approx. 7 s after the TRANSFER key has been pressed if no other keys has been pressed.
- If the called number is occupied, the user can activate an automatic redial by pressing the UNHOOK key while hearing the *Occupied tone*.

When the call is completed the user can terminate the call by pressing the DISCONNECT key.

The GEOSM *draws the attention of the user when either an incoming call arrives or when an outgoing call is answered, and the user can then initiate the call as part of an automatic process.*

It is in particular possible for the user to set the GEOSM *so it unhooks automatically freeing his attention and hands.*

If the user has made the call by entering the number to be called, the displayed name may serve as an additional confirmation: It is easier to see that names with words of different lengths and letters of different heights are different than to see that a displayed number is different from the expected one. The display of the called name makes it therefore possible for the user to perceive at a glance if he has entered the wrong number.

In addition the user can terminate a call while focusing his attention elsewhere.

If the called number is occupied the user can activate an automatic redial in precisely the same manner as when he makes an ordinary call.

The making of a call is well adapted to inattentive use: The start and termination of calls can be done by habit because they in all cases are activated by precisely the same physical actions.

Transmission of DTMF tones

If a key with a digit is pressed during an active call, the associated DTMF (Dual Tone Multiple Frequency) tone is sent. Digits coded as DTMF tones can for instance be used for selecting an extension line in a local phone system or be transmitted to a pager.

This function is well suited for inattentive use: It is simple and is operated in precisely the same manner as the entry of a number to be called on the GEOSM *and on an ordinary phone.*

Use of a Notepad function

This function is used for storing a phone number during an active call, for instance if the remote user suggests that the user calls a certain number.

When a number is entered during an active call and transmitted as DTMF tones, it will be stored when no digits have been entered during the last approx. 7 sec.

The number will be placed at the top of the number list, and the user can recall it by pressing the UNHOOK key.

The notepad is used during an active call, and it is well suited for inattentive use: The user shall not do any additional operations, but only enter the number to be stored.

Call waiting

The user can get a *Call waiting* if during an active call either his phone is called or he makes an additional call.

If the user is called while in the middle of an active call, the function alerts the user with a *beep,* and the display on the *GEOSM* shows the text *Call waiting.*

The user makes an additional call while having an active call in precisely the same manner as an ordinary call: By entering the number and pressing the UNHOOK key, or by selecting the number or name to be called in the number list and pressing the UNHOOK key.

If the user presses the UNHOOK key, the active call becomes the waiting call and the waiting call becomes the active one: The user can change back and forth between two simultaneous calls.

If the user presses the DISCONNECT key while another call is waiting, the active call will be disconnected and the *call waiting* becomes the active one.

The operation of the call waiting function is well suited for inattentive use:

- *The user makes an additional call in precisely the same manner as when he makes an ordinary call.*
- *The user makes a* call waiting *active in the same manner as when he makes any other call.*
- *The user can change back and forth between the two calls by doing only one physical action.*
- *The termination of a call is done in precisely the same manner as when there is no* call waiting.

It is therefore easy for the user to operate the call waiting *functions as part of an automatic process.*

Making a conference call or transferring a call

When the user has an active call and another waiting call, he can convert them to a conference call, a 3-party call, by pressing the TRANSFER key, and acknowledging the conference call by pressing the TRANSFER key a second time after a pre-set delay of approx. 0.7 s.

If the DISCONNECT key is pressed during a conference call, the *GEOSM* is disconnected whereas the two remote users can continue the call: That function can be used for transferring a call to another phone. However, the function is not implemented in the current GSM system, but can only be used in systems with additional facilities.

The conference call and manual call transfer are integrated with the ordinary calls and call waiting functions. The user can therefore with minimal attention add a call waiting to an ordinary call and convert the active call and a call waiting to a conference call.

However, it may be inconvenient if an active call and a call waiting are converted into a conference call by accident. It is therefore necessary to acknowledge the conference call before it is set up. The acknowledgement is made in the same manner as the request for a conference call: by pressing the TRANSFER key. This means that the user in some cases might activate a conference call by pressing the TRANSFER key twice as part of an automatic process or by accident. The second depression of the TRANSFER key is therefore only accepted after a delay, making it impossible to press the TRANSFER key rapidly twice in succession.

Showing the duration and price of the last call

The *GEOSM* shows the price and duration of the last call while the DISCONNECT key is depressed.

When the call is completed., the user can therefore with a minimal amount of effort perceive the price of the call.

Changing the settings of the *GEOSM*

All the functions that are not used during a call are accessed by pressing one of the three soft keys. Each of these keys gives access to a set of functions indicated by the icon on the key:

- The key STORED MESSAGES gives access to the functions used for listening to voice-mail messages, reading a short message or writing a short message to be transmitted.
- The key CALL CONTROL gives access to setting the *automatic call transfer*, blocking for incoming or outgoing calls and the setting of any preferences for use when selecting the service provider.
- The key SETTINGS gives access to changing the settings of the *GEOSM*, for instance the Pin code, precoded names and numbers in the number list and the tone used for drawing the attention of the user when the *GEOSM* is called or when a short message arrives.

In every state it is possible to return to the state above by pressing the DISCONNECT key, whereas the confirmation of a selected value is confirmed by pressing the UNHOOK key.

The use of soft keys means that the number of choices on each level can be three times larger than the number of choices at the level above, and the total structure can therefore be very flat: The lowest level of choices can be reached by pressing at the most only three keys. On that level the user can scroll between the choices by using the arrow keys.

The structure for the GEOSM *is adapted to inattentive use in two ways:*

- *It is not necessary for the user to use the soft keys for changing any settings while he is in the middle of an active call. It is possible to operate all call related functions as part of an automatic process.*
- *The soft keys make it possible to show in clear text the function of each soft key in each state, and it is always possible to backstep one level. The structure is therefore well adapted to browsing or trial and error as described in* ***9.6 Use of browsing and trial and error*** *where the user looks for a particular element while devoting minimal attention to the search.*

Quantitative evaluation of the *GEOSM*

In this quantitative evaluation, only the points with larger than ideal values are listed (the values in brackets are for the GSM1):

Problem points describing how the equipment presents itself to the user:

1.2	Blurring, jagged edges or parallax of elements shown on a display or any distracting patterns on a display	- *	(0)	
1.4	Ratio between 11 mm and the height of the presented text in mm		3.7	(2.8)
1.5	Ratio between 1 mm and the line width of the presented elements or icons in mm		2	(2)
1.8	Ratio between the number of elements whose meaning cannot be discriminated from the meaning of other elements after the reading of only a single word and the total number of elements presented in verbal form	0.3	(0)	
1.9	Ratio between the number of icons the user cannot easily associate with one word describing their meaning and the total number of presented elements		0.3	(0.4)
1.11	Number of states where the equipment does not draw the attention of the user when the user should pay attention to it		-*	(1)

Problem points describing how the user must decide upon an action and initiate it:

2.1	Number of states		36	(39)
2.2	Ratio between the number of hidden states and the total number of states		0	(0.08)
2.3	Ratio between the number of states and the total number of connections between the states		0.6	(0.9)
2.4	Average distance between the states	3.1	(6.5)	
2.6	Ratio between elements with misleading labelling and the total number of elements		0	(2)
2.7	Total number of functions		34	(41)
2.8	Average number of separate actions needed for activating each function	3.5	(8.8)	
2.9	Average number of actions that shall be done in order to complete a task		6.3	(8.9)
2.10	Average number of functions making use of each actuator	1.5	(1.8)	
2.11	Ratio between the number of actions in each task that has to be done in a specific order and the total number of actions necessary for each task		0	(1)
2.12	Ratio between the number of choices that cannot be undone in one operation and the total number of choices	0.06	(0.2)	
2.13	Number of choices that cannot be undone and where no request for acknowledgement is made		1	(14)
2.14	Ratio between the number of cases where the next action in a task is not clearly indicated and the total number of states		0.03	(0.3)

* These values cannot be determined for a simulated prototype.

Problem points describing the physical actions the user must make when operating the equipment:

3.1	The number of sharp edges or protruding parts on the equipment	- *	(0)
3.2	The number of situations where the user cannot change his position or must grip the equipment with a constant muscular force while using or carrying it	- *	(1)
3.3	The number of actuators that can be activated by accident while the equipment is not used, for instance while it is carried	- *	(8)
3.4	The ratio between the number of physical actions where continuous visual guidance is necessary and the total number of physical actions	- *	(1)
3.11	Number of knobs that are not resilient	- *	(0)
3.12	The ratio between 18 mm and the average of height and width of keys in mm	1.3	(1.3)
3.13	Number of keys without tactile feedback at the depression where they are activated	- *	(All)
3.14	The ratio between 3 mm and the distance in mm from the depth of depression where the keys are activated to the lowest position of them	- *	(0.3)
3.15	Number of keys without a resilient bottom	- *	(All)

* These values cannot be determined for a simulated prototype.

Comments to the quantitative evaluation.

The most serious design problem identified during the quantitative evaluation was the number of texts where the meaning depended on the reading of more than one word. It is, however, possible this particular problem can be alleviated by modifying some of the texts.

According to the quantitative analysis the *GEOSM* is as good as or better than the *GSM1* on most points that can be determined when only a simulated prototype has been made of the *GEOSM*.

Classification of the usability of the *GEOSM*

The *GEOSM* can be classified as:

> *2.: Elementary use is easy, though other use, programming or adjustment is cumbersome.*

Compared to the *GSM1* the *GEOSM* offers fewer functions, but the functions available in the *GEOSM* are better integrated and easier to operate for the user. The result is therefore that the user easily can access most of the functions in the *GEOSM* and in particular can operate them during inattentive use.

14.4 INATTENTIVE USE AND THE GOAL OF COMMUNICATION EQUIPMENT

The ultimate goal of communication equipment is to make the user completely unaware of it. The user should ideally feel that he is in the same room as the persons he is communicating with.

One step in that direction is to make communication equipment the user can operate while focusing his attention on something else.

Implementation of the requirements for inattentive use

The *POT+* can be implemented in a normal fixed or cellular phone system. However, it will function vastly better if the system makes it possible to make an additional call while having an active call, and if a conference call for more than three persons are supported by the communication system.

The *GEOSM* terminal can be used in the current GSM system. However, it will become more useful in a system where it is possible to make one call while having another active call, and where *manual call transfer* is supported. Both of these facilities can be offered in local, PABX, systems for cordless communication.

The prototypes of the *Pot+* and the *GEOSM* show that it is possible to implement the different requirements for inattentive use in communication terminals. However, details in the design can be crucial for inattentive use of the terminal, and all parts of a terminal for inattentive use must therefore be adapted to the inattentive use.

A comparison between the *Pot1* and the *GSM1* terminals described in chapter **13. Evaluation of communication equipment** and the *Pot+* and *GEOSM* terminals shows that the inattentive use of the equipment can be made significantly easier by modifying only a few details in the design. *The difference between a terminal that is well suited for inattentive use, and another terminal that only with difficulty can be used by an attentive user is often slight.*

Inattentive use and a virtual meeting

Communication equipment that can be operated while the user focuses his attention on something else can ultimately be used in a manner that resembles a virtual meeting: The participants can communicate freely without paying any attention to the terminals, they can talk, interrupt each other, and, if fax or file transfer facilities are included, pass pictures and documents back and forth.

The user will probably always be aware of the equipment, but he will not think about its use or availability.

Such a virtual meeting cannot fully replace a meeting where the participants are physically close, but it can provide vital information and a feeling of comfort to persons who, for some reason or another, are physically separated from their co-workers.

> When two minds of high order, interested in kindred subjects, come together, their conversation is chiefly remarkable for the summariness of its allusions and the rapidity of its transitions. Before one of them is half through a sentence the other knows his meaning and replies. Such genial play with such massive materials, such an easy flashing of light over far perspectives, such careless indifference to the dust and apparatus that ordinarily surround the subject and seem to pertain to its essence, make these conversations seem true feasts for gods to a listener who is educated enough to follow them at all.
>
> William James [1890: 992]

15. DESIGN OF EQUIPMENT FOR INATTENTIVE USERS

This chapter describes the methods that can be used when designing a user interface or a piece of electronic equipment for inattentive use.

The design of electronic equipment for inattentive use is much more demanding than the design of electronic equipment for attentive users that through intelligence, diligence and careful reading of the user guide can obtain the desired results when operating the equipment.

The success of a particular design depends on the process that leads to it and on the methods and descriptions applied in the design. If a fundamental but wrong decision is made at an early state in the design process, it may be next to impossible to design a user interface that fulfils the requirements, and if the proper methods and descriptions of the design are not applied, the designer may not even become aware of some of the errors in the design.

Ideally, the design methods should make it possible to reach the best possible result with the least possible effort.

That is only possible if the design is based on a precise description of the users dispositions and the situations experienced by the user. The design process described in this chapter is therefore divided into two different phases: *During the first phase the purpose and functions of the equipment and the thoughts and behaviour of the user are described, during the second phase theory and creativity are combined in the actual design of the user interface.*

15.1 DESCRIBING THE PURPOSE AND FUNCTION SET OF THE EQUIPMENT

A piece of electronic equipment for inattentive use will only be successful if it offers functions that make it significantly easier for the user to produce a useful result with the equipment than without it, and it is therefore essential that both the general purpose and the functions of the equipment are properly defined.

This subchapter describes how the purpose, tasks or paths and functions of the equipment can be specified in a manner consistent with inattentive use.

The specification of the purpose, tasks or paths and functions of a piece of equipment is demonstrated with examples from the design of a kitchen timer similar to the timers described in subchapter **9.4 Making useful associations**.

Information sources

The functions defined for the equipment shall adhere to the requirements stated in and derived from the following three sources of information:

- Guidelines given at the start of the design process. The persons paying or authorising the design of a new piece of equipment will often list some requirements that should be fulfilled by the equipment. In addition it is possible that the product shall fulfil a particular set of standards or requirements; a GSM phone shall for instance fulfil the requirements stated by ETSI, as described in subchapter **14.1 An example of official requirements for communication equipment**, and normal telephone equipment shall fulfil a number of requirements stated by the international telecommunications authorities.
- Functions and facilities in already existing pieces of equipment. It is the rule rather than the exception that similar pieces of equipment already are in use. In subchapter **13.3 The development of communication equipment** it is for instance described how the functions in existing communication equipment seemingly is developed from the functions in earlier, more primitive, pieces of communication equipment. In such cases, the users operation of a new piece of equipment is influenced by habits and conceptions acquired when operating earlier types of equipment, and it is therefore often advantageous if the functions in a new piece of equipment resembles the functions already conceived by the user.
- Descriptions of the users thoughts and behaviour in the situations when he will use the equipment. Without such a description it is very difficult to improve the operation of the equipment, because both guidelines for the design and any information derived from existing equipment are oriented backwards, away from the actual user.

The final set of functions specified for the equipment should as well as possible fit the information from the three sources above, and the functions should be as precisely defined as possible before the rest of the design is begun. However, it may be necessary to *modify* the description of the functions later during the design, for instance when it becomes necessary to find or test solutions of specific design problems.

Information sources for the design of a kitchen timer.

The following information sources can be used when designing a kitchen timer:

- Functions and facilities in already existing pieces of equipment. These are described in subchapter **9.4 Making useful associations**.
- A description of the users thoughts and behaviour in the situations when he uses the kitchen timer. Such a description shall be shown in the following subchapter **15.2 Describing the thoughts and behaviour of the user**.

Use of current task analysis

The definition of the functions and their relations are described as "task analysis" by Bass and Coutaz [1991: 20]:

> Developing the task hierarchy is more difficult than selecting the basic operations on task objects, for the hierarchy contains assumptions about how the operator will solve the problems posed by the task domain. Consequently, we must rely on informal analysis of the data gathered during the building of a model of the operator. One way to exploit the experimental data is to identify the major task groups that sit on top of the hierarchy and place the task object operations at the bottom of the hierarchy. The intermediate levels are then filled in by working down from the top levels and up from the bottom levels, attempting to match the results from the two directions. That is, scenarios are generated that describe the type of problems the operator will wish to solve and these scenarios are then examined in an effort to infer an appropriate task hierarchy.

Tasks analysis as described here raises two problems:

- It is based on assumptions about how the operator will solve problems posed by the *task domain,* that is in the particular situations when he uses the equipment, and these assumptions are based on a model or a description of the user. Even if the description of the user is based on the actual behaviour of human beings as described in chapter **7. Thoughts with and without attention** and in chapter **9. Associations, impulsive power and effort**, it will be very difficult to make any valid assumptions about how the user will solve specific problems during the operation of the equipment. If the user employs browsing or trial and error as described in subchapter **9.6**, it is even likely that he at different occasions will solve the same problem in different manners.
- Bass and Coutaz describe a hierarchy of tasks, presumably a tree-like structure where each task at the top level can be broken down into a number of subtasks. However, it is often not possible to fit all the tasks into such a hierarchy, for instance because one *task object operation* often is part of different task groups, or because each task at different times can be made up of different *task object operations.*

The task analysis presented by Bass and Coutaz raises problems that are difficult to solve, it offers no specific clues as to how the different tasks can be classified, and without such a classification it is difficult to create a structure covering all the different tasks and the results of their fulfilment.

Bass [1993: 38-39] classifies the different tasks as either "Abstract level tasks", "Metaphor level tasks", or belonging to the "Concrete task level", but his classification bears very little resemblance to the manner in which a user may conceive of the different tasks.

I will therefore introduce a descriptive structure consisting of 4 levels:

1. *The purpose* stated for the equipment.
2. *The tasks* made possible by the equipment.
3. *The functions and options* implemented in the equipment.
4. *The actions* the user can do when operating the equipment.

Level *1* to *3* should be completed when the purpose and functions of the equipment is described, whereas it is necessary to design the actuators and the format of the user interface before level *4* with the possible actions can be described. The possible actions should therefore not be described together with the function set and purpose of the equipment but should be described as part of the actual design of the user interface.

The purpose of the equipment

The purpose of a given piece of electronic equipment can often be expressed in one sentence, and that sentence is the most general information about the tasks made possible or facilitated by the use of the equipment.

For a cellular phone as *GEOSM* described in subchapter **14.3**, the purpose may be stated as follows:

> *The phone makes it possible to talk with remote users at other phones in the public telephone system, and to receive and transmit short text messages.*

The purpose of a given piece of electronic equipment is often expressed as a *declaration of intent* rather than of *fact,* for instance *The phone should make it possible to communicate with.., The phone is designed for verbal conversations...,* or *The phone should hopefully facilitate....*

It makes sense to express the purpose of the equipment as a goal instead of as a reality in a requirement specification; however, as seen from the examples above, a goal tends to be wordier and more vague than a stated reality.

The purpose of the equipment is normally the most essential part of the design goal, and it is normally stated before the design starts. If it is not changed during the design of the equipment, it can be used as a guideline during the design and evaluation, minimising the risk of the design *slipping,* in particular if it also is ascertained by reviews or usability tests that the equipment can fulfil its purpose under the circumstances where it normally is operated.

Purpose of a kitchen timer

The description of the purpose of a kitchen timer was gradually improved; the first description was:

> *The kitchen timer shall give an alert when a pre-set period of time has expired.*

That is a description of an intent rather than a fact: It is not a very bad description; however, it is not a very precise description either.

The next description of the purpose was somewhat improved:

> *The kitchen timer gives an alert when a pre-set period of time has expired.*

That description of the purpose is still not satisfying: The alert from the kitchen timer is necessary but not an end in itself. The stated purpose can therefore be fulfilled even though the user cannot hear the alert in the situation when the timer is used.

The purpose of the kitchen timer was then finally described as:

> *The kitchen timer draws the attention of the user when a pre-set period of time has expired.*

That description of the purpose of the timer is satisfying: It describes the final result of the use of the timer, namely that it draws the attention of the user after a pre-set period of time.

Tasks and paths

The user operates the equipment in order to accomplish some sort of desired outcome. He will activate a number of functions until he perceives that he has reached such an outcome, or in other words carried out a task.

The user will activate one function after the other, and *each of the users operations are therefore analogue to a progression along a path.* In some cases the user can complete the task by use of an automatic process similar to a path leading directly to the goal, in other cases the user may follow a long and twisted path through the different functions presented by the equipment.

It is therefore necessary to define each task in two different ways:

- According to the expected result of it, an outcome that is useful or desired by the user. Such a result may for instance be the transmission of a short message to a remote user of a cellular phone.
- According to the different paths that may lead to its conclusion. If the task consists of the transmission of a message, one path may consist of
  entering the message, selecting the receiver in a short number list and finally *pressing the transmit button.* Another, and equally valid, path may consist of *dialling the number the message shall be send to, entering the message, entering another message instead of the first* and *setting the transmission to occur at a predetermined time.*

The tasks are essential for the users understanding of the equipment, and they should therefore be reflected in the structure of the equipment:

- The user will normally start operating the equipment because he wants to accomplish a particular result. The structure of the user

interface as presented to the user should therefore be divided according to the different results the user can accomplish, that is according to the different tasks.

- The paths through the equipment determine the order in which the user will operate the different functions, and the most frequently used paths should therefore be as easy to follow as possible—they should be supported by suitable guidance and requiring only a minimal number of actions.

Tasks related to a kitchen timer

The user may do the following tasks related to the timer:

1. Set the timer and stop it when an alarm sounds after the timer has expired.
2. Set the timer without stopping the alarm after the timer has expired.
3. Set the timer and stop it before the timer has expired.
4. Restart the timer with a previously set time.

At first glance it may seem that task 1 fully describes the operation of a kitchen timer. However, users will often do one or more of tasks *2* to *4:*

2. The user may for instance remove the tea filter from the tea pot when he hears the alarm from the distant kitchen timer; in that case he definitely does not want to return to the kitchen in order to turn the alarm off.
3. If the user observes that some operation is completed, for instance that the steak in the oven has been roasted sufficiently, he will want to stop the timer when he stops the operation and before the timer expires.
4. The user will often do several operations of the same duration, for instance fry a beefsteak the same period of time on both sides. In that case the user does not want to set the same time twice.

Functions

A function in the equipment fulfils 2 characteristics:

- It is a distinct entity the user can conceive of in the equipment—it is known by the user as a separate element.
- The activation of the function changes one or more elements in the equipment, but the activation in itself does not necessarily lead to a useful result. When the user enters a phone number to be called, it brings him closer to the completion of a task, but the result of entering the phone number is only useful if it is preceded and followed by the activation of other specific functions.

It is therefore quite common that functions are described as processes and not by their results. For a cellular phone examples of functions may be *dialling* or *disconnecting.*

A practical advice to the designer: During the design of the user interface a mnemonic abbreviation for each function is very useful—it is often not possible to write the full name of the function, and the abbreviation is easier to recognise than a reference number for the function.

The functions should be described as specifically as possible; if it is possible to describe a meaningful intermediate result during the operation of a function, it should therefore normally be divided into two functions. Some examples are:

- If a function is described as *Scrolling in a list* the function will include both the scrolling upwards and downwards, and it may even be possible to scroll in a manner so only every third element in the list is shown; if the *Scrolling in a list* function is replaced by two functions, one *Moving down in list* and another *Moving up in list,* the result of the function is much more unambiguous.
- If the description of the user interface of a phone includes the function *Selecting the number to be called,* the function may include any scrolling up, down or sideways in a list and it may or may not include the depression of a key that actually initiates the call. If the functions *Scrolling up* and *Scrolling down* are implemented together with one function *Initiating the call* the function for *Selecting the number to be called* becomes totally superfluous.

However, the result of each function shall be meaningful. It makes therefore no sense to divide the function *Entering the number to be called* into a number of other functions: *Entering the first digit, Entering the second digit* etc..

Each such function can be part of one or more tasks, the function *Dialling* can for instance be used when making a call or when the user wants to transmit a short message written in text.

The user activates each function by doing one or more actions; the *Dialling* of a number consists for instance of one physical action, the depression of a key, for every digit in the number to be dialled.

Functions defined for a kitchen timer

The following functions are identified for a kitchen timer:

- *Set the timer:* The activation of that function may require a large number of separate actions, for instance one depression of a key for every additional minute the timer is set to.
- *Set the timer to 0 hour and 0 s.*
- *Start the timer.*
- *Stop the timer.*
- *Stop the alarm.*

The list shows that it is impossible to reach a result that in itself is useful by activating only one function. The user gains for instance nothing by operating *Set the timer* if he never *Start the timer.*

Options

An option in the equipment fulfils 3 characteristics:

- *It is a distinct entity* the user can conceive of in the equipment. It is in other words known by the user as a separate element.
- *It is a semi-permanent control function* used for changing the values of one or more parameters; the values of these parameters

determine the result of activating one or more functions or whether it is possible to operate them.

- *An option is normally not part of a task,* and it may even be blocked so the user cannot change it. The user will therefore normally change the options when he is not carrying out a task using the equipment.

Examples of options are:

- The enabling or disabling of a precoded *automatic call transfer* to another phone if nobody unhooks the cellular phone.
- Tuning or adjustment information for the radio frequencies used by the radio.

Because the options normally are not set during the completion of tasks, they should be separated completely from the functions used for completing the different tasks in the user interface. The only exception is the case when the user in a particular situation of use or state may discover that it is necessary to change the value of one or more parameters. In that case it should of course be possible to change the value without leaving the actual state. One example of that is a multilingual spell checker. When activating that function, the user may find out that it is set to the wrong language, and it should therefore be possible for him to change the setting without leaving it and accessing a special *settings and options* state.

The user sets each option by doing one or more actions: The setting of an *automatic call transfer* may for instance include one or more actions used for accessing the different types of *automatic call transfer* and an action where the specific type of call transfer is selected.

Options in the kitchen timer

The analysis of the situation of use showed that it in most cases is unnecessary to set a kitchen timer with the same precision as an ordinary watch, it will for instance normally not make any difference if the timer is set to 15 or 16 min.

The analysis of the situations of use showed also that it is very inconvenient if the user shall depress a key once for every minute and hour the timer is set to, for instance press a key 30 times for setting the timer to 30 min.

An option is therefore defined, so the kitchen timer can be set to either *Fast setting* or *Full precision:*

Fast setting: The timer can be set to 1, 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 25, 30, 40 and 50 min, to 1 h and 0, 10, 20, 30, 40, and 50 min., 2 h and 0, 20 and 40 min, 3 h and 0 or 30 min, or to 4, 5, 6, 7, 8, 9, 10, 11 or 12 h.

Full setting: The timer can be set to all values from 1 min to 12 h.

Such an option may be set by a small switch beneath the kitchen timer.

Actions

Each action can be conceived of by the user as one physical movement, and the actions are therefore the lowest level of units in the operation of the user interface. Each action consists of the activation of one actuator, for instance a key, in the user interface.

One example of such a physical action is the depression of one key during the dialling of a number.

Most pieces of equipment have more functions than actuators, it is therefore often necessary to let the effect of each action depend on the actual state of the equipment such that the same action activates one function in one state and another function in another. That may not cause any problems for the user, if the functions activated by the same action in different states are similar, for instance if a key pressed in the *Off* state turns the equipment *On*, and the same key pressed in the *On* state turns the equipment *Off*. If the same action, as an alternative, in one state turns on the light in the display and in another state turns off the equipment, the result may be an occasionally screaming user.

The possible actions depend on the actuators implemented in the equipment. Their description must therefore await the design of the format of the user interface; it is not possible to describe them together with the purpose, tasks, functions and options of the equipment.

The relation between tasks, functions and actions

In most cases, the completion of a task will consist of the operation of a number of different functions, and the operation of each function will in the same manner consist of a number of actions. However, some tasks may consist of just one function, and it may sometimes even be possible to complete a task by performing one single action. One example is the turning off of a radio.

The paths followed by the user when he completes the different tasks will often more resemble the content of a dish of spaghetti than a neat root structure. If the designer assumes that the tasks and functions all constitute a hierarchy, so no tasks will overlap, it is therefore likely that the description of the different tasks and functions will be incomplete: The designer will at the most describe one of the many possible tasks the user may do in order to accomplish a similar result.

If the designer, as an alternative, adapts the structure to all the possible paths the user may follow, the result may resemble the state diagram of the *Pot+* shown in subchapter **14.2**.

Relation between tasks and functions in the kitchen timer

A total of 4 different and possible tasks are described for a kitchen timer in an earlier part of this subchapter. However, if the designer assumed that the tasks had to be hierarchical without any overlap, only one of them could be described.

15.2 DESCRIBING THE THOUGHTS AND BEHAVIOUR OF THE USER

It is impossible to reach the best possible result if the design process, as described in subchapter **1.2 The frustration of design**, is more focused on the technical implementation of the user interface than on the users perception of the situation when he operates the equipment. It is therefore essential that a good description of the users thoughts and behaviour is produced before the start of the design.

In computer science the word *model* is often used for designating the description of the users thoughts and behaviour. One example is Bass and Coutaz [1991: 15] who use the term "Model the operator" for the writing of a description of the user. The use of the word *model* can degrade or limit the quality of the information about the thoughts and behaviour of the user:

- It is very easily confused with the computer inspired models of human thinking, and as described in subchapter **6.2**, the use of such models results in restricted and misleading descriptions of the behaviour of the user.
- It is easy to assume that such a *model of the user* ought to be logically consistent, without one part of the model contradicting any other, even though the thoughts and behaviour of the user seldom are consistent or without contradictions.

I will therefore use the word *description* and not the word *model* of the users thoughts and behaviour.

The *description of the users thoughts and behaviour* should cover but not be restricted to the following areas:

- *Tasks,* carried out by the user.
- *The situations experienced by the user* when he carries out a task or uses the equipment.
- *The elements the user conceives of* when using the equipment.
- *The dispositions and habits* influencing the users behaviour.
- *Special limitations of the users,* for instance if some of them deviate significantly from the average, for instance because of a larger or smaller physical stature, physical disabilities or reduced sight or hearing.

Tasks the user carries out

The tasks should first be described from the users point of view and not in relation to the equipment, cause a description with a close relation to the equipment limits the possible choices when designing the user interface; in the worst case some of the stated tasks may even be irrelevant for the user.

One example is a task related to the GSM phone; it can either be described as *completing a phone conversation* or as *completing a phone call.* It can be seen that the first description of the task offers several advantages:

- It is more precise: The second description can be interpreted either as only the establishment of the connection or as the establishment of the connection and the following conversation.
- It describes directly the result desired by the user: It is quite possible to complete a phone call without accomplishing any result desired by the user, for instance if static makes it impossible to hear what the remote user is saying.
- It gives the designer more freedom: It is quite possible that some types of communication equipment can make a conversation possible without the establishment of a call.

The description should cover as many as possible of the tasks carried out by the user with some relation to the equipment, because a more adequate description makes it easier to design and evaluate all the possible paths through the functions implemented in the equipment. The use of a cellular phone for the GSM system may once more serve as an example: The user can complete a phone conversation, but he may also use the phone for listening to any messages on an answering machine or to find out what time it is. If these tasks are not included in the description, it is not possible to consider whether or not the user interface should be adapted, such that it becomes easier to transmit a precoded sequence activating the answering machine or giving the exact time in response.

It is the rule rather than the exception that the user interrupts one task and progresses with another or in general changes his mind while he is carrying out a task. It is therefore essential that as many as possible of the irregularities in the described tasks are identified. Each task should therefore be described as consisting of a number of separate steps or functions, and

the points where the user may substitute one function for another or interrupt one task and progress with another should be identified.

Even when such a thorough description of the different tasks is made, the designer may later discover that the users find new applications for the equipment and combines the different tasks in ways the designer did not imagine.

Tasks done by the user when operating a kitchen timer

This description is in addition to the 4 different tasks described in subchapter **15.1 Describing the purpose and function set of the equipment**.

The use of the kitchen timer and the tasks directly associated with it are always subordinated other activities that takes precedence: The user will for instance put some food in a pot over the boiler and then start the timer when the contents of the pot start boiling.

The user will often be doing two or more tasks in parallel, for instance boil one item of food while frying another.

That observation means that it will be useful if the user can perceive from the timer which item of food the displayed time is related to, and if the user can use the kitchen timer for two or more time settings in parallel.

However, because the user will have focused his attention on the different items of food in progress, a timer with two or more timers in parallel should be as easy to use as a timer with a single setting.

Situations when the user operates the equipment

It is necessary to describe the situations when the user operates the equipment because the associations the user makes during the operation, as described in subchapter **9.4 Making useful associations**, depend on the users conception of the situation, and because perceptions or activities in some situations may interfere with the operation of the equipment, as described in chapter **11. The environment and the work process**.

The description of the situations of use should therefore consist of two parts:

- The different situations of use as described by the user. Such situations will very often be characterised by a reference to a particular locality or other ongoing activities and not by anything resembling states in the equipment. One situation related to the GSM phone is *answering a call while driving a car.* As described in subchapter **14.3 *GEOSM:* a communication terminal for inattentive use**, the specific state of the phone when answering a call while driving a car depends on whether or not an *auto answer function* is enabled.
- A description of each situation, listing the elements in the environment the user must try to stay aware of, or the elements that may draw his attention, and any other activities that in the particular situation may interfere with his operation of the equipment.

It is essential that as wide a range of situations of use as possible are identified, in particular because the more extreme situations are the ones where the operation of the equipment is most difficult. One way of assuring that and at the same time having some fun is to try to identify the most peculiar situations of use, for instance *using the GSM phone while sitting in a tree, receiving a call right after having closed the lavatory door from the inside* or, as described in Subchapter **1.1 The wonder of inattentive use**, *operating the equipment while driving a bicycle in darkness*.

In addition, it is necessary to try to identify the situations during use that normally are hidden from the designer, for instance the situations where the equipment malfunctions in one way or another.

Situations experienced by the user of a kitchen timer

The user of a kitchen timer will in general experience two different types of situations while using the kitchen timer:

- The user is busy preparing different dishes and continuously working on a number of tasks needed for their preparation. In that situation the user must co-ordinate the states in the preparation of the different dishes; he will often use the kitchen timer for that purpose, and he may often change the setting of the kitchen timer because the results of inspections of the dishes under preparation or delays in his own work make it necessary to reduce or extend the duration of one or more states in the preparation of the different dishes.
- The user may start the preparation of a dish, for instance the roasting of a turkey, and then leave the kitchen and do completely unrelated tasks or nothing at all. In that situation he will not change the setting of the kitchen timer while it is running. However, it is essential that the kitchen timer can draw his attention when it expires, even though he is physically separated from it.

Elements the user conceives of during the different tasks

The equipment for inattentive use should make use of the associations that already are known by and perhaps habitual for the user as described in subchapter **9.4 Making useful associations** and not be in conflict with them. However, as described in subchapter **7.3 The changing stream of thought** the transitive parts of the thought are too fleeting to be described.

What can be described are the elements the user already conceives of during the different tasks, the elements the user may make an association to and in some cases the association it is most likely that the user will make.

The elements the user conceives of are normally strongly influenced by the users previous experience with similar equipment and they can roughly be divided into two groups:

- *Objects* that are manipulated one way or another.
- *Functions* that are activated in order to make a desired change to an object.

The elements belonging to both groups should of course be described, and they should be described from the users point of view. Even though the user employs the same name for a function as the designer who is collecting the information, it is quite likely that he conceives of it in a different manner.

Items the user conceives of while using a kitchen timer

The user will normally conceive of the different items of food that has to be processed for a certain period of time, before the user either stops the processing or investigates if the processing should continue for an additional period.

The items of food are typically conceived of as items that are processed on a particular burner on a stove or in the oven.

The different items of food can therefore be designated according to the burner or oven in which they are processed.

The user will typically process 3 different items of food, where each processing involves 2 or 3 different steps that must be completed in sequence, and the processing of all items of food should be completed at the same time.

However, even though the user is doing a highly complex process, he will normally not conceive of a total plan covering the duration and necessary time of completion for each step in the processing of each item of food.

The kitchen timer should therefore not be a planning tool but only make it unnecessary for the user to focus his attention at short intervals on the expected times of completion for each item of food.

Dispositions and habits of the user

As described in subchapter **9.3 Different users decide in different manners**, the user can be disposed towards working in different manners. In addition, the user may habitually choose particular actions as described in the subchapters **7.6 Different types of inattentive use** and **10.3 The structure of physical actions**.

A description of the dispositions of the user are best made by starting with a plain vanilla description of the users education and previous experience before a more detailed description of the users dispositions are made. If, for instance, it already is known that the user is employed at construction work, it is easy to deduce that he probably is not disposed towards being careful when handling the equipment.

In addition to the description of the dispositions, it is necessary to make an explicit description of the habits of the user, in particular of the automatic processes that are part of his physical actions. Such a description can be essential for the success of the design, because acquired habits, as described in subchapter **9.5 Choosing an action**, may overrule the reasoning of the user during the use of the equipment.

Dispositions and habits of users of a kitchen timer

The kitchen timer is used by normal persons cooking or preparing food in a kitchen.

The user is normally disposed towards focusing his attention on the preparation of the food or on any guests in the kitchen, and will only focus a minimal amount of attention on the use of the kitchen timer.

It is therefore essential that the kitchen timer appears to be easy to use, that it uses keys instead of something that should be set precisely, and it should be as easy as possible to change batteries—ideally the kitchen timer should be powered by solar cells or another renewable energy source.

Special limitations of different users

It is very common that part of the potential users have special debilities or limitations that should be taken into account when designing the equipment. Some examples are:

- Operators of cranes and heavy machinery often have reduced hearing, it may in particular be difficult for them to hear tones at high frequencies and to discriminate a sound with a high level of background noise.
- Many users 50 years old or older find it difficult to read texts on keys used for controlling the equipment without using glasses.
- A significant proportion of persons employed in low or unskilled jobs are incapable of reading any sort of user guide for the equipment, and an even larger proportion will not read it although they are capable of doing so.
- People using working gloves or employed at work where they must use a large degree of manual force will often find it difficult to hit keys of a normal size or to adjust knobs requiring delicate movements.

The users in the preceding examples are normally not described as disabled even though their ability to perceive and to carry out physical actions are significantly lower than average.

Special limitations of the users of a kitchen timer

The users of the kitchen timer will, because of other tasks done in parallel with the operation of the kitchen timer, often have wet or oily fingers when operating the kitchen timer. That should be taken into account when designing the keys.

Methods for acquiring the information about the user

The designer can get information about the thoughts and behaviour of the user by applying one or more of the following methods:

- *By using similar equipment* for a prolonged period of time. My experience shows that this method can be very valuable if the designer not only tries the equipment once or twice, but for a period of time actually uses the equipment in the same situations as other

users. The designer can then by introspection get a much more varied and detailed material about the completion of different tasks than by using any other method.

- *By talking with users*. Most users can describe the different tasks they are doing with a large amount of details, and the users are often the only real experts in the tasks; they can explain how the tasks *really* are done, whereas the persons planning or managing the work often can explain only how they are *supposed* to be done. If the user is given the opportunity to describe the different tasks in his own words, it is in addition possible to use that description as a basis for describing the elements the user conceives of during the different tasks.
- *By observing users doing the different tasks*. That is by far the slowest and often the least productive method for acquiring information.
- *By asking the user to explain each operation as he is doing it*. My own experience indicates that often is the best method for acquiring information: The users habits assure continuity in his description of each task, and it is often possible for the user to show and explain a task simultaneously when it cannot be fully explained in words.

It takes time to get all the pertinent information from the users, and my own experience indicates that *the designer should ask any question that comes to his mind, even if he feels the question is surrounded by a fringe of stupidity.*

Assembling a description of the user

The descriptions of the different users may appear to be amorphous and inconsistent and very different from the precise set of requirements that normally are required as a basis for developing a piece of electronic equipment.

However, the description of the different users can be improved in three different ways:

- By making separate descriptions of different types of users for the same piece of equipment, for instance one description of a typical user without any relevant experience and another description of a typical user who already has used a similar piece of equipment. The description of each type of user can then be simpler and more consistent than the total material covering all the possible users.
- By realising that there never can be a one-to-one relationship between the total amount of possible tasks and situations described by the user and the paths and states presented by the equipment. The operation of the equipment can fit the thoughts and behaviour of the user, but, the equipment can never contain more than a superficial model of the user.
- By trying to get a feeling for the user. My own experience indicates that if the designer tries to get a description of the user that is as total as possible, he may at least occasionally manage to *get under the skin* of the user, and imagine how the user will react to a specific part of the equipment.

The seeming looseness and inconsistencies in the description of the users thoughts and behaviour should under no circumstances be used as an excuse for making a superficial or imprecise description of the thoughts and behaviour of the user.

My own experience indicate that a good description of the situation of use and of the users thoughts and behaviour often makes it possible to develop new innovative features that may give specific pieces of electronic equipment a competitive advantage

Results of the description of the user of a kitchen timer

The precise description of the tasks in general done by the user of a kitchen timer lead to the design of a kitchen timer with several independent timers, where each timer was associated to a burner or to the oven.

15.3 CURRENT DESIGN PRINCIPLES AS COMPARED TO THE DESIGN REQUIREMENTS

When designing electronic equipment for inattentive use, the designer will often rely on the currently accepted guidelines for user interfaces for electronic equipment. In this subchapter I will therefore investigate if the normally stated requirements are sufficient for electronic equipment for inattentive use.

I will compare the requirements for inattentive use with the design guidelines given in the following 4 books:

- Deborah J. Mayhew's [1992] book on *Principles and guidelines in software user interface design*. This book compares different types of user interfaces.
- Microsoft's [1987] *The windows interface: An application design guide*. These guidelines should assure that all Windows-based applications are visually and functionally consistent.
- Eric Wagner's [1988] *The Computer Display Designer's handbook*. His focus is on the design of displays for control room applications. His emphasis is therefore on the presentation of a large amount of information on each display picture.
- *Strategies for real time system specification* by Hatley and Pirbhai [1987] describes a methodology based on the data flow modelling techniques developed by Tom deMarco (Hatley and Pirbhai) [1987: 5]. These methods should make it possible to design a more structured and more consistent piece of equipment.

The first three books provide a curious mixture of very human and down to earth advice for designers of user interfaces combined with models of the user as a modular constructed machine with some data acquisition and processing capabilities, and they present a number of guidelines for user interfaces that are equally applicable for user interfaces for attentive and inattentive use.

The authors of the first three books assume that the user is paying attention: The user may occasionally be absent from the equipment, but during actual use his attention is on the equipment. The means for drawing the users

attention to the equipment is therefore given a very low priority; however both Mayhew [1992: 46] and the book from Microsoft [1987: 41-2] mentions the use of flashing icons for drawing the attention.

The fourth book (Hatley and Pirbhai) [1987: 11] describes a so-called "structured method" for specifying software and electronic equipment in general. The use of such a structured method may make it possible to produce equipment where the interfaces between different parts of the equipment are more functional and well defined. However, the methods raise some problems when used for designing the user interface for equipment for inattentive use.

Perception of the state of the equipment

Both Mayhew [1992: 458-504] and Microsoft [1987: 75-121] recommends the use of small size icons, the use of textures for accentuating their shape, the use of symbols that can be identified from a single feature, and that icons always should be combined with text.

Differently, Wagner [1988: colour plate 23] uses icons without texts and combines different features in one symbol: He assigns a specific meaning to a colour combined with a specific symbol.

The guidelines presented by Mayhew [1992], Microsoft [1987] and Wagner [1988] omit a number of the requirements described in chapter **8. Perception during inattentive use**. Some examples are:

- Neither Mayhew [1992], Microsoft [1987] nor Wagner [1988] stresses the need for organising the elements on the screen from left to right and from top to bottom.
- Microsoft [1987: 143] uses "Directory tracking texts" or "Paths" as for example "C:\Alpha\Beta\Gamma\and Delta" as file names.
- Wagner [1988: 154] stresses the use of what he calls a "free", that is an empty, background. However, in his examples he shows screen pictures with line drawings or reliefs in the background [1988: colour plates 15-18]
- Neither Mayhew [1992], Microsoft [1987] nor Wagner [1988] stresses the need for letters of a sufficiently large size: The headings or titles used in some of the presented screen pictures resemble more ornaments than any sort of meaningful information.

Aids to the users deciding upon the proper action

Mayhew [1992: 95] describes the principles for organising and designing the different elements in the equipment as follows:

> Simply put, the term "mental model" refer to the user's current state of knowledge, both factual and procedural about a complex system that may have invisible parts and processes. *Users always have mental models and will always develop and modify them, regardless of the particular design of a system.* Our goal as user interface designers is to *design so as to facilitate the process of developing an effective mental model.*
>
> [M. italizing]

Mayhew [1992: 104-111] presents a number of seemingly empirical guidelines and stresses that the structure of the equipment should be consistent, unambiguous and concrete instead of abstract. However, she does not describe how the consequences of errors made during an automatic process can be minimised, and she does not discuss how the different elements of the equipment can be adapted to trial and error.

Even though the requirements stated by Mayhew are sufficient for designing equipment for use in situations when the user always can reason about every step in the process, they are not sufficient when the user browses or uses trial and error during the operation of the equipment.

Hatley and Pirbhai [1987: 45-47] describe the structure of the equipment as consisting of a number of processes connected by different data flows. The description can be repeated at different levels, so each process can consist of a number of processes connected by data flows. Such a structure makes it possible to organise the elements of a piece of equipment or software, and to reduce their codependencies to an absolute minimum, and thereby produce equipment or software that is easier to implement and test.

However, the structured method described by Hatley and Pirbhai [1987: 45-47] is not suitable for describing a user interface for inattentive use:

- For inattentive use each state of the equipment should give access to the group of functions the user needs during a specific type of situations during use, and such an organisation of the different functions or processes is totally different from the structure that can be defined by the internal data flows in the equipment: The user will in several different states of the equipment need access to the same process or part of the data flow, and he will from one state in the equipment need access to several different processes or data flows.
- The data flow structure tries to divide the software into well defined units, whereas a user interface for inattentive use, as described in subchapter **9.5 Choosing an action**, should minimise the distance between the functions and offer as many different connections as possible between the different states or functions.

I will conclude that the use of the methods described by Hatley and Pirbhai [1987] during the design of the user interface often can lead to a less than ideal result.

Physical actions

The actuators on the equipment are not mentioned by neither Microsoft [1987] nor Wagner [1988], even though they are highly relevant for both descriptions of standards for user interfaces. Mayhew [1992] describes the actuators on the equipment in a very perfunctory manner and describes (Mayhew) [1992: 381] for instance the acceptable "key force range" as "15–125 grams". That requirement is too wide to be of any practical value: As described in subchapter **10.4 Reaching, stopping or grasping**, the risk of work related injuries may be increased significantly when the force needed for pressing the keys exceeds 60 gr.

Result of the comparison

A number of important requirements for electronic equipment for inattentive use are missing in the currently stated requirements for electronic equipment, as described by Mayhew 1992], Microsoft [1987] and Wagner [1988]. The stated level for user interfaces for normal attentive use is therefore insufficient for electronic equipment for inattentive use.

In addition, data flow methods, as for instance defined by deMarco and described by Hatley and Pirbhai [1987: 35–58], are unsuitable for designing and describing a user interface for inattentive use. It is therefore necessary to employ other and better description methods when designing a user interface for inattentive use.

15.4 CREATIVITY DURING THE DESIGN PHASE

It is the exception rather than the rule that the successful design of a piece of electronic equipment progresses in something similar to a linear fashion. My own experience, as partly described in subchapter **1.2 The frustration of design**, indicates that the design process may lead to an inferior result if the designer tries to make the design from the top and down or does not continuously cross check and correct already described parts during the design process.

The design of a piece of electronic equipment is a creative activity similar to writing with several false starts and parts that has to be corrected or discarded during the design process, and it is even possible that parts that are discarded at one point in the process later are reintroduced.

As an example, I will describe part of my own work process during the design of *GEOSM*. I made the description in parallel with the design of the phone and it is presented without any later changes of the contents:

As point of departure I chose the *POT+* terminal, but found that the design had to be radically changed in order to give the best possible access to the functions used in the GSM system.
I decided also to limit the design to the functions that were used when initiating a call and during a call. Over the following week the design became more detailed and the different functions became more integrated:

—

Monday:

- I started work on a state transition diagram and tried to make a Hypercard prototype based on that.
- The Notepad and the transmission of DTMF tones were combined to one function.
- Differences between the situations experienced by the user and states in the equipment were identified.
- States indicating *Call to an occupied phone* and *Call to a non existing number* were introduced.
- The Number list and the retrieval of the last called number were combined into one function.

—

Tuesday:

- It was made possible to see the duration and price of a call while the DISCONNECT key was held down.
- 2 Soft keys were added to the design.
- A hard labelling of each soft key with an additional function was added.
- A third soft key were added to the design.
- One position for a key was in surplus: A key for calling a pre-programmed number was added.
- The design began to seem very complex, and it became difficult to see it from the users point of view.

—

Wednesday:

- I wrote a user guide for the phone—it resulted in the introduction of direct connections between the *Dialling* and the *Use of list* states.
- I considered if a combination of other keys could be used for ON/OFF, freeing one key. In the end I decided to stay with the dedicated key for on and off.
- The texts on the Soft keys were replaced with symbols, because keys with text could not be shown in a sufficient quality in the user guide.

—

Thursday:

- The UNHOOK key became in addition an ENTER key to be used every time entered digits or information should be stored.
- The Timer T1 was introduced so that all digits would be cleared from the display if no action had been done during a period of 7 s.

- *Manual call forwarding* and Conference call were introduced using the key for calling a pre-programmed number.

The key was renamed the <-O-> or SPREAD key. [the SPREAD key was later renamed the TRANSFER key]

Friday:

- A decision table for each key was defined, and it became possible to define the results of each key activation not only as a consequence of the actual state, but also as a result of other parameters or settings in the equipment.
- The key for transmitting a pre-programmed call was changed to a key that only recalled a number of pre-programmed digits. Otherwise the risk of a call being transmitted by accident was too large.

—

Saturday:

- I decided to add a *request for acknowledgement* before a conference call was set up, because the set up of an unwanted conference call could be very awkward for the user.

—

Sunday:

- I made an updated and more detailed state diagram for the phone.

—

Monday:

- I found that the detailed state diagram was very complicated: it might be used as an illustration, but not as a design tool.
- An optional function was added: It transmits a call if no action has occurred for a certain period of time, for instance T1 or 7 s, after the UNHOOK key or SPREAD key has been pressed.

During the week I produced documents equalling at least 25 normal pages, even though the final design can be described on 6 pages at the most. I found that the work on paper was essential, because the gradual improvement of the design was possible only when I had something visible to improve upon.

The improvements were possible only when I accepted errors in my work. It was not possible to make everything perfect at once and even a rejected idea might at a later time be useful in the design. One example is the key for transmitting a pre-coded call as described for the *Wednesday: Friday* I changed it into a key that only recalled the pre-coded digits, and *Sunday* I changed it back into a key that after a certain delay could transmit the pre-coded call.

My experience also indicates that the result becomes better if the thoughts can mature for a certain time. Because of that the design process cannot be rushed beyond a certain limit, and if the feeling of a gap—or an aching void—appears in the stream of thought, as described in subchapter **7.3 The changing stream of thought**, it is quite likely that it only can be filled after a break or after the invocation of one of the three B's: *Bed, Bath* and *Breakfast*.

15.5 USE OF DIFFERENT DESCRIPTIONS OF THE USER INTERFACE

The user interface for a piece of electronic equipment can be described in a number of different ways, and it is not possible to make one description that highlights all the requirements of inattentive use.

A description of the different states in the equipment is for instance indispensable for showing the different paths the user may follow when completing a task, but normally it cannot show:

- The effects of any different values of a parameter during the operation of the equipment, for instance the result when trying to increase the volume if the maximum volume already has been reached.
- Any inconsistencies in the operation of the different functions in the different states, for instance if a given function for some reason is available in all of the states except one.
- Any inconsistencies in the physical actions required in the different states, for instance if a function in one state is activated by pressing one key and in another state by pressing another.

The first point is necessary for the detailed specification of the equipment, whereas any inconsistencies as described in the last two points will disrupt the automatic processes of the user, and therefore make the inattentive use of the equipment much more difficult.

In addition, it is normally not possible to restrict the design to one-to-one relationships between states, functions, and actuators: The same function should often be available in some but not all of the states, and even though the actuators should operate in a uniform manner in all states, it is normally not possible to make their operation in the different states absolutely identical.

The designer should therefore use a number of different types of descriptions during the design process.

The descriptions of the purpose, tasks, functions and options in the equipment are made when the purpose and functions of the equipment are defined.

In the *design phase* the following descriptions of the user interface are made:

- User guide
- Parameter list
- Format of the user interface
- State diagram
- State and action table
- One or more prototypes

Each of these describes one or more aspects of the user interface.

It is of course possible to describe the user interface in other formats. However, the formats described here makes it possible to get an easy overview over each of the critical parts of the design, they make it easy to identify inconsistencies in the design, and compared to less formalised verbal descriptions they are comparatively brief and therefore easier to produce and review.

User guide

A good user guide should give the information the user needs for operating the equipment in the order he needs it, and it should therefore be similar to the stream of thought experienced by the user while passing through the different parts of the tasks.

One example is shown in subchapter **14.3** where it is part of the description of the *GEOSM* terminal.

The user guide can therefore be used for assuring that the path through each task is as simple and easy to follow as possible: If the path cannot be described in a user guide it is unlikely that the user can follow it. My own experience indicate that it therefore often is best to *start the design of the user interface by writing at least a preliminary user guide.*

User guide for the kitchen timer

The kitchen timer can be used for setting times and alarms for items of food being prepared on up to 4 different burners or in the oven.

Selection of timer:
- The kitchen timer contains 5 separate timers: The timer symbols are placed in the same manner as the burners and the oven in a normal stove.
- Press the × for selecting the timer to the right or left of the currently selected one.
- Press the ¬ key for selecting the timer above or below the currently selected one.

Set time
- Press the HOUR key for increasing the shown hours one step.
- Press the MIN. key for increasing the shown minutes one step.
- Press the HOUR and MIN. keys simultaneously for setting the timer to 0 hour and 0 min.

Start and stop timer
- Press the START/STOP key.

Stop alarm
- Press the START/STOP key, or
- if you press the HOUR and MIN. keys simultaneously, the timer will in addition be set to 0 hour and 0 min.

Changing batteries

- ----------

Parameter List

It is possible to define every single different value of any parameter in the user interface as a state. However, the multitude of almost similar states will then make the structure of the equipment unwieldy.

I have therefore chosen only to designate something as a separate state if it is identified by a separate text or indicator presented by the equipment.

The description must therefore include other parameters indicating for instance the number actually shown in the display or the setting of a volume control.

In addition the parameter list should include the following information:

- A list over all the external events that affects the state of the equipment. For a phone that may for instance be an incoming call. Such external events may all be described as parameters that are given certain values when specific events happen.
- The timers used in the equipment and the criterias for their activation. One example of such a timer, is the timer returning the equipment to standby if no key has been touched for a period of time.

These parameters should together with the actual state of the equipment fully determine the elements the user can perceive from the equipment.

Parameters in the kitchen timer

The following parameters are necessary for the functions in the kitchen timer:

Hour set (1)... Hour set (5):
These parameters store the hours that are set for each of the 5 timers.

Min set (1)... Min set (5):
These parameters store the minutes that are set for each of the 5 timers.

Hour act (1)... Hour act (5):
These parameters store the actual number of hours each of the 5 timers has reached in their counting. When the alarm is stopped after timer *n* has run out the *Hour act (n)* is set to the value of the *Hour set (n).*

Min act (1)... Min act (5):
These parameters store the actual number of minutes each of the 5 timers has reached in their counting. When the alarm is stopped after timer *n* has run out the *Min act (n)* is set to the value of the *Min set (n).*

Alarm timer:

The timer is started when the alarm state is entered, when it expires the alarm stops and unless another timer has expired, the timer returns to standby.

Hour set (n) ? 0, *Min set (n)* ? 0 while *Hour act (n) = Min act (n)* = 0 marks an active alarm, that is a timer that has expired and not yet been reset.

Heater:

Contains the number of the burner or oven whose value currently are shown in the display. The parameter can have a value from 1 to 6, where the lowest field, similar to the oven, equals both the value 5 and the value 6. That is done in order to make it easier to implement the selection of a timer.

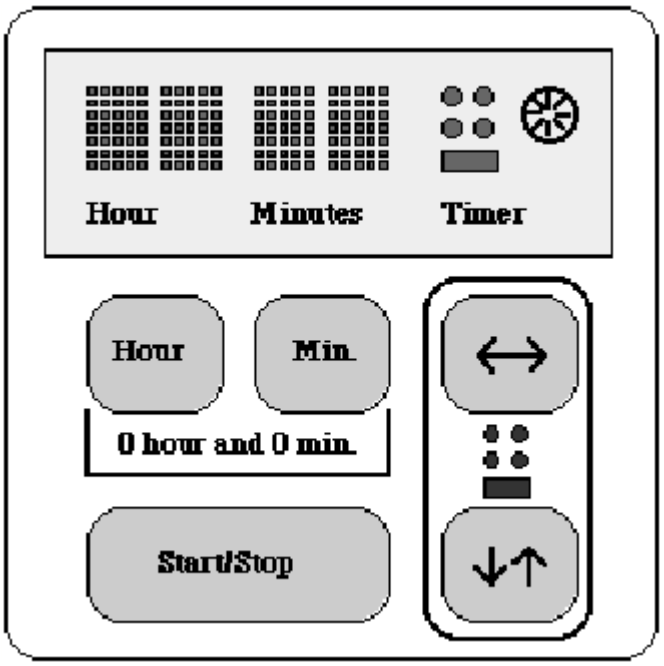
Format of the user interface

The format of the user interface determines the information the user may perceive and the actuators he may operate and therefore the actions he may do when operating the equipment.

The format of the user interface consists of a hardware and a software part:

- The hardware consists of the actuators, for instance keys, and of any screens, displays or sound or vibration generators used for presenting the information.
- The software part consists of formats for information presented on the display and sound or tactile signals that are used by the equipment.

It is essential that each element in the user interface is assigned an identifier that is independent of the appearance or format of the element, so that it is possible to change the appearance or format of the element after it has been introduced.



User interface for the kitchen timer. It is shown in close to natural size and with all fields in the display lighted.

The fields on the user interface are used for displaying the following information:

- The four fields above the words *Hour* and *Minutes* display the actual number of hours and minutes in 5 x 7 dot-matrix displays.
- The field above the word *Timer* indicate the currently selected timer, only one of the figures in it will be visible at any one time.
- The wheel-shaped figure to the right simulates a running clock by showing the spokes one at a time in a clock-wise direction while the selected timer is running.

The user interface is equipped with the following keys with tactile feedback:

- HOUR
- MIN.
- START/STOP
- ´
- Ø `

Audio signals:

- Low frequency beep when a key is pressed.
- High frequency error tone when a key without a function in the particular state is pressed.
- Repeated low-high frequency alarm tone, when a timer has expired.

State diagram

The state diagram shows the different states of the equipment and how it is possible to pass from one state to another, and it is an intermediate step

between the user guide and the table describing the relation between the states, actions and functions in the equipment.

The state diagram is used for tracing the paths associated to the different tasks through the different states of the equipment, so that the necessary number of activated functions and changes of the state of the equipment can be minimised for as many of the paths as possible. When that is done, *it is possible to minimise the number of elements the user shall perceive when carrying out each task and the number of actions the user must do before it is completed.*

The precise format of the state diagram is always a compromise between two requirements:

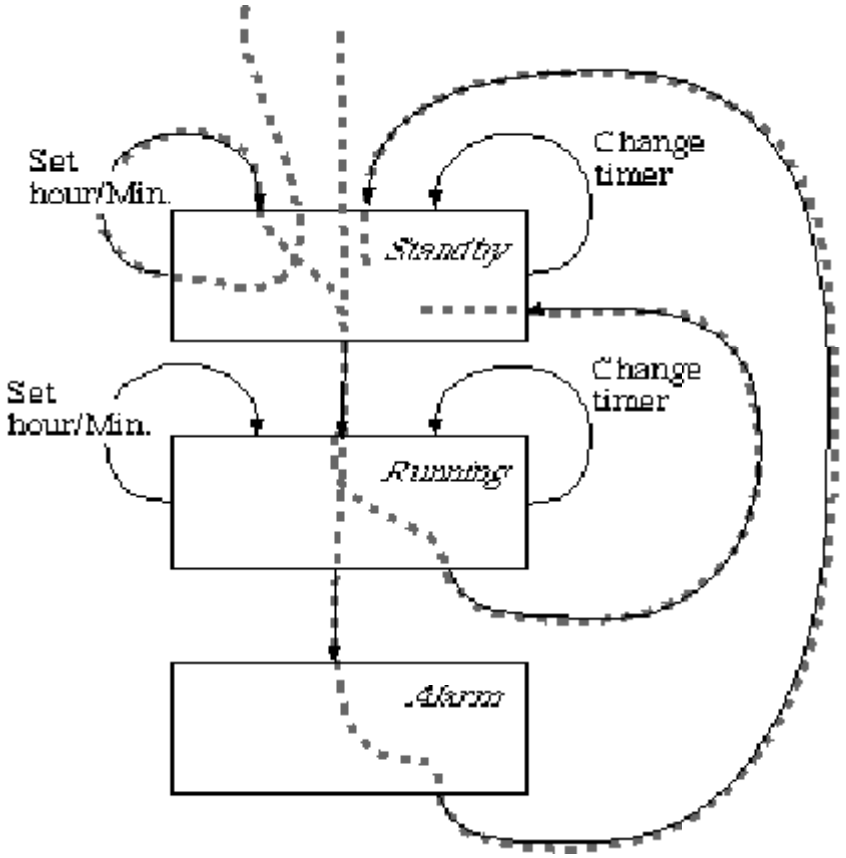
- Making the state diagram as informative as possible by including as much information as possible, for instance the display text in each state and the function or action associated with each connection from one state to another.
- Making it easy to get an overview over the different states and paths between them and reducing the amount of information that shall be updated on the state diagram during the design phase.

I will give the second requirement the highest priority, primarily because a state diagram with a large amount of details is more difficult to change, and such a state diagram will therefore often hamper the design process. At least during the design process, the state diagram should only show the states, their names and the connections between them.

The diagram may also be easier to comprehend if some relations on the state diagram are left out, for instance the relation making it possible to return to standby directly from any other state. Such a relation should simply be indicated by a note at the bottom of the diagram.

The state diagram should be based on the paths needed by the user through the different states and functions rather than on some elegant overall structure; my own experience indicates that *the seemingly elegant graphical structure of a state diagram often imposes additional and really unnecessary actions on the user, and the structure of the equipment that seems well ordered and logical on a drawn diagram often is felt as illogical during actual use.*

The state diagram is only one of the descriptions that are used during the design of the user interface, the completion of a state diagram must never during the design be seen as a separate task that can be completed independently of the other descriptions.



State diagram for the kitchen timer. Some of the previously described tasks or paths are shown as dashed lines

State and action table

The table describes:

- The functions and changes of the state of the equipment that can be activated with any given action.
- The functions that are available in any state of the equipment.
- The information that is presented to the user in each state of the equipment.

The table is used for ensuring that *the results of each action are uniform in all states, and that the user in each state has access to the functions and information he needs in the actual situation of use.*

The table consists of:

- One column for every possible action. It is sometimes possible to define more than one action for an actuator, as for instance the *click* and *double click* on the mouse. Each action should then be given a separate column.
- One column for every timer used in the equipment.
- One column for each external event that affects the condition of the equipment.
- One column for every type of information presented to the user, for instance every field of text shown in the display, lighted icons or audio signals.
- One row for every state the equipment can enter.

- Entries, each consisting of the function activated by the action in the particular state, any conditions that may affect its function or activation, the results of the activation of the function if they are non-trivial, and the state of the equipment after the action has been done.

The table describes for each state in the equipment:
- The results of any possible action
- The effect of any timers
- The information presented to the user

If some of the entries or information presented to the user cannot be shown in the table, they can be marked with suitable numbers that refer to notes or auxiliary tables. In addition it may be useful to add reference numbers to any texts presented to the user that later has to be translated into different national languages.

	HOUR Pressed	MIN. Pressed	HOUR & MIN. Pressed	START/STOP Pressed	´ Pressed	Ø` Pressed	Timer Exp.
Stand-by	Hour set (Heater) = Hour set (Heater) + 1 step	Min set (Heater) = Min set (Heater) + 1 step	Hour set (Heater) = 0 Min set (Heater) = 0	Start Timer (Heater) ->*Running*	Change Heater: 1->2, 2-1, 3->4, 4->3, 5->6, 6->5	Change Heater: 1->3, 3->5, 5->1, 2->4, 4->6, 6->2	->*Alarm*
Running	Hour act (Heater) = Hour act (Heater) + 1 step	Min act (Heater) = Min act (Heater) + 1 step	Hour set (Heater) = 0 Min set (Heater) = 0 - >*Standby*	Stop Timer (Heater) Hour act (Heater) = Hour set (Heater) Min act (Heater) = Min set (Heater) ->*Standby*	Change Heater: 1->2, 2-1, 3->4, 4->3, 5->6, 6->5	Change Heater: 1->3, 3->5, 5->1, 2->4, 4->6, 6->2	->*Alarm*
Alarm	Hour act (Heater) = Hour act (Heater) + 1 step	Min act (Heater) = Min act (Heater) + 1 step	Hour set (Heater) = 0 Min set (Heater) = 0 If no other timer has expired ->*Standby*	Hour act (Heater) = Hour set (Heater) Min act (Heater) = Min set (Heater) If no other timer has expired ->*Standby*	Error tone	Error tone	If no other timer has expired ->*Standby*

***State and action table* for the kitchen timer: The states are shown in the left-most column, the possible actions at the top of each of the other column.The *state and action table* for the kitchen timer shows the effects of depressing each of the keys, of a simultaneous depression of the HOUR & MIN. keys and of the expiration of the different timers.**

Prototype

A prototype or simulation of the equipment is the most elaborate description of it. If suitable notes and displays of the different parameters are added to it, it can in fact show the same information as all the other descriptions combined, and it can show the information from the viewpoint of the user, not the designer.

A prototype offers therefore the following advantages compared to the other descriptions of the user interface:

- The prototype can be used for usability testing.
- The prototype can be understood by persons who cannot visualise the final user interface from a study of the other documents describing the user interface.
- The prototype highlights any problems in the design, problems that very well may have passed unnoticed in the other descriptions.

The different prototypes will very often only describe part of the user interface. When that is the case it may be advantageous if it is indicated in the other descriptions of the user interface precisely which elements that are covered by the different prototypes.

A prototype of at least part of the user interface is therefore useful already from the beginning of the design; it may even be easier to make a user guide and a prototype first and then complete the other descriptions afterwards.

Prototype of the kitchen timer

Unfortunately, it could not be included here.

Gradual improvement of the descriptions

The design of the user interface consists of a gradual improvement of the different descriptions of it.

The designer may during the design of the user interface identify conflicts between the different requirements. When that is the case, the different requirements should normally be given the following priorities:

1. Assure that similar actions lead to similar results in all states. That will improve the operational speed and reduce the risk of the user making any errors and is probably the most essential point when designing user interfaces for inattentive use.
2. Reduce the consequences of any errors the user may make, in particular when they cannot easily be *undone* for instance by requesting an acknowledgement. Such error situations are not very frequent, so it makes no sense to make the whole operation of the user interface more difficult because of them.
3. Reduce the number of actions that are necessary for completing the tasks that the user will do most often. That includes the fitting of the states of the equipment to the situations experienced by the user, so that the user should not

do a large number of actions in order to move from one state to another if the same actions or information could have been placed in one state. The designer should only remember that the users often do more different and more varied tasks than he imagines, so his job is not done when he has minimised the number of actions in the one task he imagines the user does most often.

The same action will often be part of several different functions, the same function can be part of several different tasks, and it is even possible to use different functions for completing a particular task. This means, that the structure of the equipment cannot be specified from the top down or from the bottom up as a simple hierarchical structure—the descriptions of the different aspects has to be made in parallel.

It is therefore not possible for the designer to complete one description and move on to the next—the design based on the next description will very often result in changes in the first.

The descriptions of the user interface can be compared to a work of art. *When the design is completed, it should appear as a unity where all parts fit into the total design.*

15.6 EVALUATION DURING THE DESIGN PROCESS

The evaluation of the design of the user interface should serve two purposes:

- It should make it possible to detect and correct errors as early in the design process as possible, reducing the wasted amount of time and effort.
- It should inspire to improvements in the design—such improvements are in most cases only possible when an error or a problem are identified in the design.

The evaluation of a user interface is probably the most emotional part of the design of it. The designers has often strong feelings about what he feel is his masterpiece and will therefore object to even mildly critical comments.

My own experience indicates that the evaluation of a user interface is more open and inspirational if the following conditions are fulfilled:

- The person or persons criticising the user interface should identify and describe any problems but never try to solve them. If they try to define the solutions, they leave nothing for the designer.
- The designer should accept that if part of the user interface causes negative comments, it is likely that something is wrong with it, even if the persons criticising the user interface cannot describe precisely what the problem is or describe why it is a problem.
- The evaluation should be done several times during the design process. It is much easier to accept critical comments to a user interface if they are given 3 or 4 times during the design process than if they are given only at the end of the design process where it is very difficult to change anything in the design.

A professional designer will normally accept critical comments and try to evaluate his own work while it is going on. He cannot be creative and critical at the same time, but the design process can be similar to the work process

of an artist who interrupts his painting and looks at the model to see if he has caught the right expression.

Petroski [1985: 44] describes a design process as follows:

> The process of ... design may be considered a succession of hypothesis that such and such an arrangement of parts will perform a desired function *without fail*. As each hypothetical arrangement of parts is sketched ... the candidate structure must be checked by analysis. The analysis consists of a series of questions about the behaviour of the parts under the imagined conditions of use... [P. italizing]

Petroski describes the design of bridges and other physical structures, but his description is equal valid for the design of a user interface.

The designer should during the design process compare each part of the design with the theory and the descriptions of the thoughts and behaviour of the user and use the quantitative guidelines as described in subchapter **13.1 Evaluation methods and criterias** as a checklist for evaluating the design.

The designer should operate each of his prototypes and use the introspective method until he has identified as many problems as possible in the design. The introspective method is described in more details in subchapter **13.1 Evaluation methods and criterias** together with the use of experiments where a group of users operate a prototype or the actual equipment. If feasible the designer should insist on at least one such experiment during the later part of the design process.

It is always easier to correct any errors during the design process than after the product has gone into production.

15.7 LEARNING BY PERCEIVING AND CORRECTING ERRORS

The design process is easier if the amount of errors that has to be corrected are minimised. Petroski [1985: 163] writes:

> The paradox of engineering design is that successful structural concepts devolve into failures, while the colossal failures contribute to the evolution of innovative and inspiring structures. However, when we understand the principal objective of the design process as obviating failure, the paradox is resolved. For a failed structure provides a counterexample to a hypothesis and shows us incontrovertibly what cannot be done, while a structure that stands without incident often conceals whatever lesser lessons or caveats it might hold for the next generation of engineers.

Petroski writes once again about the design of bridges and other physical structures, but his description is equally valid for the design of user interfaces.

There is a multitude of ways in which the design of a piece of electronic equipment can fail, so it becomes unsuitable for its intended purpose. Most of these ways are not very obvious, and it is impossible to formulate simple and

precise rules that can predict whether a particular design will fail, or whether it can be used successfully.

It is therefore often necessary to conduct extensive usability tests and to implement a large number of corrections, and the time spend on these activities can be reduced significantly if as many errors as possible are identified in earlier designs and avoided in the current one.

16. UNSOLVED ISSUES

This book covers a wide range of topics, and during the work on it I have therefore uncovered a number areas where more material describing different aspects of human thinking and behaviour is needed.

Derived from chapter **7. Thoughts with and without attention**:

- The relation between visual and verbal thoughts and attention and to what extent they can be independent.
- The precise function of the prioritising or ordering of different actions—the *contention control*.

Derived from chapter **8. Perception during inattentive use**:

- How much more difficult is it to perceive elements shown on a screen, when they present contradictory clues to their depth or shape.
- To what degree is the attention drawn to symbols that are brighter than the background and at the same time either flashing or seemingly moving towards the user, as compared to symbols that only are brighter than the background.

Derived from chapter **9. Associations, Impulsive Power and Effort**:

- The function and effect of intuition in problems solving, in particular when operating a piece of electronic equipment.
- The problems experienced by the user when it is difficult to conceive properly of and discriminate properly between elements presented by a piece of electronic equipment.

Derived from chapter **10. Physical actions**:

- The relation between different characteristics of keys, the strains on fingers and hands and the risk of work related injuries.

Derived from chapter **11. The environment and the work process**:

- Experimental results describing the interference between verbal thinking and the use of the left hand as compared to use of the right hand.
- Empirical research of the manner in which users think and act when they shall try to operate a new and unknown piece of electronic equipment.

In order to make the evaluation of equipment more precise and generally applicable, the following experiments should be completed:

- Reviews of equipment where the reviewer has no previous experience using it. I have substantial experience using the equipment evaluated in chapter **13.**, and with less experience using the equipment it is possible that the reviewer cannot find the same amount of problems in the equipment.
- Evaluation of usability of equipment using the methods described in this book and done by other persons than the present author. It is possible the methods shall be modified or defined in more details in order to make it possible to compare evaluations done by different persons.

In order to make the results more operational, there is a need of more material describing different parts of the design of electronic equipment:

- A more precise definition of the level of performance actually expected by the users. If the ordinary voice-only phone is taken as representing that level, the level may be based on the degree of attention, speed of operation and error rates the normal user experiences while operating the phone.
- Finding a method for selection of messages and receivers that is better suited for inattentive use than the scrolling in different lists.
- Experiments testing the usability of the prototype terminals described in the book. The human mind is extremely complex, it is therefore advantageous to do such a testing in a realistic setting employing a wide range of potential users.
- Test of the value of the quantitative evaluation and comparisons with the level of usability found through experiments. That is necessary for ascertaining the reliability of the quantitative methods.
- Use of the described design methods for the design of equipment where the designer has no previous experience doing the tasks the equipment is intended for. It is likely the design in that case is more difficult than when the designer already knows the situation of use by heart.
- Use of the design methods by other persons than the present author. The use of the methods depend to a large extent on the skill and motivation of the designer, and it is therefore possible that other designers sometimes will experience more problems or get a less satisfactory result.

However, none of the points listed in this chapter affect the general conclusion.

17. CONCLUSION AND FINAL DISCUSSION

This chapter describes to what extent the goals listed in chapter **4** have been fulfilled, and it gives an overview of the results described in this book. These results are not described in the same order as in chapters **8** to **11** and **13** to **15**; they are divided according to topics, such that the description of each topic includes:

- Requirements for the design
- Design methods
- Evaluation of the design

17.1 FULFILMENT OF THE GOALS OF THE BOOK

This book should in its entirety prove or disprove a hypothesis consisting of 3 points listed in subchapter **4.1 Overall goal of the book**.

The points can briefly be stated as:

- When the user is inattentive to the equipment, it becomes more difficult for him to carry out any useful action.
- When the equipment draws the attention of the user, he will not always be aware of events happening in his environment.
- It is possible to design equipment where the limitations of the user are taken into consideration.

The extent to which each point is proved or disproved is discussed in the following; *proved* or *disproved* does not signify the establishment or rejection of formal proofs, but signify—as in everyday language—the establishment of some facts beyond reasonable doubt.

Doing useful actions without paying attention

The user can only carry out a useful action if he perceives the relevant elements presented by the equipment, settles upon a proper action, and completes one or more physical actions leading to the desired result.

Perception during inattentive use

In chapter **7. Thoughts with and without attention** the effect of paying attention to something is described, in particular that the user better can perceive, conceive of and distinguish between different things when he pays attention to them, and chapter **8. Perception during inattentive use** elaborates on that. That chapter describes in particular that an inattentive person:

- Tends to perceive what is expected instead of what is presented. The inattentive person will in particular find it difficult to perceive differences between two elements when they are not presented simultaneously.
- Can perceive simple elements, but cannot perceive things consisting of several unrelated elements. The inattentive person cannot, for

instance, correctly perceive elements characterised by different combinations of shapes and colour.

- Can perceive the meaning of single words, but cannot perceive the proper meaning of a sentence or several unrelated words. The inattentive person will often perceive one or two words in the sentence and assume a meaning based only on them.

The inattentive users perception of the equipment may therefore be erroneous.

Conscious decisions during inattentive use

The user can be inattentive in a number of different ways. In chapter **7. Thoughts with and without attention** the following 3 are identified:

- The user can be in a *state of reduced conception* where he neither conceives of nor thinks about what he senses.
- The user can be *shifting his attention back and forth* so he at the most only pays attention to the equipment for a short period at a time.
- The user can operate the equipment as part of an *automatic process* where the actions follow each other in a habitual manner.

When the user is in a state of reduced conception, he will often repeat the same action one time after the other without any regard to its consequences.

During shifting attention the user will by a voluntary effort focus his attention on one thing after the other, but when his *attention* is focused on one thing, he cannot control voluntarily what other things he at the same time will be *aware* of. It is therefore possible that he will remain unaware of an event requiring a conscious decision.

When the user operates the equipment as part of an automatic process he will make slips or errors as described in subchapter **9.5 Choosing an action**. When that happens he follows his habit in a slightly different manner—he may for instance replace one action in the automatic process with another similar one.

When the user operates the equipment as part of an automatic process, he associates without any effort from one part of the process to the following ones. The user can therefore only stop the process by making a conscious decision, and even after the user has decided to stop the process, he may, as described in subchapter **10.3 The structure of physical actions**, complete one or two actions before the automatic process is completely stopped.

During inattentive use it is therefore possible that the user makes an error, because his action in a particular moment is born out of habit and not based on a conscious decision.

The action does not lead to the proper result

During inattentive use it may be difficult for the user to act in a manner that leads to the desired result.

Subchapter **9.5 Choosing an action** describes that the inattentive user cannot make and carry out a plan that covers several actions: Based on his perceptions in the moment when he decides, he can at the most decide upon the next action he will do.

The same subchapter describes also that the user always will make mistakes, for instance when he occasionally devotes less than sufficient attention to a specific action.

This means that even if the inattentive user has perceived the state of the equipment correctly, he may act in a manner that does not lead to the proper result.

Conclusion on the possibility of doing useful actions without paying attention

It is significantly more difficult for the user to complete a useful action when he is inattentive, as compared to when he focuses his attention on the thing he acts on and the action he is carrying out.

The inattentive user and the environment

As described in subchapter **7.5 Attention** it is possible that a person who focuses his attention very narrowly or very intensely cannot perceive things outside the area he focuses his attention on.

Chapter **3. Inattentive use may be the rule rather than the exception** describes among other topics how the actions or personal well-being of the user often is degraded if he becomes unaware of events happening in his environment. One example of that is the person driving a car: If he becomes unaware of any other cars on the road, it may result in an accident.

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

Design of equipment for inattentive use

It is possible to use a piece of electronic equipment without paying attention, if it is adapted to the specific limitations of inattentive use:

- Chapter **8. Perception during inattentive use** describes how the elements presented by electronic equipment can be adapted to the limitations of the perception of the inattentive user.
- Chapter **9. Associations, impulsive power and effort** describes how the structure and elements of electronic equipment can be adapted to the limitations of the reasoning of the inattentive user.
- Chapter **10. Physical Actions** describes how electronic equipment can be designed so the movements needed for operating it can be done without paying attention.
- Chapter **11. The environment and the work process** describes how interference between the operation of the equipment and other activities can be reduced.

The specific requirements described in these chapters shall be listed in the following subchapters **17.3** to **17.7**.

However, it is also necessary to show that the different requirements can be combined in one piece of electronic equipment. Chapter **14. Communication equipment for inattentive use** describes therefore two pieces of communication equipment that fulfil the requirements described in chapters **8.** to **11.**.

It is demonstrated that a designer who knows the requirements can design equipment so that the limitations of the inattentive user are taken into consideration; the designer can minimise 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.

Proof or disproof of the hypothesis stated at the beginning of the book

This book should prove or disprove a hypothesis consisting of 3 points listed in subchapter **4.1 Overall goal of the book** and repeated in an abbreviated form at the beginning of this subchapter.

The preceding part of this subchapter describes how each of the points have been found to be correct beyond reasonable doubt. *The hypothesis stated at the beginning of the book can therefore be regarded as proven and the goal as fulfilled.*

17.2 EVALUATION OF THE APPLIED METHODS

Subchapter **6.5 The description of the human mind made by William James** lists a number of reasons for using William James's [1890] *Principles of Psychology* as basis for the work.

William James [1890] introduces the introspective method, and Chapters **7.** to **10.** shows that the introspective method makes it possible to identify a number of aspects of the inattentive user and to identify specific problems when he operates a piece of electronic equipment.

Even though results achieved through the introspective method must be corroborated with information from other sources, the method can give an extensive and detailed information in a much shorter time than possible if the same information should be gleaned from usability studies where the researcher does not use the equipment extensively but only interviews users and observes their behaviour.

The introspective method is therefore a valuable addition to the methods normally used when evaluating user interfaces for electronic equipment.

William James [1890] gives a consistent and very detailed description of the human mind, and in particular chapters **7.** to **10.** demonstrate that the concepts introduced by him are indispensable for describing the inattentive user and for analysing the newer results of the cognitive psychology:

- Treating *the thought and its object as two different concepts* makes it possible to describe the difference between being aware of something and paying attention to it.
- *The stream of thought* makes it possible to describe the consequences if the user is interrupted before his thinking has reached a conclusion.
- *The act of conception* makes it possible to describe the state of reduced conception in a usable manner, and to give a much more detailed and usable description of the perception and thinking of the user.
- The descriptions of *reasoning* and of *the role of will and effort* makes it possible to give a detailed description of the different factors that may prevent the user from initiating the proper action.

The use of the concepts and framework of William James makes it therefore possible to give a much more detailed description of the thoughts and limitations of the user than the one possible if a computer inspired model of the human mind is used, for instance as described in subchapter **6.2 Use of computer inspired models of the users mental processes**.

The earlier parts of the book shows that William James's [1890] *Principles of Psychology* is the best possible basis for an analysis of the users thoughts and actions: The results are better than if the work was based on the information-processing or neurophysiological approaches.

17.3 EQUIPMENT WHOSE CONDITION CAN BE PERCEIVED DURING INATTENTIVE USE

As described in subchapter **8.2 Perception, concepts, habits and expectations** the user can only perceive the condition of the equipment if he can sense the elements presented by it and conceive of them in a meaningful manner.

Subchapter **8.4 Perception, shifting attention and automatic processes** describes in addition that whereas an attentive user often can reconsider and correct a wrong perception, the inattentive user often will act upon the wrong perception and make an error.

Perception during inattentive use

Subchapter **8.4 Perception, shifting attention and automatic processes** describes that both an attentive and an inattentive user easier can sense the elements presented by the equipment if:

- All elements are presented in an order from left to right and from the top to bottom, because our eyes normally scans a visual field in these directions. The order should be followed both for all elements presented on a screen, for all other indicators and for all keys and other actuators on the equipment.
- The screen of the equipment presents the elements without any blurring, jagged edges or parallax caused by the thickness of the screen. Even if the blurring or jagged edges barely are perceptible, they can still impede the sensing of the elements.
- The screen of the equipment is without any disturbing patterns for instance from drivers for the display. In particular disturbing patterns consisting of vertical and horizontal lines should be avoided.
- The presented elements are natural looking and small, normally narrower and lower than 2 cm, distributed on a uniform and unobtrusive background. The user interface should resemble a landscape with objects distributed in it, and not a wall with the elements perched in pigeon-holes.
- The elements consist of lines with an approx. width of 1 mm, equalling a height of any letters on approx. 11 mm.
- The elements are made with textures or colours that distinguish them from the background and from other elements.
- The elements are not defined as different combinations of several unrelated parts or parameters, for instance different combinations of shapes and textures or colours; when an element consists of a different shape and a different texture or colour, it should be possible to discriminate the object by perceiving either the shape or the texture or colour.

It is not possible to produce a screen or display that can display elements as discernible as elements in the physical world; keys and indicators should therefore when possible be made as separate physical elements.

The user will often conceive of a less known element as a similar well known element, for instance an element the user just has seen or an element the user associates with a well known name. It is therefore easier for the user to perceive elements he can conceive of or associate with another already known element, but it is difficult for the user to discriminate an element that is similar to another more well known element presented by the equipment. All elements presented by the equipment should therefore be clearly differentiated and each element should resemble other already well known elements, for instance things in the physical world, digits or geometrical figures with a well known name.

The inattentive user can in the same moment only perceive and hold in the consciousness three nonsense syllables or five words, and my own experiments show that single words in a sentence easily are overlooked. It should therefore be possible to perceive the meaning of a verbal element by perceiving at the most two or three words, and different elements should differ by more than a single word, the inclusion or omission of the word *not* is for instance not sufficient for differentiating two elements during inattentive use.

Words are normally as easy to perceive as icons, and it may be difficult to associate a name with an icon. The different elements should therefore be marked with words instead of icons; the only exceptions are keys and hardware labelling where the available area is too narrow for printing a word, or where the production of versions for different languages is not economically or logistically feasible.

Audio messages should if possible only be used for drawing the attention of the user, because he may have focused his attention elsewhere while the message is played; if, for some reason, it is necessary to present a spoken message, the user should be alerted before any essential information, and the vital information should be repeated.

Design of the elements of the user interface

The distribution between elements implemented in hardware and elements shown on a screen and, in some cases, the labelling of the keys are often decided at the beginning of the design process. If, for instance, part of the equipment is a normal PC, what can be implemented in hardware is given by the keys and labels presented by the standard keyboard. The designer must then try to reach the best possible result in a sometimes almost impossible situation.

However, as described in subchapter **15.5 Use of different descriptions of the user interface** the major part of the elements in the user interface is normally designed together with the format of the user interface, though the final writing of the display texts can be postponed until the completion of the *state and action table*.

Evaluation of the elements of the user interface

It is not possible to define a quantitative figure that gives a meaningful indication of the problems caused by elements being implemented on a less than perfect screen instead of as hardware, and it is not possible to define a quantitative figure that describes which figures that are similar and difficult to discriminate. A review should therefore always explicitly discuss these two points.

The remaining parameters related to the perception of elements can all be analysed as part of a quantitative evaluation as described in subchapter **13.1 Evaluation methods and criterias**.

17.4 EQUIPMENT THAT ATTRACTS THE ATTENTION OF THE USER WHEN AND ONLY WHEN IT IS NECESSARY

The equipment should alert the user or draw the attention of the user when he must pay attention to the equipment and make a conscious decision.

Subchapter **8.5 Sensations drawing the attention** describes how the equipment can draw the attention of the user by presenting figures with a distinctive *slope* , granularity or TEXTURE, or even better by presenting figures of a different colour or **brightness**, or ideally by using flashing figures or figures seemingly moving towards the user.

If the user cannot keep the equipment continuously in his field of vision, the equipment can draw the attention of the user with an audio signal, if necessary intermittent, with a fast rhythm, with loud and high or obnoxious penetrating tones or with a human voice impressing some urgency. However, no matter the type of audio signal, the user tends to confuse sounds from different pieces of equipment or from the equipment and the environment. It is therefore necessary to design audio signals so they are easy to discriminate when the user cannot perceive the direction they are coming from.

As an alternative the equipment can draw the attention of the user by some sort of tactile signal. The user can very easily perceive that such a signal comes from the equipment, but it attracts the attention of the user in a very forceful manner, and therefore it cannot be used while the user may be carrying out some critical task, for instance driving a vehicle.

The equipment should not draw the attention of the user, when it is unnecessary that he pays attention to it. This means that the equipment of course should not sound alarms or ask for acknowledgements when the consequences of an error are trivial, and, as described in subchapter **9.4 Making useful associations**, the elements of the equipment should be vivid and distinctive so that the user can perceive and act upon them without paying continuous attention to the equipment.

Design that draws the attention of the user

Subchapter **9.5 Choosing an action** describes how the user always during an automatic process will make slips and errors, and subchapter **10.3 The structure of physical actions** describes how the user may complete one or two actions before the automatic process is completely stopped.

During the design it is therefore essential that the designer ensure that the equipment draws the attention of the user, when he, as part of an automatic process, is about to do an action that cannot be undone.

Evaluation of how well the equipment draws the attention of the user.

It is possible to enumerate the states in which the equipment should draw the attention of the user but does not do it and the states in which the equipment flashes or sounds some alert drawing the attention of the user, even though it is quite unnecessary to draw the attention of the user. These points can therefore be included in the quantitative evaluation of the design as described in subchapter **13.1 Evaluation methods and criterias**.

It is, however, not possible to define a figure that describes the vividness or distinctiveness of the different elements presented by the equipment. That point should therefore be given special consideration when the design is reviewed.

17.5 EQUIPMENT WHERE THE USER WITH MINIMAL ATTENTION CAN DECIDE UPON AN ACTION

Chapter **9. Associations, impulsive power and effort** describes the steps the user goes through before he initiates an action:

- The user must conceive of the problem to be solved in a manner where he can solve it.
- The user must make an association to possible actions either directly or through some sort of reasoning.
- The user must select one among several possible actions.
- When the user has selected an action, he must expend some will and effort in order to initiate it.

During inattentive use it is not always possible for the user to decide upon the proper action:

- If the user is in a state of reduced conception, he can neither conceive of nor think about what he senses, and therefore he cannot consider which actions he should initiate.
- If the attention of the user is shifting, it may be attracted to something else before he can initiate an action.
- If the user operates the equipment as part of an automatic process, the actions can happen independently of the objects of the thoughts.

Subchapter **9.3 Different users decide in different manners** describes how different users are more or less capable of thinking in pictures or of perceiving subtle differences in meaning, and their decisions may be dominated by reasoning, intuition or will and a desire for action. It should therefore not be necessary for the user to recall any sort of visual information when operating the equipment, the texts presented by the equipment should be as unambiguous as possible, and the equipment should give help or support for the careful or intuitive user and minimise the risk of any damage being done by a user whose will and effort is unimpeded by excessive thinking.

Subchapter **9.4 Making useful associations** describes that if some of the elements in the equipment are confusing or labelled in a misleading manner, the user will continue to make errors even after he has learned to use the equipment and the operation of the equipment has become part of an automatic process.

It is therefore essential that all misleading or confusing elements are removed from the equipment. Such misleading or confusing elements include:

- *Hidden states*, so the user cannot perceive the actual state of the equipment but is forced to remember it during the operation of the equipment.
- *Invisible choices*, where the user cannot perceive the choices that are available but must recall their existence before he can select them.
- *Identical or very similar names* used for different elements.
- *Using familiar words with an unfamiliar meaning.*
- *Using symmetrical elements*, for instance elements that only differ from each other by one being to the right and another being to the left or one being with a *dash* and the other being without a *dash*. Such elements are often confused.
- *Labelling functions as things*, for instance use of the word *Door* for *Close door*.
- *Invisible or missing relations between elements:* One element affects another when the user does not expect it, or an element does not affect another when the user expects it.
- *The same function gives slightly different results* or is operated in slightly different manners in different states of the equipment.

The list may be incomplete—designers of electronic equipment are still finding new ways of misleading or confusing the users.

Subchapter **9.5 Choosing an action** describes how an inattentive user cannot make or use a plan for his operation of the equipment, but must base each action on the elements he can perceive at the moment when he makes the decision, and subchapter **9.6 Use of browsing and trial and error** describes how the user therefore often uses browsing and trial and error instead of finding and carrying out a sequence of actions that leads directly to the desired goal; browsing and trial and error can be done as an automatic process, so the user can devote his attention to other tasks, and the use of browsing and trial and error is often faster than if the user tries to find the best possible sequence of actions by reasoning.

The equipment should therefore be adapted to operation as part of an automatic process and in particular to the use of browsing and trial and error:

- The number of actions needed for finding a particular state or function should be minimised. That can be done by reducing the number of states, by providing as many connections as possible between the states and by reducing the distances between them by using a multi-dimensional structure instead of a one-dimensional scrolling menu.
- The number of actions needed for activating a function should be minimised.
- It should be possible for the user to do as many different tasks as possible and whenever feasible to do the different parts of a task in any order.
- It should whenever feasible be possible to *backstep* to the last state by doing just one action, and it should be possible to *undo* any function when it is feasible.
- When the user cannot *undo* a change of state or a function by doing a single action and the consequences of the change of state or activation of a function are non-trivial, the equipment should draw the attention of the user, and the user should acknowledge the choice before the state is changed or the function activated.
- The user should be provided with *road signs* making it easier to move towards the state or function he is looking for, so that he is not forced to use a map or guide over the states or functions.

If the user hesitates, it is possible that his attention is drawn to something else before he initiates the action. The equipment should therefore reduce the hesitation of the user. That can be done by providing *backstep* and *undo* functions and *request for acknowledgement* as earlier described. The user will then know that the consequences of making an error will be minimal. In addition, it is essential that the users rhythm of work is unbroken and that the user can trust the equipment. The equipment should therefore be reliable, and in particular react quickly in a uniform manner when the user has made an action. That can in particular be a problem for communication equipment, where delays in the communication system are unavoidable and of varying duration. In such cases, it is essential that the condition of the equipment continuously is displayed to the user.

Design where the user with minimal attention can decide upon an action

The design can never be better than the information it is based upon. It is therefore essential that the designer makes a good description of the possible users:

- Tasks carried out by normal users of the equipment.
- Situations experienced by the users of the equipment.
- The dispositions and special limitations influencing the actions of different groups of potential users.

Apart from that, the designer should use the *state and action table* described in subchapter **15.5 Use of different descriptions of the user interface** to assure that each state contains the functions the user needs in a particular situation and that each action when feasible gives the same or a similar result no matter the state of the equipment.

The designer should also assure that the user easily can follow all possible paths through the different functions he may choose for completing the same task; that is done by tracing each task on the state diagram as described in subchapter **15.5 Use of different descriptions of the user interface**.

The designer should finally assure that all misleading and confusing elements are eliminated and that all texts are unambiguous. That is done through a thorough reviews as described in **15.6 Evaluation during the design process**, or when the designer or a participant in the review acts as the Devil's advocate and tries to blow holes in every part of the design.

Evaluation of how well the user can decide upon the proper action with minimal attention

The quantitative evaluation as described in subchapter **13.1 Evaluation methods and criterias** can be used for evaluating how easy the equipment can be used while paying minimal attention to the operation of it.

However, the quantitative evaluation cannot be used for identifying:

- All cases where the text may be ambiguous.
- Any particular problems in one of the paths that can be used for completing a task.
- That functions in each state fit the needs of the user in the situation when he accesses it.
- That a specific action when feasible gives the same or a similar result in all states.
- That the equipment is reliable, also after wear and tear and a period of use.

These points should therefore be addressed specifically during the reviews.

17.6 EQUIPMENT ON WHICH THE USER CAN DO A PHYSICAL ACTION WITH MINIMAL ATTENTION

The user will often hold or carry the equipment for prolonged periods of time, move around it, lift it, change batteries, or open or close covers, and he will do these actions without paying attention to the equipment.

Subchapter **10.3 The structure of physical actions** and **10.4 Reaching, stopping or grasping** describes therefore how the equipment can be adapted to these situations of non-use:

- The equipment should be without any sharp edges or protruding corners that may cause trouble when the user does not pay attention to the equipment.
- Prolonged periods of static use of muscles can be harmful, so it should be possible for the user to vary his physical position while holding or using the equipment.
- If the equipment is portable, it should be designed such that the user does not drop the equipment if he does not pay attention and therefore loosens his grip.
- It should be possible to lift the equipment, change battery or open or close covers on the equipment without changing the grip on it.

In addition, subchapter **9.3 Different users decide in different manners** describe how a significant number of users *think with their hands* and intermittently may rub, scratch or move parts of the equipment—the equipment should therefore be designed such that it withstands such a treatment for a prolonged period of time.

It should be possible for the user to operate the equipment with as little attention as possible on each separate physical action.

As described in subchapter **10.2 The use of visual guidance** and subchapter **10.3 The structure of physical actions** it is therefore necessary that the equipment fulfils a number of requirements:

- It should be possible to do all physical actions on the equipment without continuous visual guidance. That means, in particular, that keys ideally should have a width and height on at least 25 mm if the user cannot rest his wrist or another finger on the equipment while activating the key.
- It should at any time be possible for a user to make use of visual guidance while making a physical action.
- The equipment should be designed such that it can be operated with both hands, because use of the left hand normally interferes less with verbal thinking.
- The equipment should be mechanically reliable with a reliable tactile feedback from all actuators.
- It should be possible to operate the equipment without making any combination of movements that conflicts with previously learned combinations of movements, for instance movements learned for touch typing.
- It should be possible to operate the equipment without making any precise curved movements and without making any simultaneous but different movements with 2 or more fingers or with 2 or more hands.

In addition subchapter **10.4 Reaching, stopping or grasping** describes some requirements that should be fulfilled by all knobs and keys:

- If the user, before he reaches for a knob, cannot see the direction he shall turn it, the maximum angle it can be turned should be less than 90°; if the user, before he reaches for a knob, easily can see the direction he shall turn it, the maximum angle it can be turned may be increased to 180°.
- All knobs should be resilient so the user gradually can stop his hand and fingers after he feels the surface of a knob.
- All keys should provide a tactile feedback at the point of depression where they are activated, and after the point of activation it should be possible to depress them further down to a resilient bottom position.
- If keys are depressed continuously, for instance during touch typing, the maximum force needed for depressing a key to the position where it is activated should be below 60 g or 0.6 N.

Subchapter **10.5 Turning of knobs, adjustment of settings and handwriting** and subchapter **10.6 Speaking** describe some physical actions that are ill suited for inattentive operation of electronic equipment:

- If feasible, any use of handwriting or other actions that require precise movements should be avoided, because such actions normally require a precise guidance or feedback and easily are affected by emotions as described in subchapter **10.3 The structure of physical actions**.
- It should be possible to operate the equipment without using any spoken commands. The only exception is the use of a voice activated recorder or transmitter that reacts so fast on the detection of a voice that no part of the spoken message is lost.

Physical design of electronic equipment for inattentive use

In most cases the designer of the user interface cannot decide all relevant parts of the physical design of the equipment. A number of different persons may bear a decisive influence:

- Part of the physical design may be decided by managers who have required that the equipment should be based on specific hardware units, for instance on a normal PC. However, even in that case it may be possible for the designer to request a keyboard or other actuators that fulfils the requirements for inattentive use.
- Part of the physical design may be done by an appearance designer. As shown by one of the examples in subchapter **1.2 The frustration of design** that may lead to a design that is highly praised but ill suited for inattentive use or, in the worst case, for any sort of use at all. The designer of the user interface may then be forced to fight it out with the appearance designer.
- Some of the parameters are determined by the persons doing the mechanical design; important parameters as the movement, tactile feedback and force needed to depress the keys depend on specific details of the mechanical design. In that case it is essential that the designer at the earliest possible time states these requirements as precisely as possible.
- It is finally possible that the designer as described in subchapter **15.5 Use of different descriptions of the user interface** can design the different actuators together with the format of the user interface.

The physical design and the design of the different actuators involve often a number of different persons, and my experience as described in subchapter **1.2 The frustration of design** indicate that the designers negotiating skills may be as essential as his professional skills during the physical design and the design of the actuators.

Evaluation of the physical design of electronic equipment for inattentive use

The quantitative evaluation described in subchapter **13.1 Evaluation methods and criterias** can be used for evaluating all parts of the physical design.

The only exceptions are the mechanical reliability of the equipment and the resilience and precise *feeling* or characteristics of knobs and keys on the equipment; subchapter **10.3 The structure of physical actions** and subchapter **10.4 Reaching, stopping or grasping**, describe how these parameters affect an inattentive user much more than an attentive user.

The mechanical reliability of the equipment and resilience and characteristics of any knobs and keys should therefore be evaluated separately and treated explicitly during the reviews.

17.7 EQUIPMENT WHERE ONE ACTION DOES NOT INTERFERE WITH ANOTHER

The inattentive user will often operate the equipment while thinking about or trying to do something else, and even when the operation of the equipment is part of an automatic process it may interfere with his thinking or physical actions.

If the user has to use both his hands or eyes when carrying out a task, it will almost inevitably interfere with other tasks.

However, in other cases it is possible to minimise or even to eliminate the interference between operation of the equipment and another task: The equipment can for instance be designed such that the user easily can make a strong association from each function to the actuator that activates it, and such that all actuators can be identified equally well from the names they are labelled with and from their shape or position. It is then possible for the user to think about the activation of all functions in either a verbal or a visual or spatial manner, and it is therefore possible for the user to think about the operation of the functions in a manner that interferes minimally with the other task he is carrying out.

In addition, it should be easy for the user to adapt the equipment to his own operation in the specific situation, in particular to reposition it, change the fingers he uses for operating it, and change the manner in which he holds it. Even though such an adaptation does not reduce the interference significantly, the user will feel the equipment is easier to use and the inattentive use will therefore be easier.

The user should finally have continuous access to a suitable user guide for the equipment. Even though such a guide cannot solve the problems of a badly designed piece of equipment, and even though the user never may look in it, it will make him more confident and thereby make it easier for him to operate the equipment.

Design of equipment where the interference with other tasks are reduced

The design of equipment where the interference between the operation of the equipment and other tasks are minimised requires a proper description of the situations of use, in particular the environments in which the equipment may be used.

However, even when a thorough description of the different situations of use has been made, it is difficult to design equipment where the interference between use of the equipment and other tasks are minimal in all situations, and it is therefore often necessary for the user to adapt the use of the equipment to the specific situation of use. Because of that the equipment should be made as flexible as possible: The designer should identify and remove any unnecessary restrictions or limitations he has put into the user interface.

Evaluation of the degree of interference between the operation of the equipment and other tasks

The interference between different actions is in general not as well understood as for instance the perception of different elements. It is sometimes essential that the interference between operation of the equipment and other tasks is minimised, and such a minimised interference can only be assured by doing usability tests. In that case the equipment should be tested under conditions that are as similar as possible to the situations in which it is going to be used.

17.8 ATTENTIVE AND INATTENTIVE DESIGN OF ELECTRONIC EQUIPMENT

A piece of electronic equipment will always require some minimal amount of attention: The designer may either focus his attention on every detail of the design and make it as good as possible, or the user may be forced to focus his attention on details of the operation while he completes a task.

The kitchen timers analysed in subchapter **9.4 Making useful associations** demonstrates how small and almost trivial errors in the design can make inattentive use very difficult.

In chapter **13. Evaluation of communication equipment** a combined phone and fax and a cellular phone are evaluated. It is likely that the actual design of the two pieces of communication equipment is the result of a development where more and more functions has been added to the equipment, and it is likely that the designers did not have the proper tools for making a design that was easy to use or suited for inattentive use. That is probably often the case.

However, in the cases described in subchapter **1.2 The frustration of design** it seems that the designers and the manufacturer employing them cared very little about whether or not the electronic equipment could be operated by the actual users. They had a captive audience and knew the low level of usability would remain hidden until the equipment was purchased and the users started to use it.

In most cases the user has purchased the electronic equipment before he finds out that it is very difficult to use, and, as described in chapter **3. Inattentive use may be the rule rather than the exception**, he will at one time or another be forced to use it without paying continuous attention to the operation of it.

That problem can only be solved if the usability of electronic equipment is evaluated before it is acquired.

Institutional customers could make a review of equipment to be bought in large quantities and for instance use the quantitative methods described in subchapter **13.1 Evaluation methods and criterias**. These methods are less costly than a usability test and the results can be used for comparing different pieces of electronic equipment.

Reviewers for newspapers and magazines could also use the quantitative method for evaluation of the usability—the usability could then carry the same weight in the reviews as the ticking off of functions.

It can be stated through legal measures that if a piece of electronic equipment cannot be used for the tasks and in the situations it is intended for, it constitutes a defect in the equipment, so the customer always can return it and get his money back. It is today possible to get the money back if there are any errors in the manufacture or workmanship of a piece of equipment, whereas the customer is not protected against even grave errors committed in the design phase.

As an alternative, an independent agency can evaluate the usability of electronic equipment, and the results can be shown in data sheets or on the packaging or at least be made available for potential customers. The classification of usability described in subchapter **13.1 Evaluation methods and criterias** can be used for that purpose:

5. As usable as possible.
4. Elementary use is easy, though other use, programming or adjustment is cumbersome.
3. Elementary use is cumbersome, or other use, programming or adjustment is very difficult.
2. Elementary use is very difficult.
1. Ill suited for the state purpose.

Without public evaluations of the usability of electronic equipment, it is likely that most manufacturers will continue to give a lower priority to an improved usability during normal and inattentive use than to the addition of more features or the reduction of the costs of production.

The examples described in chapters **8. Perception during inattentive use**, **9. Associations, impulsive power and effort** and **10. Physical Actions** show that electronic equipment that is unsuited for inattentive use can be a continuous nuisance, and the inevitable errors during its operation will always result in a waste of time.

If the equipment is discarded or remains unused because it is unsuited for its intended purpose, it is a waste of resources and money.

And more than that; the examples in chapter **3. Inattentive use may be the rule rather than the exception** and the descriptions in subchapter **8.4 Perception, shifting attention and automatic processes** and in chapter **10. Physical Actions** show that *the adaptation of electronic equipment to inattentive use often is essential for preserving the health and well-being of the user.*

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APPENDIX A: BRIDGE EXPERIMENT

This experiment should investigate how the mental model of a given topic might affect the perception of the same topic. The experiment was done with a number of bridge players. All of the involved bridge players used the same conventions or rules for interpreting a set of 13 randomly picked cards. For that reason, I could assume that they used similar mental models for interpreting the sets of cards.

The mental model of a set of 13 cards consists of the following key elements:

- The point value: An ace is set to 4 points, a king to 3 points, a queen to 2 points and a knight to 1 point. In general, a set of cards shall contain 12 points or more in order to start bidding, and 6 points or more in order to support the partners bidding.
- The distribution—the number of cards in each colour. In general only colours with 4 cards or more can be bidden, even when the partner has started the bidding.

SCHEDULE

The experiment was conducted:

- February 9, 1994
- March 23, 1994

A number of notes were made at the time the experiment was conducted, but the results could not be finally processed before June 1994.

STRUCTURE

The experiment used a total of 10 different sheets. Each sheet showed a set of cards on the front side and a slightly different one on the back side. One set of cards consisted of the cards being described with the nomenclature used in written bridge exercises and using 14 pt. helvetica font. The remaining sets were produced by making a colour photocopy of each set of cards with a green background. The cards were shown in natural size and close to natural colours. The cards were in all cases placed with cards of the same colour in one row, similar to the convention used by all bridge players when putting down the cards.

The sets were all drawn at random from a pack of cards. However, after a set had been drawn, one or more cards were removed and other added in order to keep the point value between 10-14 and a close to average distribution of the number of cards in the different colours. That was done in order to avoid very uninteresting or very interesting sets of cards, where no full mental picture might be build up—if a set of cards for instance contained only 4 points, all other features might be considered irrelevant by the player.

The set of cards on the front side and the set of cards on the back side of each sheet should be slightly different. That was done by drawing cards at random and replacing them by others. However, none of the cards placed at

the bottom line of the sheet were replaced by other, since they might be too conspicuous.

The sheets were all numbered, with a label on the front side. However, it would make no difference if the participants saw the back side before the front side.

The 10 sheets were set up with the following differences between front and back side:

Set	Comments	Point value	Distribution
1		identical	Different, both a black and a red colour was changed.
2	Description instead of picture of cards on the back side	Identical	Identical
3		Identical	Different, although only the red colours were changed.
4		Different	Identical
5		Ace replaced by picture cards, but identical point value	Identical
6	Order of hearts and diamonds different on the back side	Identical	Identical
7	Cards moved a little bit around	Identical	Identical
8		Identical	4 clubs and 5 diamonds replaced by 5 clubs and 4 diamonds

9	Different	4 clubs and 5 spades replaced by 5 clubs and 4 spades, and 14 cards in total in the set on the back side.

SESSIONS

At both times the experiment was conducted in conjunction to a group of bridge players, making it possible for a table with 4 bridge players to participate in the experiment during a break in the game.

At both times 2 bottles of red wine were used as encouragement for the participants. Lots were drawn among the participants after the experiment had been concluded, making the chance of winning the wine independent of the result.

For the experiment was used a table set up with 4 chairs, 4 pens and a 4 fresh score sheets for each group of 4 participants.

Before the start, the participants were instructed to look on the front side of the sheet, and then to turn it around, look on the back side, mark on the score sheet if the point value or the distribution were the same on both sides and finally to pass the sheet along to the next participant.. They were in addition told that I would take time and ask them to turn the sheets and to pass them along, if they spend more than approx. 7 s looking on each side of each sheet.

A few of the participants asked if only points for picture cards and aces should be counted. I confirmed that, the participants had no other problems of understanding the instructions.

The first group of participants had appx. 65 hours of education and training in bridge, the majority of the second group consisted of players with several years of playing experience.

During the experiment it was not necessary to instruct the second trained group to pass the sheets along, they looked appx. 3 sec. on each side of a sheet before noting down the result and passing the sheet along.

RESULTS

A total of 29 bridge players participated in the experiment:

- February 9, 1994: 11 participant
- March 23, 1994: 18 participants

Perception of identical and different values and distributions

There was a remarkable difference between the error rates in the cases where both sides of the sheet showed the same distribution and the cases where the two sides of the sheet showed different distributions. It seems that

the participants were significantly more inclined to see two slightly different sheets as identical, than to see two identical sheets as different. The same tendency was less significant for the point values, the reason may be that calculating the point value and remembering the resulting figure was fairly easy for a large number of participants.

The values used for the testing was calculated from the percentages of correct responses:

Set of parameters	Average	Varians	Samples.
Same value	0.81	$1.91 * 10^{-3}$	8
Diff. value	0.74	$5.54 * 10^{-3}$	2
Same distribution	0.8	$2.39 * 10^{-2}$	5
Diff. distribution	0.59	$8.67 * 10^{-3}$	5
Same parameters total	0.81	$9.28 * 10^{-3}$	5
Diff. parameters total	0.61	$1.21 * 10^{-3}$	5

A test in the gaussian distribution showed that the difference between sheets with same and different point values was not significant. A similar test in the gaussian distribution showed a better than 99 % probability for the percentages of correct responses being different for sheets with the same and with different distributions.

Perception of differences between values and distributions

There was a difference between the results obtained when comparing the point values and the distribution of the cards. That was to be expected, cause the point value may be remembered as one digit, whereas the distribution in general is remembered as 4 digits. The tendency was more significant for the experienced players in the second test, the reason may be that a number of players in the first test with very limited experience found it more difficult to calculate the point value.

Set of parameters	Average	Varians	Samples.
First test, point values	0.7	$2.44 * 10^{-2}$	11
First test, distribution	0.61	$2.67 * 10^{-2}$	11
Second test, values	0.84	$6.43 * 10^{-3}$	18
Second test, distribution	0.74	$4.01 * 10^{-2}$	18

A test in the gaussian distribution showed that the less experienced players showed no significant difference in the perception of point values and distributions. The experienced players showed a better than 95 % probability for the results for point values and for distributions being different. However, as can be seen from the figures above, point values and distributions are perceived with almost the same error rate, when the parameters on both sides of the sheet are identical. The difference can be related to an added number of errors when perceiving a sheet with a different distribution on each side.

Perception differences related to the level of experience

There was a difference between the participants in the first test, who had a limited training, and the participants in the second test, who had several years of experience:

Set of parameters	Average	Varians	Samples.
First test, point values	0.7	$2.44 * 10^{-2}$	11
First test, distribution	0.61	$2.67 * 10^{-2}$	11
Second test, values	0.84	$6.43 * 10^{-3}$	18
Second test, distribution	0.74	$4.01 * 10^{-2}$	18

A test in the gaussian distribution showed a better than 99 % probability for the point value results being different for players with limited training and experienced players, and a better than 95 % probability for the distribution results being different for players with limited training and experienced players.

Correlation between point values and distributions

It might be expected that the results for the point values and the results for the distribution are correlated, for instance that the participant is more likely to assume that the distribution for a sheet is different when the point value is different. In order to investigate that, the correlation between the replies on point values and replies on the distribution was calculated using the actual replies, without considering whether the replies were right or wrong:

Correlation = -0.28

This value makes it unlikely that the replies on the point values and the replies on the distribution have influenced each other.

Results from specific sheets

At first glance the replies for a number of sheets showed significant deviations. However, because the results clearly did not follow the same gaussian distribution, they had to be divided into four groups for processing:

- Same value
- Diff. value
- Same distribution
- Diff. distribution

It was then possible to test the result for each sheet as a binomial distribution against the average for each group.

Only one result was different from the average of its group with a better than 95 % probability for the difference being non-random. That was the distribution for set number 6, showing a result significantly above average. On the back side of the sheet, the hearts and diamonds were shown in opposite order and with a slightly different spacing between the cards:

- This may have drawn the participants attention, resulting in a more precise scrutiny of the sheet.
- Both the opposite order and the different length of the two colours may have been overlooked because of the slightly different spacing, and the two wrongs might together have produced some right answers.

It is therefore not possible to conclude anything on this result.

EVALUATION

A number of valid results with general relevance has been obtained. However, it has not been possible to identify instances where the specific mental model of the bridge players has influenced the results.

APPENDIX B: TEXT AND FIGURES EXPERIMENT

From a number of specific instances it seemed likely that a number of discrepancies could be overlooked when considering a text or a figure. This experiment should provide some figures for determining how many discrepancies it was possible to overlook while still declaring that the texts or figures were identical.

SCHEDULE

The experiment was conducted in the period from February to June 1994, and the results finally processed in June 1994.

STRUCTURE

The experiment used two stacks of stapled sheets in A6 format. One stack consisted of 6 sheets with a text on each side of each sheet, the other stack consisted of 6 sheets with 5 figures on each side. On the backside of each sheet were boxes for marking if the texts or figures seemed identical on front and back side. Both stacks were given to the participants in an envelope with instructions printed on the front. It was therefore possible for the participants to do their part of the experiment when convenient. The envelope contained a stamped envelope for returning the results.

Texts used in the experiment

The texts consists of 3 different types:

- The first 3 texts were taken from descriptions of personality types [Fordham: 1953] and translated into Danish. The texts on the back sides were put together from parts of the personality description on the front side and parts from another personality description. It was therefore possible to create some discrepancies from the text on the front side to the text on the back side and within the text on the back side. The participants were asked to consider if the texts on the front and back sides of the sheet seemed to describe the same person.
- The next 2 texts were adapted from technical manuals. The participants were asked to consider, if the texts on the front and back side of the sheets seemed to describe the same piece of equipment or software.
- The last text was written specifically for this test. The participants were asked to consider if the texts on the front and back side of the sheets were identical.

In all cases, the participants were asked to mark if the described topic or the texts on both sides of a sheet were similar, for instance if they seemed to describe the same topic.

An English version of the text is presented first, followed by the Danish text actually used in the experiment:

Sheet 1, front side. This text is a description of the thinking type:

- He bases his life on principles and would like others to do the same. Wherever possible his family, his friends, and his working associates are included in his scheme of living, and he has a strong tendency to believe that his formulae represents absolute truth, so that it becomes a moral duty to press its claims.
- Han baserer sit liv på principper og vil helst have at andre gør det samme. Når det er muligt, inkluderer han sin familie, sine venner og sine kolleger i planen for sit liv. Han tror at hans indstilling til livet er den absolutte sandhed, så det er hans pligt at bringe den videre til andre.

Sheet 1 back side. The text describing the thinking type is combined with the last sentence describing the extroverted feeling type:

- He likes logic and order, and is fond of inventing neat formulae to express his views. He believes, that he is rational and logical, but in fact he suppresses all that does not fit into his scheme, or refuses to recognise it. At best he is sympathetic, helpful and charming; at worst superficial and insincere.
- Han kan lide logik og orden, og er glad for at finde præcise formuleringer af sine meninger. Han tror han er rationel og logisk, men overser eller undertrykker alt hvad der ikke passer ind i hans planer. I bedste fald er han sympatisk, hjælpsom og charmerende, i værste fald overfladisk og uærlig.

Sheet 2 front side. The text describes the sensation type:

- He takes everything as it comes, experience things as they are, no more and no less; no imagination plays around his experiences, no thought attempts to look deeper into them or explore their mysteries—a spade is a spade; neither is any real valuation made; what counts is the strength and pleasure of the sensation.
- Han tager alting som det kommer, oplever tingene som de er, ikke mere og ikke mindre. Han fantaserer ikke over sine oplevelser og prøver ikke på at forstå deres baggrund eller afsløre deres mysterier, en spade er en spade, han prøver ikke at vurdere værdien. Det eneste der betyder noget er nydelsen og styrken af hans oplevelser.

Sheet 2 back side. The first and last sentence describes the sensation type. The remaining part describes the intuitive type:

- He is frequently easy, jolly with a great capacity for enjoyment. He dislikes intensely anything that is familiar, safe or well-established. He is no respector of custom, and is often ruthless about other people's feelings or convictions when he is hot on the scent of something new; everything is sacrificed for the future. He may degenerate into a restless pleasure-seeker forever looking for new thrills.
- Han er ofte let at komme om ved, munter og med en stor evne til at nyde. Han kan forfalde til en hvileløs nyder som altid jager nye oplevelser. Han kan ikke fordrage noget der er

velkendt, sikkert eller veltableret. Han respekterer ikke traditioner og er ofte hensynsløs overfor andre personsers følelser eller overbevisninger, når han er på sporet af noget nyt. Alt bliver ofret for fremtiden.

Sheet 3 front side describes the introverted feeling type:

- May give an impression of coldness. Unadaptable and disconcertingly genuine, and if ever forced to play a role, is likely to fall to pieces. But in intimate circles when attached by strong emotional ties, his value is well known, and he makes constant and reliable friends.
- Han kan virke kold. Han har svært ved at tilpasse sig og er altid forstyrrende ægte. Hvis han skal spille en rolle, vil det som regel mislykkes. Men sammen med nære bekendte hvor der er stærke følelsesmæsige bånd, er han værdsat og han kan skabe tætte og langvarige venskaber.

Sheet 3 back side describes also the introverted feeling type. However, in this case the person is changed from male to female:

- Still waters run deep: Reserved, with much sympathy and understanding for anyone suffering or in need. Her feeling flows secretly into her children; she is not demonstrative, but has all the same a passionate love that will become apparent if the child is seriously ill.
- Det stille vand er ofte dybest. Hun er reserveret med meget sympati og forståelse for folk der lider eller er i nød. Hun skjuler sine følelser for sine børn. Hun viser ikke følelserne men har en indre kærlighed som kan komme frem hvis et barn bliver alvorligt sygt.

Sheet 4 front side:

- <u>Address function:</u>
  The identity of the radio is called the address. It may consist of up to four digits. These digits can be shown in the address list/stand-by display as a word on up to 4 letters. The address can be selected by pressing the A-button or simply by pushing the digits on the keypad without pressing the A-button first.
- <u>Adresse-funktionen:</u>
  Radioens nummer kaldes adressen. Den kan bestå af op til fire cifre. Disse cifre kan vises i adresselisten/stand-by lyspanelet som et ord på op til fire bogstaver. Adressen kan vælges ved at trykke på A-tasten eller blot ved at taste cifrene på tastaturet uden først at trykke på A-tasten.

Sheet 4 back side:

- Address selection from the keypad:
  Press # for starting the address selection. The backstep arrow in the display over the CH-key shows, that the last digit may be changed by using this key. When the last digit is entered the radio will return to the revised stand by display showing the selected address after A. If your entering of digits has not been accepted, you shall investigate the channel selection, turn the radio off and on and start once more by pressing #.

- Adressevalg fra tastatur:
  Tryk # for at indlede indtastningen. Den baglæns pil i lyspanelet over CH-tasten viser, at sletning af det sidst indtastede ciffer kan ske med denne tast. Når sidste ciffer er indtastet vender radioen tilbage til det reviderede stand by lyspanel med den valgte adresse efter A. Hvis din indtastning ikke accepteres, skal du undersøge kanalindstillingen, slukke og tænde for radioen og starte forfra ved at trykke på #.

Sheet 5 front side:

- If reference is described as references they shall be placed after an exclamation mark (!) and they shall be in the reference form used in the database, i.e. either A1 or R1C1. A1 is standard but you may change to R1C1 by using the work area command in the alternative menu.
- Hvis reference angives som referencer skal de stå efter et udråbstegn (!), og de skal være i den referencemåde der bruges i databasen, dvs. enten A1 eller R1C1. A1 er standard, men du kan skifte til R1C1 med kommandoen arbejdsområde i menuen alternativer.

Sheet 5 back side. In this text, the word reference is replaced by the word link followed by the word reference in brackets:

- Links (references) are not stored in variables for macro-routines returning the link. That is due to the link (reference) being translated immediately to the content of the referred variable. The work with the link needs a name assigned by using the ASSIN.NAME function. The macro formula shown below assigns the name SALE to the active variable in the data base.
- Links (referencer) lagres ikke i variabler til makro-rutiner, der returnerer linken. Dette skyldes at linken (reference) straks oversættes til indholdet af den variabel, der refereres til. Arbejde med selve linken kræver tildeling af et navn med funktionen ANGIV.NAVN. Med nedenstående makroformel tildeles navnet SALG til den aktive variabel i databasen.

Sheet 6 front side:

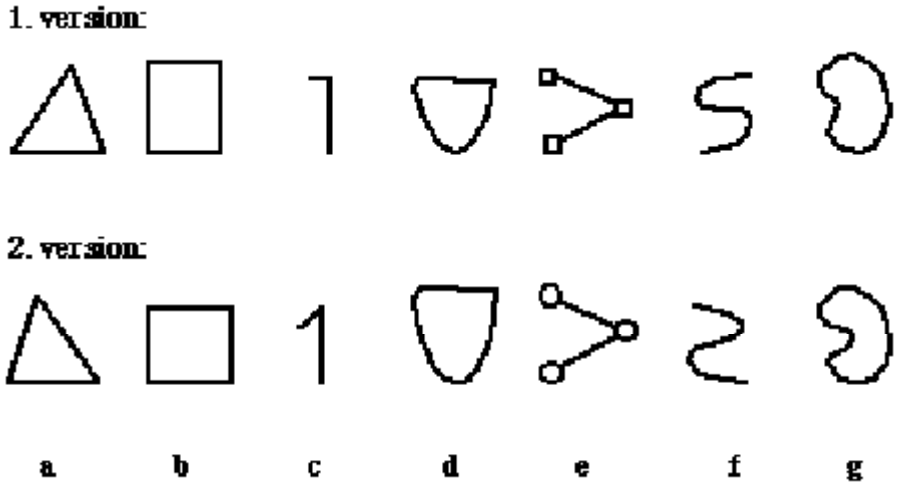
- He turned on the lights and opened the solid box. Inside was a package. He placed it on the table and unwrapped it. Inside was a bundle of papers, almost two inches thick. He lifted the papers out of the wrapping, handling them with great care, since they were fragile and of the most secret kind. He took the first one and started to read, pronouncing each word as he read. At last he looked up - contemplated for a moment the secret content of the papers. Then after a long sigh, he wrapped up the papers, placed them in the safe box, locked it, put the key in his pocket, went out and locked the door.
- Han tændte lyset og åbnede det solide skab. Indeni var en pakke. Han lagde den på bordet og pakkede den ud. Den indeholdt et bundt papirer, tykt og gammelt af ælde. Han tog papirerne ud af indpakningen, meget forsigtigt, siden de var af den mest hellige type. Han tog det første og begyndte at læse, højt mens han udtalte hvert eneste ord. til sidst så han op, tænkte et øjeblik over

papirernes hellige indhold. så, efter et langt suk, pakkede han igen papirerne sammen, lagde dem tilbage i skabet, låste det, tog nøglen i lommen, gik ud og låste døren til rummet.

Sheet 6 back side. One word is changed from the front side. The intelligent reader may be capable of finding it:

- He turned on the lights and opened the solid box. Inside was a package. He placed it on the table and unwrapped it. Inside was a bundle of papers, almost two inches thick. He lifted the papers out of the wrapping, handling them with great care, since they were fragile and of the most sacred kind. He took the first one and started to read, pronouncing each word as he read. At last he looked up - contemplated for a moment the sacred content of the papers. Then after a long sigh, he wrapped up the papers, placed them in the safe box, locked it, put the key in his pocket, went out and locked the door.
- Han tændte lyset og åbnede det solide skab. Indeni var en pakke. Han lagde den på bordet og pakkede den ud. Den indeholdt et bundt papirer, tykt og gammelt af ælde. Han tog papirerne ud af indpakningen, meget forsigtigt, siden de var af den mest hemmelige type. Han tog det første og begyndte at læse, højt mens han udtalte hvert eneste ord. til sidst så han op, tænkte et øjeblik over papirernes hemmelige indhold. så, efter et langt suk, pakkede han igen papirerne sammen, lagde dem tilbage i skabet, låste det, tog nøglen i lommen, gik ud og låste døren til rummet.

Figures used in the experiment



The sets of figures used in the experiment

A total of 7 sets each with 2 different figures were used. For each sheet 5 figures were drawn at random, and it was then randomly decided which of the figures should be similar and which different on each sheet. Finally 2 of the total of 30 sets of figures were changed in order to show 2 versions of all sets of figures, one with 2 similar figures and one with 2 different figures.

SESSIONS

Before the main part of the experiment, 3 samples of prototype envelopes (beta) were distributed to friends and family. The result was that the content was usable, although the instruction had to be improved.

The final envelopes were distributed with a short introduction to interested members of a writing workshop and a course in model drawing. In addition a number of envelopes were placed with a note in a consulting firm and in the Department of computer science, University of Copenhagen .

RESULTS

22 replies were received in total.

Perception of texts

The results for the 6 texts were as follows:

Text	Average response	Fraction of correct responses
1	0.64	-
2	0.23	-
3	0.36	0.36
4	0.45	0.55
5	0.23	0.23
6	0.36	0.64

A number of possible relationships between the contents of the texts and their perception was investigated:

- The results from the first two texts show, that one conflicting sentence in general are tolerated, whereas the majority notice if half of the text conflicts with the preceding text. The difference between the 2 cases is statistically significant on the 99 % level with a test in the binomial distribution. Even though the range of possible variations of texts are very big and minor changes in the specific wording may affect the result, it is likely that one conflicting sentence in most cases will be overlooked whereas a change involving a larger part of a text is noticed.
- The results from text 3 shows, that a majority concludes the type of person is different simply because *han* (*he*) is replaced by *hun* (*she*). it seems that a simple keyword may dominate the way a text is perceived.
- In case 4 the texts on the two sides are logically contradictory. In this case almost half the participants did not find the contradiction. It may be concluded that technical relationships described in plain text often are difficult to understand.
- In this case one keyword was replaced by another keyword, with the result that the majority concludes that the texts cannot describe the same piece of software. As for the third text it seems that a single keyword may be decisive for the interpretation of the text.
- In the last text one word was replaced by another word, with only a little bit more than one third of the participants not noticing the

replacement. It seems that a single different word is noticed even though the rest of the texts are the same.

- The correlation between the results from texts number 3 and 6, and 4 and 5 were investigated in order to find out if participants with good results in "daily language" texts (texts no. 3 and 6) also had good results in the more technical texts (texts no. 4 and 5). However, no relationship was found between the participants abilities to perceive the two types of text.

Perception of identical and different figures

There was a remarkable difference between the error rates in the cases where identical and different figures were shown:

Set of parameters	Average	Varians	Samples.
Same figure	0.90	$3.77 * 10^{-3}$	14
Diff. figure	0.65	$3.60 * 10^{-2}$	16

The difference was shown to be statistically significant on a 99 % level with a test in the gaussian distribution. It seems that the participants were significantly more inclined to see two figures as identical than as different.

Perception of individual figures

Average and variation were calculated for all figures, for the total number of occurrences of each figure, and for the number of occurrences where different versions of each figure had been shown on each side of the sheet:

Figure	Total avg.	Total var.	Diff. avg.	Diff. var.
1.a	0,72	$7,77* 10^{-2}$	0,48	$1,03* 10^{-3}$
1.b	0,88	$1,02* 10^{-2}$	0,8	$1,03* 10^{-3}$
1.c	0,84	$3,44* 10^{-3}$	0,89	$2,75* 10^{-3}$
1.d	0,70	$4,75* 10^{-2}$	0,52	$9,30* 10^{-3}$
1.e	0,80	$1,17* 10^{-2}$	0,67	$1,31* 10^{-2}$
1.f	0,80	$1,72* 10^{-2}$	0,68	0,00
1.g	0,65	$1,13* 10^{-1}$	0,36	$1,65* 10^{-2}$
Total	0.76	$3.70* 10^{-2}$	0.65	$3.60 * 10^{-2}$

Some figures gave above average results. The different versions for figures 1.b and 1.c was significantly better discerned than average. The total results and the results for the cases where the versions of the figures on each side of the sheet were tested separately in the gaussian distribution, giving a better than 99 % probability.

Other figures gave below average results. The different versions of figures 1.a. 1.d and 1.g were less discernible than average. The total results and the results for the cases where the versions of the figures on each side of the sheet were tested separately in the gaussian

distribution. The total results showed no significant difference, whereas the cases with different versions of the figures on each side of the paper showed, that different versions of the figures were more difficult to spot with a better than 99 % probability.

The discerning of differences in the figures may be explained by the following model:

- Cases where one version of the figure already has a specific name are the easiest to discern, as shown by one version of figure 1.b resembled a square while one version of figure 1.c resembled the digit *1*. All things equal, difference of that type will only be overlooked in half as many instances as for an average figure.
- Cases where the proportions of the figures are slightly different or where the second version of the figure is mirrored are the most difficult ones to discern. That covers figures 1.a, 1.d and 1.g. All things equal, a difference of that type will only be spotted in between 75 % and 50 % of the cases where a difference on average is discerned.

Figure 1.f represents a special case, where the second version of the figure is mirrored whereas the first version of the figure resembles the letter *S*. The results for that figure is just a little bit about average, making it possible that the two tendencies in the model cancel each other out

EVALUATION

The many possible variations in both the wordings of the texts and the precise geometry of the figures mean that the results shall be used with care and only when supported by other material. Given that, the described results are applicable.

The unsupervised conduction of the experiments gave the participants a chance for cheating on the results. However, the results make it likely that the amount of cheating was insignificant—if somebody cheated we might expect something close to a 100 % correct answer.