Part I
The Problem:
how to apply fundamental experimental psychological knowledge

1. From psychology to practice

Everybody from young to old is confronted with computers and the efficiency of this cooperation depends on the way the interface fits human beings. The very existence of recent terms like computer illiteracy and computer analphabetism suggests that all is not yet perfect. How can we design an interface so that people can use it as effortlessly. Solutions thought to solve the Problem include technologies such as 'help', 'wizards' and very human-like 'personal assistants'. From a psychologist's point of view there are some doubts about the effectiveness of these technical solutions (Verhoef, 2001a, 2001b, 2001c, 2001d, 2003a, 2003b, 2003c). All too often new technologies have spawned new problems, that have again required new solutions, usually without the intervention of the specialist in one half of the whole issue, the Man (Gillan and Schvaneveldt, 1999; de Wilde, 2000). So, what has psychology to do with the design for interfaces, a lot or a little? As today's tasks impose increasingly more load on psychological functions especially the mental ones rather than muscular functions, the conclusion has to be that, psychological knowledge of how people operate, has an increasing role to play in the design for interfaces. This book shows psychological knowledge can be used to design interfaces that people can use effortlessly.

2. Maintaining a scientific approach in practice

One of the problems for psychology as a discipline, if it wants to influence the world, is how can you get across what that discipline has learnt? For a well-known professor who is able to present psychological information in an attractive way, presenting that information is fun and customers gladly listen to the message. A fresh graduate, one who still has to learn how to present psychological information and is not working in scientific environment, finds it difficult not to compromise too much of experimental psychology in favour of arriving at a practical psychological answer to someone else's question.

As Schön (1983) stated, 'a crucial and important step' in practice is intuition. The same observation was made by Wurman (1990). I have tried, in my role as a designer and consultant, *not* to rely on 'folk psychology' and intuition. I have attempted not to compromise, while working to blend the essence of psychological knowledge with the demands of presentation to audiences that often sought a justification of their own approach solving a psychological problem while I was developing a psychological based approach that did not have that problem in the first place. The reason for not compromising was that I have learned that psychological processes are difficult to observe and logical reasoning about such processes, more often than not, complicates the matter (Schön, 1983); the problems that have to be solved are usually too complex for a common sense approach. In my first reports for customers who had requested the evaluation of a design, I maintained a psychological structure. The reports always included chapters on movement, perception, language, memory, thinking and the task to perform. A typical title was "Perceptual and cognitive aspects of vending machines" (Verhoef, 1986). Of course, I soon realised that I had to change this structure because information about perceptual and cognitive aspects 'is not what we want to know'. The apparent structure of the reports then became more practical, starting, for instance, with the buttons and information at the upper left hand corner and ending with the buttons in the

lower right hand corner of the vending machine. However, the psychological underlying structure, determining how and why the design was the way it was, remained the same. I discussed, as far as needed, motor, perceptual and cognitive aspects of each button, but now keeping the psychological information restricted to what was minimally necessary to justify the design specifications.

What was missing turned out to be any principles that defined, a priori, how to go about developing a design that would meet the requirements of being psychologically and ergonomically responsible, well designed from the start by bringing in appropriate knowledge at the *beginning* of the design process. Designers faced with such evaluations, often quite critical of their efforts, could not be provided with concrete advice on how to go about their work without having to wait for an evaluation post hoc of why they had failed. If we are to develop such an approach, we need to decide how to proceed. In scientific psychology it is good practice to make such a choice explicit. In the scientific literature one can find both elementary and holistic approaches to solving cognitive psychological problems in the design of interfaces. The first question that I have to answer here is - Which approach to apply – Holistic or Elementary?

3. Which approach to apply

3.1 Elementary approach

Experimental psychologists, who work in a scientific environment, are able to focus on one small aspect of human beings and can apply an *elementary approach*. The hypothetico-deductive methodology that experimental psychologists apply to the subject matter, lends itself to the acquisition of detailed information about specific psychological structures and functioning. This means that they typically operate with the elements of their field of study, rather than with the compounds those elements constitute. The experimental psychologist is more often akin to a chemist who knows all about H and all about O but who does not know what happens when two H and one O is combined. The properties of the liquid water do not follow naturally from the properties of the two gases Hydrogen and Oxygen.

Experimental psychologists can provide practitioners with straightforward answers to questions regarding psychophysiological properties of elements of interfaces such as, character size, colour and luminance contrast. In that respect there is no gap and a fresh graduate can easily answer practical questions like: 'How big should the letters be on the package?' or 'Can this cockpit display be seen under conditions of bright sunlight?' The analogy with the problem of the elementary chemist becomes clear when one realises that the fresh graduate is faced with a quite different set of problems when asked more complex, but important questions such as 'Can these letters be read on the cockpit display under conditions of high workload?' Simple text-book knowledge does not provide the answer.

3.2 Holistic approach

When I graduated it was known that the elementary approach was not sufficient (Foley and Moray, 1987; Neisser, 1976; Whiteside and Wixon,

1985; Wolters and Ten Hoopen, 1989). In practice psychologists have to be chemists who know that combing two H with one O will give water and what you can do with water. In practice I have found that experimental psychologists who try to answer real life questions cannot restrict themselves to a single element, to just one single human function. How can one answer questions like: "Where to position the OK button" and "What should be the depth and the breadth of a menu?" using elementary psychological knowledge about perception of size, luminance, colour and flashing? Of course, one can answer these questions using empirical techniques; setting up a number of possible examples and measuring performance under different conditions. Many experimental psychologists will gladly perform these kinds of experiments that should enable them to declare a winner in the performance stakes. However, accepting such questions and using a comparative empirical methodology ignores the fact that an interface has, at the same time, input requiring motor activities, presentation of information requiring perceptual activities, the use of language in the form of text or graphics, assumptions about the use and storage of information in memory and, finally, often requires thinking activities by the user. Between all these types of activities there are interactions.

Suppose, as an example, an experimental psychologist had to answer the question: "Where to position the OK button on a screen?" Using experimental psychological methods and having several conditions for the position for the OK button the psychologist will be able to produce tables presenting human performance on the positions investigated. The method, of course, is scientifically sound. However, is the conclusion a sound one too? There is no specification of what is meant by 'performance'. A holistic approach would give the following restrictions reducing generalizability.

a) motor restrictions
 The conclusion is only valid with the type of motor interface investigated, for instance having a particular mouse, having a particular anthropometric shape; and having the cursor at a particular position on the screen. Experienced researchers know that actual performance may be heavily influenced by such apparently 'irrelevant' details and obscure a clear result.

b) visual restrictions
 The conclusion is only valid with the presentation investigated. Changing visual appearance may change the search time needed to find the button in the first place. The conclusions might not be applicable

when fonts, icons, luminance, colours, flashing, arrangement of elements on the screen or number of visual elements on the screen is changed. Finding a single button on an otherwise empty screen may not be the same as finding the same button when there are thirty other buttons competing.

c) language restrictions

The position for the OK button is not the real problem. 'OK' itself is not 'OK' as was horrifically demonstrated by the Tenerife aircraft accident that even today is the worst civil aviation accident ever. This accident has shown (Raad voor de luchtvaart, 1979) that even with highly experienced and trained users there can be confusion on what is 'OK' means and 'OK' should never be used.[1] In addition, there might be confusion with synonyms for 'OK' like 'run', 'apply', 'enter', and 'execute'. The experimental tables presenting motor speed and accuracy of several screen positions for the 'OK' button might not reveal any of these language problems.

d) memory restrictions

Many designers suppose that a standard position for a button leads to better performance because human learning will cause better performance. In general, 'OK' is the most frequently used function of a window and therefore should be the default value. When using a keyboard the user can 'press' 'OK' by pressing the 'enter' key. In that case the position for the 'OK' screen button is irrelevant and learning the standard position for the button will not increase performance. When the user does not use the keyboard but uses a mouse, the user will never be able to find the location of the 'OK' button blindly. Anticipation of actions and peripheral vision are still needed to find the button. In that case, there will be no gain in number of actions or speed, especially not when there is a clear visual context of the button (e.g. a vertical or horizontal control area in which 'OK' is positioned) or when there are slight variations in the position for the button. This suggests that the positions of the 'OK' and the 'Annuleer' (Cancel) button in the Figure 1 can be swapped at random without having much effect on human performance.

---

[1] The crew interpreted 'OK' of air traffic control as 'OK for take off'. Air traffic control meant 'OK for route clearance.' (Raad voor de luchtvaart, 1979).

Figure 1. The position for the 'OK' and the 'Annuleer' button does not need to be fixed

e) task restrictions

Some tasks require a landscape presentation, for instance comparing objects having many characteristics. In that case control buttons like 'OK' can best be presented in a row (as in Figure 1). For other tasks, such as searching objects in a list a portrait presentation might be more appropriate. In that case an appropriate presentation for control buttons is a column.

The OK button example shows that straightforwardly applying directly experimental psychological methodology to a practical design question ("Where to position…?") does not lead to generalizable knowledge in human performance nor to a solution of the client's problem. A holistic approach is required to account the broad spectrum of human functions having effect on human performance (Wolters and Ten Hoopen, 1989; Smyth et al., 1996).

3.3 Synthetic approach

On the one hand there is fundamental elementary knowledge about perception of size, luminance and contrast. This knowledge has a firm and long-standing theoretical and empirical basis. On the other hand these variables are insufficient to understand human performance on their own. The holistic approach agues that there is a need for variables that take account for other parallel processes and interactions. Unfortunately there is no firm theoretical and empirical framework for such holistic variables. Scientific society suggests that the holistic and elementary approach belong to different worlds, the first one being the 'practical' one, and the second one being the 'fundamental' one. However, there is only one psychological world and therefore, 'practical' science should have the same framework as the 'fundamental' science and 'fundamental' science should be applicable in practice. Any framework that is developed should

provide a synthesis between elementary and holistic variables. There are several considerations for that.

a) type of methodology

When psychological processes are measured in a laboratory, there will be less noise than when measured in a field setting. These methodological differences, however, cannot make two different psychological realities. As both are dealing with human performance both should use the same concepts and elementary variables and holistic variables should be integrated somehow.

b) type of network

For an experimental psychologist in practice, however, in science there are two worlds. At one hand there are 'fundamental experimental' psychologists doing laboratory research on elements of human behaviour. 'Applied' experimental psychologists, at the other hand, do research into practice. Each world has its own journals, conferences and social networks. Having two worlds, studying the same subject, might map the social network of the scientist more than a structure for (applied) cognitive knowledge.

c) type of process

Several theories on the development of human cognition suggest that the basis of human cognition is motor and visual activity (Bruner, 1966; Piaget, 1969). It is reasonable to expect there is some correspondence between the motor and visual elementary variables and the mental variables, which as will be argued in the next chapter, do have more holistic characteristics.

To find the concepts for a synthetic approach I studied the literature on scientific ergonomics and the nature of psychology in the real world in the eighties (Foley and Moray, 1987, Neisser, 1976, Whiteside and Wixon, 1985). However, this literature did not provide a common structure of basic concepts as there is for the variables of the elementary approach. On the contrary, the literature suggested that I had to make a choice between fundamental or practical science. One early attempt to bridge experimental psychological knowledge and practice is van Leyden (1984). Van Leyden provided a psychological structure by using experimental psychological structures like reading, comprehension, decision-making, recall, speech and movement. Unfortunately there is no synthesis of that knowledge in terms of an over-all framework with related concepts. Ten years after van Leyden, Smyth et al. published 'Cognition in action' (1996, first print 1994) without any psychological clustering.

Half a decade later 'The Handbook of Applied Cognition' of Durso (1999) was published. This Handbook has five sections. These sections still do not mirror a psychological structure but are practical domains such as, business, industry, computers, instruction, health and law. Durso admits that 'paradigm pressures' for modern cognitive psychology is just as it was for its predecessor (1999). Recent literature does not suggest any real progress in the development of a synthesis of knowledge since the first publication of van Leyden (1984) or, going further back, the seminal work of George Miller (1966).

This book does not ignore the paradigm pressure and first tries to answer the question: 'how to apply fundamental experimental psychological knowledge'.

After the current Part I, describing the Problem: 'how to apply fundamental experimental psychological knowledge', Part II presents a Solution, which is a synthesis of psychological and design concepts. It tries to specify concepts that, on the one hand are applicable in practice, and on the other are fundamental. The psychological component of the Solution consists of human functions (movement, perception, language, learning and thinking). The system component is specified as the properties of elements and fields of the interface. Man and system properties are independent. This is an important cognitive psychological requirement (See chapter 11).
Part III of this book focuses on four properties of the interface (visual size, visual number, cognitive number and cognitive structure). In accordance with the Solution these are fundamental cognitive concepts. Each concept is analysed theoretically, practical relevance is estimated and designs differing on values on that concept only, are empirically tested. An experimental effect is supposed to be an empirical support for the relevance of the concept.
Part IV performs a theoretical test of the Solution by comparing the Solution of the book with other solutions.