

# Psychology and Design Research

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## 1. INTRODUCTION

A brief account is unavoidably superficial in one way or another. I will try to describe adequately the questions my research addresses, the importance of these questions, the data I have gathered in order to find answers, the conclusions that are drawn, and the references. As a consequence, I will not mention many details, although these are important to understand the design of the experiments, the analysis of the data, and the conclusions.

## 2. A MODEL OF THE DESIGN PROCESS

Psychology regards designing as a distinct category of cognitive behaviour (Simon 1973). It is only rather recently that the differences between design problems and other kinds of problems were outlined (Goel and Pirolli 1989, 1992). Design problems have a number of features that are not shared by other problems. One of the most important is that design problems need extensive structuring. In order to structure a problem one has to gather and use information. This information stems from various sources. My first involvement in design research consisted of studying the intake and processing of information during the design process (Hamel 1982). Soon, however, it became evident that I needed an empirically based description of the design process to be able to study the use of information by architects.

Until that time many models of the design process were proposed (for example, Broadbent 1973, Foz 1972, Jones 1970, Lawson 1980, Wade 1977, Zeisel 1981), but these were meant as normative models describing how the design process should look like. No descriptive theory or model was available that was tested against empirical data. Akin's model (1986) is an exception. It is a descriptive model, but at the time it was not published yet. In my opinion the normative models contain valuable notions about the structure of the design process, its components, and the relations between these. I set out to study the design process of architects.

The task analysis (Newell and Simon 1972) for my model is based upon the literature, the curricula in architectural design in the Netherlands, the description of the process by the Organization of Dutch Architects (BNA), and 15 structured interviews with practising architects. The model also incorporates the outcome of a psychological analysis of the possibilities and the boundaries of the human cognitive system pertaining to the task of designing.

Designing is regarded as a kind of problem solving. Problem solving is the execution of cognitive actions upon information in memory. Memory is conceptualised as consisting of Long Term Memory, that is information in the brain that is not active in the context of the actual problem solving, Short Term Memory, that is the information in memory that is active, and Working Memory, that is information that is activated during problem solving. Short Term Memory is the part of memory where the actual problem solving takes place. Its capacity is restricted, which means that only a limited amount of information can be attended to at a time (see Figure 1). Short Term Memory can be thought of as a spotlight that is focused on a part of the information residing in memory.

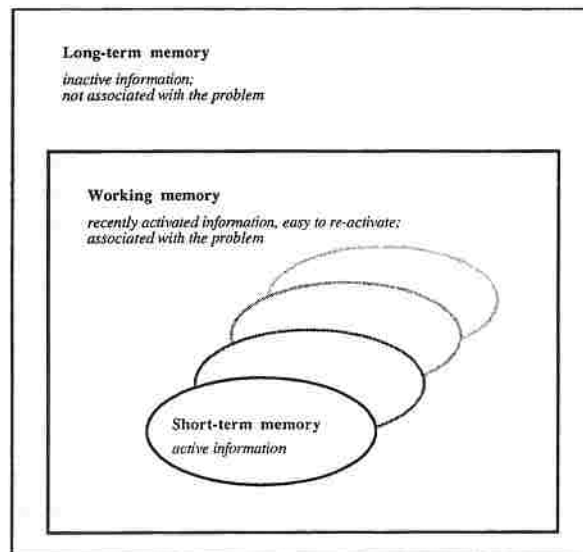


Figure 1: Memory and the activation of information

On the one hand, the active information in memory may concern the problem itself and the state it is in. This is information about 'what', it is called declarative information, and it is represented in the Problem Conception Schema (see Figure 2). On the other hand, the active information may regard the planning and regulation of the design process. This is information about 'how', it is called procedural information, and it is represented in the Task Schema (see Figure 2).

My research has firstly concentrated on the design process, its components and how these are related to each other. In other words, it was focused on the Task Schema of the architectural design process. I tried to describe in a model the cognitive activities of experienced architects during designing. The model was compared with empirical data that were gathered while 15 architects made a design individually. They all worked on the same assignment.

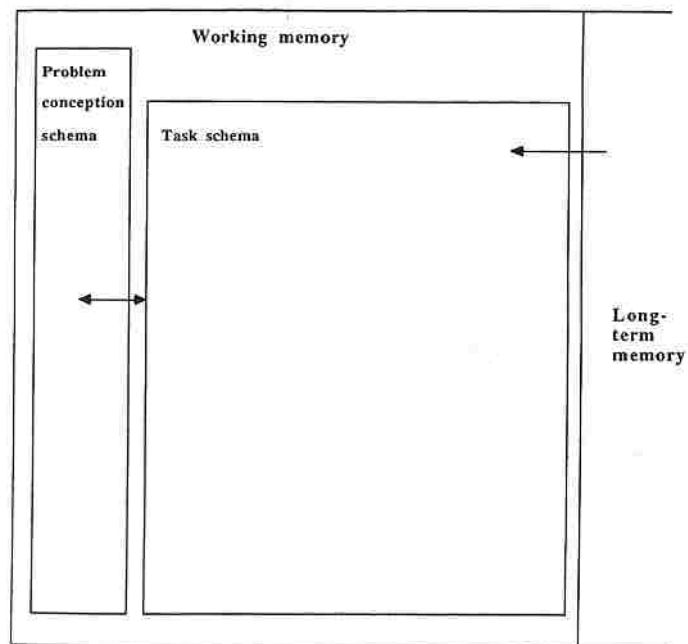


Figure 2: Information in memory

To test the model the data had to reflect the information that was attended to during problem solving. Therefore, the subjects were instructed to design while verbalizing everything they thought and did (Ericsson and Simon 1990). The verbal protocols were analyzed together with other data like notes taken, sketches made, and a record of observed activities. After the analysis of the data it was concluded that the model is an adequate description of the design process with regard to its components as well as to the relationships between them. The model consists of three domain specific components: Analysis, Synthesis, and Moulding (see Figure 3). Each of these has three domain independent components: Orientation, Execution, and Evaluation (Hamel 1990, Hamel Elshout and Meuwese 1993, Hamel 1994).

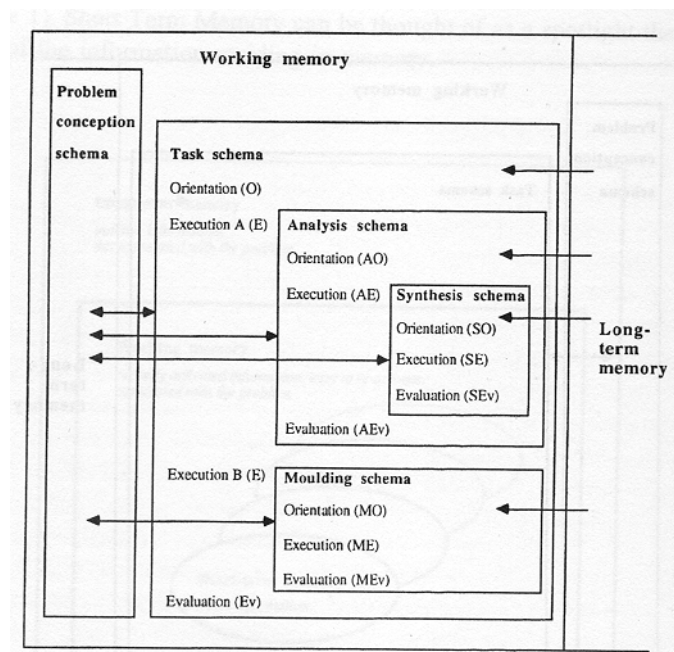


Figure 3: A descriptive model of the architectural design process

The project was initiated at the Faculty of Philosophy and Social Sciences of the University of Technology of Eindhoven with the collaboration of Willem A. T. Meuwese. It was further conducted at the Department of Psychonomics of the Faculty of Psychology of the University of Amsterdam in collaboration with Jan J. Elshout. Jan J. Elshout is professor of psychology, his background is cognitive psychology and psychology of intelligence and expertise. Ronald Hamel is assistant professor of psychology, and has a background in cognitive psychology and environmental psychology. Willem A. T. Meuwese is emeritus professor of psychology, and his background is cognitive and educational psychology.

Although the model describes the design process, it does not represent the development of the information about the design problem during the process, in other words, the development of the Problem Conception. The next project to describe is aimed at the study of precisely this development.

### **3. PROBLEM SOLVING CONSISTS OF BOTH UNDERSTANDING AND SEARCH**

In everyday language, the knowledge about a problem one is trying to solve is: everything one is able to tell about the state the problem is in. The knowledge one can verbalize about a problem reflects how well one understands the problem. This knowledge is also called declarative knowledge, and it is represented in the Problem Conception Schema (see Figure 2 and 3). Since the knowledge about a design problem develops during designing, the study of the declarative knowledge that is active during designing should have a double goal: firstly, it has to account for the development of knowledge during problem solving, and secondly, it has to account for the interaction of the development of knowledge with the cognitive activities that constitute the process. The task of designing involves the manipulation of a vast amount of knowledge which stems both from memory and from external sources. The study of the development of knowledge during designing may turn out to be very difficult, because one has to account for prior knowledge, and designers differ regarding their prior knowledge. Therefore, it was decided to firstly make an attempt at the study of the development of knowledge during problem solving with a task for which every subject's prior knowledge is the same. This task is a puzzle that is novel to the subjects, thus, at the outset they all are assumed to operate at chance level.

The puzzle is presented on a computer. It consists of five boxes containing five balls. The goal is to remove all five balls from their boxes (see Figure 4), which is not a trivial job, because their mobility is restricted in a predetermined way. We call the removal of a ball from its box and the placement of a ball into its box a move. A move changes the pattern on the screen, in other words it changes the state of the puzzle. If all states of the puzzle are linked in such a fashion that only those states are neighbours which can be transformed into each other by moving one of the balls, we have a rendering of the 'state space' of the puzzle (see Figure 5). The subjects can operate in this space by attempting to make moves. The solution can be attained by only one sequence of moves.

The moves are constrained, which means that a move is only possible if a criterion is met: the next ball to the right has to be inside its box while the other balls to the right are out. Ball A is always free to move. The criterion is represented in the pattern the subject sees on the screen. The subject has to learn to discriminate between patterns that fulfil the criteria, and patterns that do not (see Figure 5). The difficulty of the task resides in the fact that this can only be learned by trying moves. Unfortunately, if a try succeeds, the pattern changes. This makes learning very hard. Subjects typically need hundreds of attempted moves before they reach the solution.

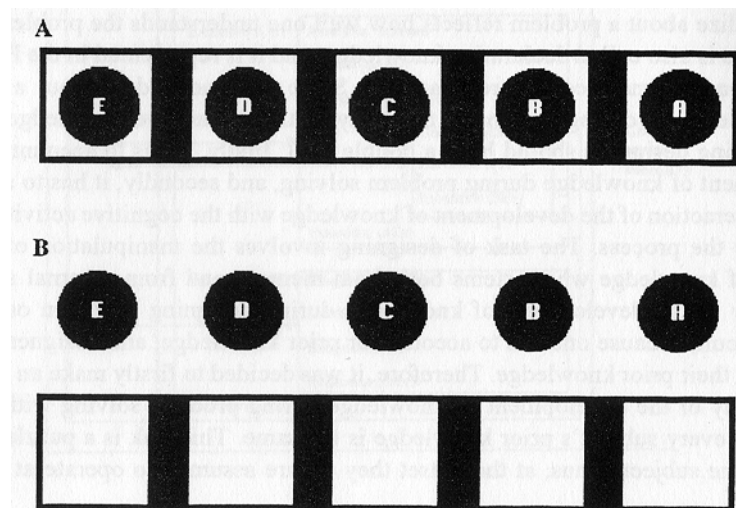


Figure 4: The Five Balls Puzzle, the start (A) and the goal (B)

We gathered two kinds of data. Firstly, a record was kept by the computer of every attempted move, together with its outcome, the state of the puzzle, and the time per attempt. Secondly, our subjects worked on the puzzle thinking aloud. The verbal protocols are data reflecting the information on which the subjects' attention was focused. The transcription of the verbal protocols could be integrated in the move records, because the computer produced two kinds of sounds, one accompanying a successful attempt and one representing an unsuccessful attempt.

Looking at the move records one gets a strong impression of a long period of muddling on in which no progress seems to be made followed by a short and rapid rush towards the solution. It seems as if nothing happens until some insight makes the solution possible (Kotovsky and Simon 1990). However, when the verbal protocols are analyzed together with the move records, we see a gradual development of knowledge about the puzzle throughout the whole process. On the one hand, simple constraints (for example, the constraint for ball B) are verbalized before the more complex constraints (for example, the constraint for ball D) and underspecified knowledge precedes fully specified knowledge, but on the other hand, misconceptions are not abandoned altogether. The move making process itself also develops during working on the puzzle. The studies (Hamel 1994 October, Hamel 1995, Hamel Elshout Frie and Jaarsveld 1995) clearly show that the process of problem solving consists of two cooperating processes, search and understanding. Tentative search (consisting of attempted moves some of which are successful and others not) leads to a better understanding (knowledge about the puzzle), while at the same time a better understanding leads to better search.

The relevance to design research is clear. Designers often express as an observation from their own daily practice that an assignment or a design problem is only fully understood once the design is produced. From this it can be inferred that designers too develop knowledge about a problem during the design process. Yet, for a good design a good understanding of the problem is necessary. The development of the understanding can be promoted by presenting designers with information. This presentation has to be in line with both the stage of the process (Hamel 1990) and the level of understanding (Hamel 1995).

The studies reported in this section were conducted at the Department of Psychonomics of the Faculty of Psychology of the University of Amsterdam in collaboration with Jan J. Elshout, and also with the assistance of the students: Liesbeth Bakker, Lonneke Frie, Saskia Jaarsveld, and Natascha Weitenberg.

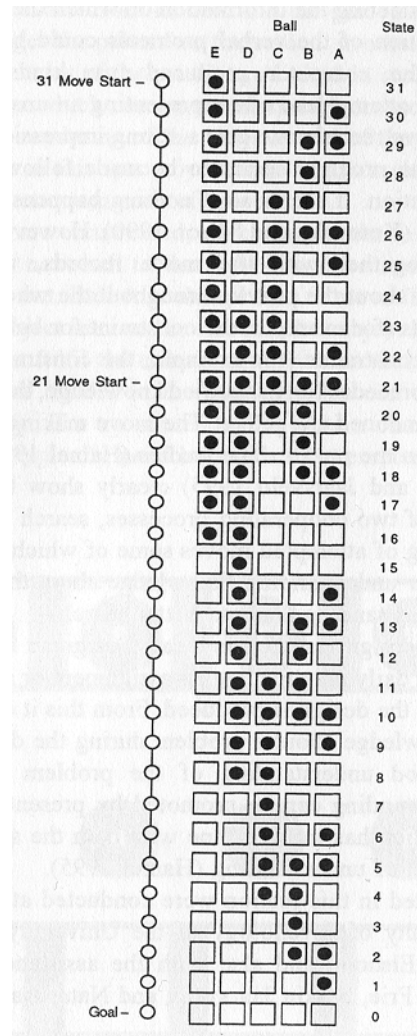


Figure 5: The state space of the Five Balls Puzzle

#### 4. NEW PROJECTS

##### 4.1 The task of the construction planner

I am participating in a research project of the Faculty of Architecture of the University of Technology of Eindhoven that aims at the development and testing of a process model of the planning process of the construction planner (Stockings 1994). I collaborate with Ger Maas who is the supervisor of the project, and with Eric Vastert. The Ph.D. student who is conducting the research is William Stockings. To me this project offers the opportunity to test the descriptive model of the architectural design process in a different domain of design, construction planning.

Ger Maas is professor of architecture, his background lies in construction and construction planning. Eric W. Vastert is assistant professor of architecture, and has a background in construction and construction planning.

##### 4.2 Sketching in the design process of industrial designers

What is the role of sketching in the design process? Does sketching enhance the quality of solutions? Do abilities of the designer, like general intelligence, visual abilities regarding imagery and perception, and creativity, influence the usefulness and quality of sketching? Does expertise influence the usefulness and quality of sketching? These are questions Ilse Verstijnen tries to answer in her Ph.D. project (Verstijnen Van Leeuwen Hamel and Hennesey submitted, Verstijnen in preparation). Jim Hennesey supervises the project, and I collaborate with him, Wim Muller, and Cees van Leeuwen.

Jim M. Hennesey is professor of Industrial Design, and is head of the IDEATE Project at the Faculty of Industrial Design of the Technological University of Delft. Wim Muller is assistant professor of Industrial Design. Cees van Leeuwen is assistant professor of psychology at the Faculty of Psychology of the University of Amsterdam, and has a background in cognitive psychology, the psychology of perception, and philosophy.

##### 4.3 The representation of characteristics of visual images

If a subject is presented with a simple linear pattern, he or she is readily able to decide if the pattern has a characteristic like parallelism, continuation, symmetry, or one of several kinds of junctions. Are subjects able to make the same decisions without the pattern in front of them, on the basis of their memories, in other words on the basis of mental images? An answer to this question is interesting for design research, because it is likely that the information which is active during designing is at least partly pictorial, and thus partly consisting of mental images. An answer puts us in a better position to face the problem of the mental manipulation of images (Rouw Kosslyn and Hamel, in preparation).

Romke Rouw, a student of mine, is conducting this study under the daily

supervision of Stephen Kosslyn at Harvard University. Stephen M. Kosslyn is professor of psychology, and has a background in mental imagery and cognitive neuroscience.

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