Personal working styles in the CAAD studio

Roel Daru
University of Technology
Department of Architecture, Urban Planning and Management
PO Box 513 5600 MB Eindhoven, The Netherlands

Myriam Daru
Winselerhof 56
5625 LZ Eindhoven, The Netherlands

Abstract

Normative and problem-solving approaches of architectural design ignore the personality aspects of the designing activity. Every architect approaches projects according to her/his [1] own strategies and tactics. Usually they do not conform to the prescriptive models of design theoreticians. Computer aided design tools should be adapted to their utility within the strategies and tactics of each and every architectural student.
We are testing the usefulness of CAAD tools developed by others or ourselves, and identifying the needs for missing tools. It is already clear that many CAAD tools reflect the point of view, of the programmer about strategies and tactics of designing and that they do not take into account the idiosyncrasies of the end user. Forcing the tools on students breeds the risk of fostering repulsion against ill-adapted tools, and consequently against CAAD.
Our research group pursues empirical research on working styles of designing by practising architects within the frame of a personality theory of actions. The results indicate that there are three main directions for designing strategies. If we want to take into account the real-world behaviour in design practice within architectural education, this implies the diversification of the exercises we offer to the students in threefold, corresponding with the three directions.
To this, we add the didactic options of complementation, compensation and support, depending on what we know about the strong or weak points of the students involved. We have started proposing choices for the exercises of our design morphology studio. Students are offered approaches and tools we consider best adapted to their own working style.

Introduction

Design methods in the sixties and seventies implied the possibility, of arriving at a unified model of the design process and using rational sequences of design decisions, but Pratt (Pratt 1984) concluded after empirical research among British architects that
1. Designers seldom work up alternative concepts. They, tend to stick with their initial idea, modifying it only as constraints demand.
2. Designers do not follow - and are unlikely to find acceptable - any, rigid or inviolate sequence of design decisions.
3. Designers seem to make little attempt to record or even to get feedback from their completed buildings. They therefore tend not to complete the 'learning loop' in their design experience
4. Designers prefer calling up their own or others' past experience in similar jobs to using published information. But they do not keep records, graphic or otherwise of decisions taken as design progresses.
Obviously, neither THE design process or THE designer exist (and certainly not the fully, rational and reasonable designer). Not only, that, but the use of new technologies influences designers and design processes in constantly, changing ways. Experienced designers are strong enough to resist rigid tools or to use them in ways not foreseen by their creators. But the rigidity of CAAD tools is very much an issue in education,

[1] In the following, whenever the architect or the architectural student will he in the masculine, the reader is asked to understand he or she.

because it can influence beginning designers negatively at a stage where they, are still malleable beings. There is still no model of the design process that leads to automated designs superior to what designers produce (will there ever be?). After a few decades of attempts we have reasons to be modest. At the same time we non, have sophisticated means to create good tools to support design tasks at a lower level, without the ambition of controlling the design process, thus leaving the control to the individual designer. That means that customising is one of the key issues. We should not be satisfied with 'majority features' but should demand 'minority features'. Tools should be adaptable to one's own personality. As educators we should reject computer programs with compelling structures which impose a working style. After all, CAAD should come so naturally to designers that they,' would not be conscious of using a computer more than they, are conscious of using a pencil. We need a designer oriented rather than a technology oriented approach. We must prevent students from being repulsed by, CAAD. CAAD should be there to support the personality of the student-designer, to enable, stimulate and enjoy, designing.

To summarise, we should change our approach from programmer to user oriented, from computer aided design to designer aided computing, from design automation to design support, from prescriptive to descriptive modelling of the design process and from personality independent tools to personality, adapted tools.

Subject style as a starting point

When attempting to personalise CAAD, **style** is an important concept. "Le style est l'homme même." said the eighteenth century naturalist, philosopher and industrialist Buffon in his 'Discours sur le style'. [2] As well as an important concept, it is an elusive one. Mostly it is defined as an essential set of properties of an artistic product, the sum of the characteristics common to a period, school or genre. In our research, we have chosen to apply the concept to the ways and means in which a designer obtains a design, that is his/her working style. We shall speak here of **subject style** to distinguish it from the traditional meaning as an intrinsic part of an artistic product. This we shall call **object style**. In his famous 1968 Karl Taylor Compton lectures on the Sciences of the Artificial, Herbert Simon (Simon 1969) stated that "both the shape of the design and the shape and organisation of the design process are essential components of a theory of design. Here we recognize our dichotomy of object and subject style. But Simon also meant that what we ordinarily, call 'style' may stem just as much from these decisions [i.e. decisions within the generator-test cycle R.D.] about the design process as from alternative emphasis on the goals to be realised through the final design." For a design program to incorporate style Simon suggested at a later stage (Simon 1970) the following as autonomous, style determining characteristics: “(1) the processes that determine the order of search, (2) stored prefabricated solution to recurrent sub-problems, and (3) stored autonomous constraints to be added to the explicitly given problem constraints.” The terms of 'autonomous constraints' as used by Simon look vague, but in fact he means **self-imposed constraints.** Self imposed constraints as we understand them are for example conformity to a grid, the use of a proportion system like Le Corbusier's Modulor or the use of building components found on the market by Charles Eames for his own house. In literature self imposed constraints have often been used to the extreme

[2] Style is Man himself. Discours sur le style, ed. Nollet (1905), p. 22.

in order to demonstrate one's virtuosity, as did the French writer Raymond Queen in his "Exercices de style”.

Continuing Simon's line of thought, Peter G. Rowe (Rowe 1987) sees style as “a concept based not on the classification of various physical features of architecture and urban design, but on the outcome of the problem-solving process itself." Consistency, in style is then a habitual way of doing things, of solving problems. Rowe speaks of certain preferred organising principles and enabling prejudices.- Simon and Rowe imply that there is a direct correlation between this 'habitual way of doing things' and the object style, without conclusively proving their point, even though they have conducted protocol research. Their research shows that a certain designer with a certain problem-solving style also has a certain object style. The difficulty in their approach is that their description of the subject style contains elements of the object style. This is also the case in Chan's research (Chan 1992). However, Chan gives more precision to Simon's and Rowe's concepts by defining goal sequences, a set of presolution models and a set of favoured forms as essential components of the subject style. But there is still no evidence in his results that one and only one particular subject style forcibly leads to one and only resulting object style, although this is implied by the conclusions. Both Simon and Chan include constraints as sources of style. As external constraints (like site, climate, economy or physical laws ...) are independent of the designer, Simon's and Chan's reasoning makes sense only if under constraints one understands self-imposed constraints. Chan includes external constraints because they are interpreted by the individual designer, but this introduces inaccuracy in the definition of style. Moreover, the distinction between constraint and presolution remains difficult if not impossible to establish beyond doubt. According to Chan, "a style is a **result** [our emphasis R.D.] of executing fixed sequences of goals (design method), applying fixed sets of constraints with each goal (design knowledge), and exercising preferred presolution models (Images) and primitive forms in the process." In our view, this definition confuses the issue of the correlation between subject style (the way in which people operate when designing) and object style (the formal characteristics of the design as a result of designing).

A more systematic exploration of correlation between subject and object styles could be the theme of future research. Little research on subject style of designers as such has been attempted up to now. We know of autobiographies of artists, essays on the working style of artists and designers, and some empirical research (mostly protocol analysis). Even in a book like the one by John A. Walker on design history and the history, of design (Walker 1989) where style is largely discussed, there is almost nothing to be found on working style. The preoccupation with style displayed by early art theorists like Semper or Riegl [3] has been replaced by discussions of meaning, types, models, structures or morphologies. Shape grammar research has been a fresh start for object style research. Instead of the verbose discourse of traditional art criticism, it has brought operational methods and techniques which allow not only analysis but also synthesis with the help of rules of composition. Furthermore, criteria have been developed to judge the quality of the style description 4. In contrast with traditional style discussions and descriptions, shape grammars allow integrating object style into CAAD. Traditional style

[3] (Riegl 1893), (Semper 1860 - 1863)
[4] For example correctness, expressiveness and appropriateness (Hemming 1987)

studies still suggest useful classifications, concepts and values and cannot he dismissed. When transformed with the help of neural network techniques, even vague descriptions can become a part of CAAD. [5] In the end we should come to an integrated theory of style, including both subject and object style. For the time being, we want to concentrate on the varieties and constants of design processes, to offer novice and experienced designers a better suited support. For novice designers in particular, we want not to impose a style, but to help them developing their own.

Interactive Personality Model (IPM)

Current design theories tell us little about the personality of designers in relation to their working style. On the other hand, most personality theories in psychology, tell us little about the way people handle situations, constraints and choices in daily life. Even though we could come to know more about people's intrinsic personality, traits, developmental stages, drives or values, it would give us little grip on our understanding of their actions as designers. We come somewhat further with personality, theories which take into account the interaction of the individual with his environment and the situation with which he is confronted. The personality theory, proposed by Hettema (Hettema 1979, Hettema 1989) seemed to us to offer a relevant framework, because its assumptions correspond largely, with the problems at hand: personality is considered as an open system, the relationship between the person and the environment is all important, processes of adaptation are conceived as general processes in which feedback plays a major part, processes are distinguished from process results (Hettema 1979). Personality is then assumed to be 'an active, intentional entity,' that has considerable impact on situations' and 'persons and situations reciprocally affect each other, so that persons obtain feedback on their actions from the situations in which they, act (Hettema 1989) p. 18-19 and (Endler and Magnusson 1976). Hettema's theory is not so much directed towards the individual as towards an intersubjective conception of situations.
We consider designing behaviour as per definition intentional (a feed-forward activity based on backward-chaining inferences, in particular for experienced designers using visual images as a starting point). We are at the same time looking for variety in designing and types of design processes rather than trying to explain a specific design process. Thus this theory was well suited to serve our research on designing behaviour.

Furthermore, Hettema has developed instruments for the description of real-life situations and the way, people react to them. He goes as far as broadly trying to predict behaviour. This gave us a possibility for empirical research, the results of which could find direct, concrete application in practice.

To explain the theory, the elements of the behavioural system can be modelled within a matrix (figure 1) The rows represent the three levels of the personality system.. from conscious thinking on the top level over innate or internalised behaviour patterns in the middle level to observable interaction behaviour with the environment on the bottom level.

[5] see for example (Coyne and Yokozawa 1992)

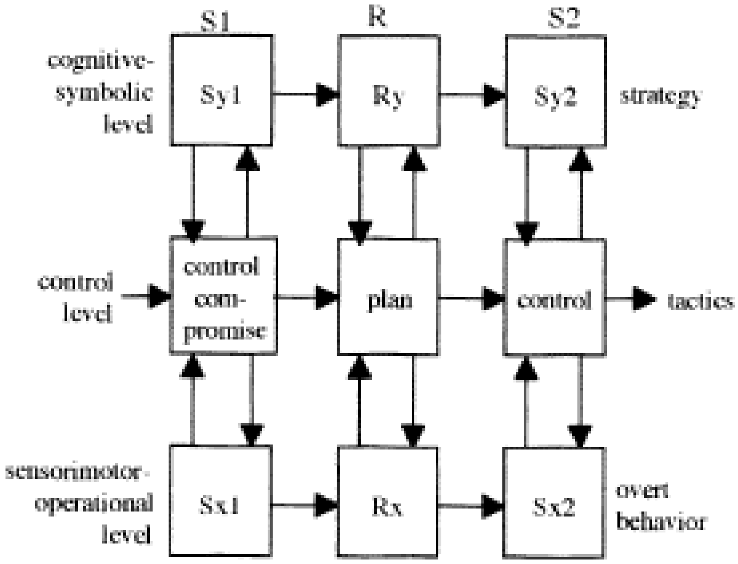

Figure 1
Subject model: elements and relations structured in levels of the personality system with strategies and tactics as determinants of overt behaviour (after Hettema, 1979)

If the environmental elements (x) at the sensori-Motor-operational level are congruent with the representational elements (y) at the cognitive-symbolic level, the system is in a state of control. Otherwise, state -transition (ST) mechanisms at the control level will be activated to alter the state of elements at the adjoining levels. Individuals will manipulate the environment to conform to cognitions at the top level and conversely, they will alter cognitions from the top level to conform to the environment. This implies on the control level that the 'control compromise' element is detecting discrepancies for correction in a 'plan', co-ordinating the misfit-fit transformation on both the conceptual and the sensorimotor-operational level. If all fits well after the transformation, 'control' is reestablished.

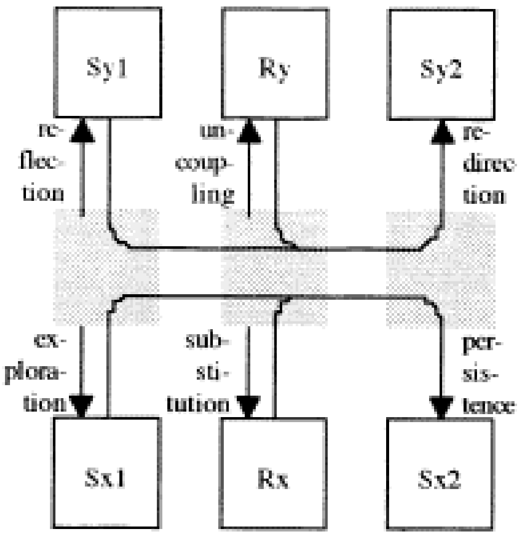

Figure 2
State transition mechanisms affecting different system elements (adapted from Hettema, 1979 & 1989)

The columns represent from left to right phases in a process, from the observed and conceptualised initial problem or situation (S_1), over the transformation rules applied to deal with such a situation (R), to the final situation or solution (S_2). On the **cognitive-symbolic** level the situation is perceived and manipulated as representational elements (Sy_l as representation of the present situation, Ry as conceptual transformation rule and Sy_2 as the conceived final situation). Corresponding monitoring elements are active on the control level. From a 'control compromise' over a 'plan' to a 'control' element. While on the **sensorimotor-operational** level actual environmental elements are shown as Sx_I (starting point), Rx (transformation) and Sx_2 (result).

In terms of actions, the three personality levels correspond with **strategic, tactical and observable behaviour**. In routine situations, a person does not need to activate ST mechanisms: all is well, there is an optimal fit between individual and environment. In a situation type like designing and in particular with unfamiliar briefs, where there are frictions between the goals to be attained and the reality, tactical ST mechanisms will provide help. The ST mechanisms are tactically, activated to re-establish and maximise control. This corresponds with the process of uncertainty, reduction in the model of sketching behaviour as presented by, Lebahar (Lebahar 1983) and discussed by Daru (Daru 1991).

Hettema identifies six types of state-transition mechanism: **reflection, exploration, uncoupling, substitution, redirection and persistence**. Those mechanisms are considered to be largely hereditary. In a stress situation, when loss of control is imminent and state transition mechanisms do not help anymore, tactical disruption mechanisms as **distraction, avoidance and extinction** are introduced to mimimise the loss of control.

If we want to avoid unnecessary stress situations in CAAD where state transition mechanisms fall, it will be necessary, to ensure a maximal compatibility of levels when designing user-machine interface and information processing procedures (Daru and van Gils 1986). Badly designed computer environments can interfere with an adequate reaction of the individual on the control level. Computer systems designers and programmers often wrongly imply that they know what a user will do and should do, or that a certain category of users is similar to another.

IPM in the architectural domain (IPMAD)

The IPM model exposed above can now be translated into architectural terms. To illustrate the point, we will use the designing of a kindergarten as an example. The conceptualised initial problem situation (Sy_l) of the architect could for example be: a first conception (an instant solution, originated from presolution inputs from the environment) of a kindergarten, here for instance as seen from the view of the child together with associated ideas about playing in a natural environment, and combined with the architect's first account of the characteristics of the brief and the site.

The initial ideas and conceptions (Sy_l) can be transformed (Ry) in a number of ways. If the emphasis is on information processing, tasks oriented heuristics (Akin 1986) could for example be applied. If visual images are developed, parti rules (Fonatti 1982; Baker 1984; Clark and Pause 1985; Baker 1989) could be used. If the same parti rules applied in a CAAD environment the transformation rules of shape grammars (Stiny 1981;

Flemming 1987) could be put to work. Where a brief or program has to be translated in a design, our own tool package 'ROP' will be of help. If behaviour is considered a priority, pattern languages (Alexander, Ishikawa, Silverstein et al. 1977) could be deployed. When adaptation to the situation is most important, deformation and (un)obedience rules (Borie, Micheloni and Pinon 1984) are applicable. And in case of already conceptualised instant solutions, evaluation rules could be activated.

The results of those transformations are for instance 'partis' (composition of shapes), desired images and in the end a completed design of a kindergarten: the aimed for final situation or solution (S_2).
The related visible behaviour (Sx_1) in the conceptualised start situation (Sy_1) could be expressed in a literature search activity of the architect involved, his visit to the site, his reading of the brief, his talking to the client.
The transformation activity Rx could next be traced in the bubble diagramming, sketching, modelling and drawing of the architect or -as Alexander has recommended warmly-his talking, looking, smelling and building behaviour without a recourse to representations such as sketches.
Finally the designed results are observable in the sketches, drawings, models and explanations produced to document the found solution of the imagined kindergarten building or the realised kindergarten as such for those who design while building (Sx_2).

But what happens if there is a friction between the architects and client first concepts about a kindergarten? If the client views the assignment from the point of view of the staff instead of the children? To control such a situation, the architect could use 'reflection' as a state transition mechanism: he could examine the position of the staff involved or put himself in their situation. Another reaction would be, to 'explore': to look in the literature for authorities with the same opinion or to identify successful applied children centred examples to justify his starting point and/or to disqualify his client's view.

The next frictions about the applications of rules could be exemplified as follows. Let's say that the kindergarten to be designed is to be located in a high density neighbourhood. Then, the initial idea, applying the rule 'if natural, than use trees and shrubs extensively', could not be realised. By replacing the originally intended rule by -for instance- the transformation rule: 'If natural, than use organic forms', the architect is exercising 'uncoupling' as a state transition mechanism. An example of 'substitution' as a reaction of some difficulty encountered is to redraw a plan or section on an other scale, or to deploy a bubble diagram or 3D model as a means to refocus on the same object by using different views or representations. If the original objective to create a naturally experienced environment for the children could not be achieved, the architect could 'redirect' his goal in for instance a socially supportive environment for both children and staff. 'Persistence' is applied in the case the architect delivers more and/or better finished and/or additional coloured drawings or 3D models in order to persuade the client rather than to change his solution. If the architect fails to restore control, he will start disruption mechanisms to minimise his loss of control. If this happens in the begin situation, he will apply 'avoidance': for instance by handing down the commission to an associate. If he ignores some elements of the brief, because he is not able to transform those elements in a solution, he is using 'extinction'. And finally, if he is for instance arguing that not a kindergarten but a social/cultural centre (with an integrated playground for small children) is the real solution for his client's problems, he is using the mechanism of 'distraction' or 'abandon' to minimise his non-control of the final situation.

Tactics can be expected to be highly idiosyncratic, that is to depend on the specific personality traits of each architect. The extent to which he is able to resist to criticism, but on the other hand to change his options when called for, to recognise the importance of new information and to take it into account, is mostly a consequence of innate characteristics (and to some extent of the state of one's nerves and health). This means that although the importance of personality traits psychology is limited, it cannot be dismissed altogether. Probably more relevant to design situations than 'general' traits are those innate abilities which allow an architect to grasp forms and to simulate 'what if' spatial scenarios as mental images (in y) and to produce manually, or by computer manipulation (in x) spatial concepts in the form of sketches or (CAAD) models. Altogether, those abilities influence success or failure in maximising control in stressful design situations. The kind of tactics applied and the way in which they are used also form a part of the specific working style (subject style) of the architect.

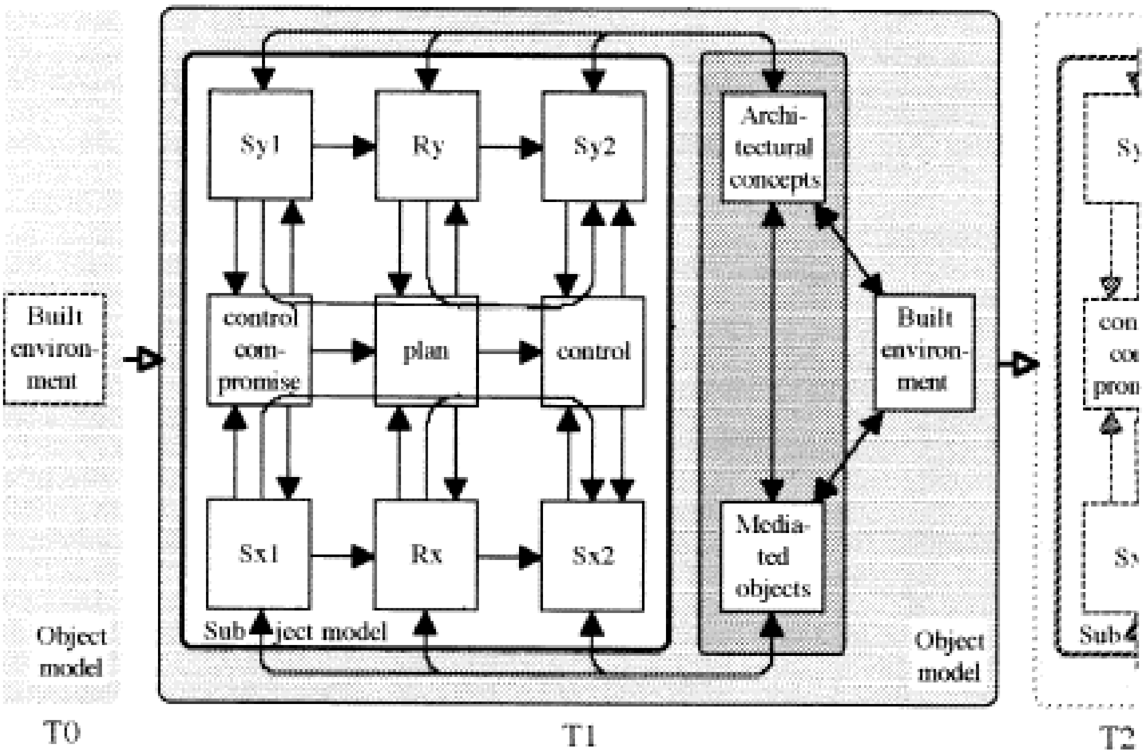

Figure 3
The interactive personality model of the architect (subject model) related to the architectural environment (object model).

Until now, we have discussed the interactive personality model (IPM) in isolation from the (architectural) domain (AD). IPMAD as a whole is represented in a schematic form in figure 3. In relation with the IPM, three environmental aspects are of interest.

First, on the bottom, the **mediated architectural object** in the form of sketches, CAAD models or photographs as they interact with the environmental elements (x) of the sensomotor- operational level of the IPM.
Secondly, in the middle, the **built environment** as the material result of the designing and building process.
Thirdly, on the top, the system of **mediated architectural concepts** embodied in the realised and mediated design.
We shall not delve into the complexities of the object model here. It is only, represented in a simplified way in relation to the subject model. The built environment is an input within the interactionist personality model, but most processes of architectural designing will result in an output - a modification of the built environment- which in turn will he part of the input in a following process of designing, at time T_n. Even unbuilt buildings can be considered part of this environment: their representations in drawings or maquettes can and do have an influence on future designs.

Subject styles of architectural designing

To get a grip on the working styles of designers on the basis of empirical research results, a Ph.D. project was started in our research group (Van Bakel 1992). The behaviour of architects has been analysed at the strategic level (as expressed by the subscript y in Hettema's model). The tactical level will be looked into in the coming period.

The experimental design can be summarised as follows:
Eleven experienced male architects, from 45 to 55 years of age were recruited by an announcement in the architectural press [6].

In a first knowledge acquisition session, a **structured interview** was carried out, to detect their conception of the architectural design process and the associated activities found important by. the architects. These interviews showed among others, that designing was experienced mostly as a centre seeking spiralling process. Interaction and communication were felt to he utterly important elements of the architects' way of working.

In a second knowledge acquisition session, the subjects were given a fictitious **design assignment,** with the following question: "You have to design a kindergarten. What would you do?" The complete documentation of a real-life project was kept at hand, but not handed out. The purpose was to have the architects ask for information at the precise moment when they wanted it. The protocolled comments of the architects were then analysed to detect their working strategy or 'battle plan' for designing. All the subjects mentioned the importance of the brief or program of requirements, as it is known in the Netherlands (P) the environmental situation (S) and the concept (C) as it is visualised in an image of the solution or part of the solution. Remarkable was the different order in which the subjects brought up those topics. All six possible permutations of P, S and C appeared in the protocols. The sequence of occurrence implies the priorities which underlay, the working style strategy.

In the third knowledge acquisition session, a **card sorting technique** on a Macintosh computer was applied to get the order and frequency, of occurrence of given concepts

[6] No female architect reacted to the advertisement.

according to the preferences of the subjects. The concepts were gathered from both the structured interviews of the first session and the Dutch Standard NVN 2574 (about the structuring of graphic and verbal data in architectural documents). In relation to the outcomes of the second session there were remarkable differences in the working styles (as expressed in the six possible permutations of P, S and C applied by the subjects involved. But the origin of those differences could be traced back to the kind of questions asked. The actual strategies followed by the subjects differs from the strategies they see as ideal. This was confirmed by the subjects, when explicitly asked about those differences. Referring to real situation introduced tactical elements into the third session.

In the fourth knowledge acquisition session, the subjects were asked to apply, a similar card sorting technique as in session three to produce a **conceptual hierarchy.** They were asked to split the concepts in two groups successively, while labelling the division of concepts with already used or new concepts. This hierarchisation was repeated until the lowest level contained small groups of two or three concepts. This process was replicated in the other direction, from the lowest to the highest level, and repeated until the subject was satistfied by the hierarchy he had produced.

There was no conceptual structure of knowledge representation to be discovered in the results which was common to all, to a group or even to two of the subjects. Obviously, there is no basis for a typology of working styles in the conceptual framework of the subjects. Although all the subjects are products of largely, the same educational Dutch culture, education did not level out their conceptual idiosyncrasies.

To recognise the most important findings in the object model of the built environment the visually imagined concept (C), the brief or program (P) and the environmental situation (S) are positioned in the object model as part of both the mediated architectural object and the mediated system of architectural concepts. The built (architectural) environment as original (referent) is placed separately but still within the object model and related to both the mediated architectural object and concepts and the start and end elements of the subject model (figure 3).

The results of the described strategic study of designing behaviour is currently being translated by van Bakel (Van Bakel 1992) into a questionnaire. It is to be automated (with the help of the application Authorware Professional) in order to identify, and report the strategic preferences of architects and architectural students. In the same vein a technique will be developed to identify individual predispositions on the tactical level. This should give us a didactic basis for individualised instructions to compensate deficiencies or reinforce capabilities and to develop personality sensitive designer aided computing tools.

A working style is defined by the strategies and tactics applied. Strategies involve knowledge and designing experience and tactics concern largely fixed innate personal behaviour. Knowledge and experience about the types of assignments influence the strategy adopted. For simple assignments, with hand sketching and drawing as transformation tools, all strategies are applicable with roughly the same efficiency. For complicated and complex tasks (with many different elements and many relationships between elements) and just with manual sketching or drawing as the available support, only the conceptual approach is effective. When sketching or drawing, the designer is restricted by, human visual and motor acuity, and temporal latencies, channel capacity, memory and attention load. This logically leads to a reduction of the complicated and complex tasks into arbitrary, or conventionally interpreted hierarchical sub tasks, as we can indeed observe in manually based design practices. Given however more efficient designer aided computing tools, the solution(s) to those complicated and complex tasks can be derived more logically from the original data. In those situations even designers with an conceptual inclination are willing to switch to a program or performance driven approach. This is made plausible by a longitudinal study, of de Haan (1992; see below, under 'Implementation of IPMAD in tools').

The codes to distinguish the six strategies sound dry and less attractive than the concepts introduced by Broadbent (Broadbent 1973). Four of the six designing strategies we identified correspond to Broadbent's concepts. But while Broadbent provides a typology, his categories still remain isolated concepts within a set. On the other hand, the six strategies distinguished by us are mutually connected, thus giving the prospect of explanation and prediction. They further offer possibilities of operationalisation within the stated theoretical framework of the object and subject styles of design.

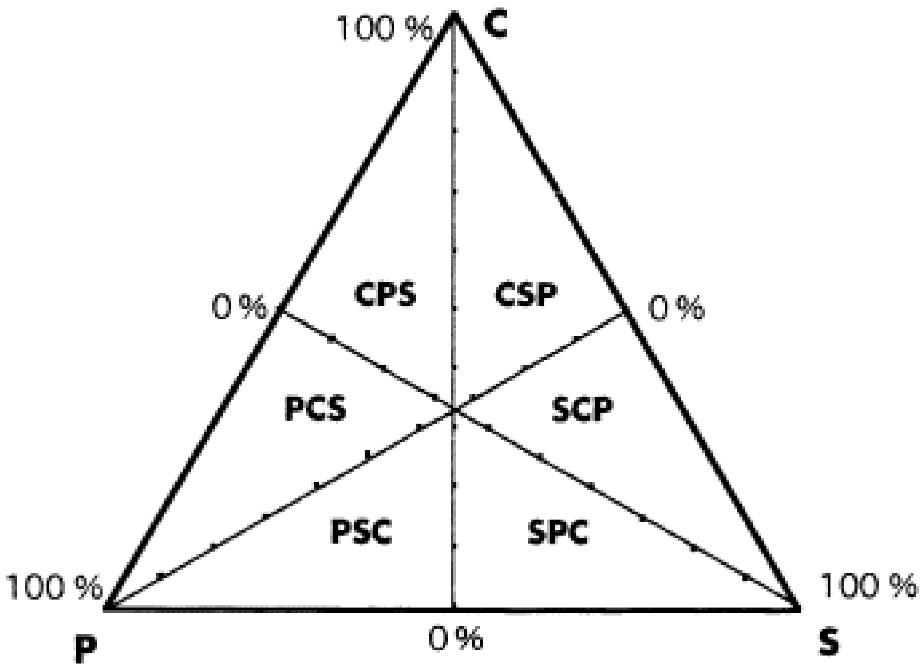

Figure 4
The six main working styles found by analysing empirical data.

After a detailed study of working style accounts by architects Broadbent came to the conclusion that four working styles could be discerned and named them 'pragmatic', iconic', 'analogic' and 'canonic'. In a second edition (1988) of his seminal work, after many lectures and discussions around the world, Broadbent replaced the terms pragmatic' by 'programmatic', 'iconic' by 'typological' and 'canonic' by 'syntactic' without essentially modifying their content. The term **'pragmatic' or 'programmatic' refers** to the use of materials and other resources at hand to modify the physical as well as the cultural (social, political, economic, moral, aesthetic, etc.) climate. In terms of our designing strategy, concept, this is the

S→P→C approach: a solution C is searched for by, trial and error, started from a fixed existing building environment S and a performance brief P.
Broadbent's **iconic/typological** type of designing describes exploiting a fixed mental image of what a building should be like (reflecting a stable close adjustment between building form and patterns of life). The corresponding designing strategy is C→P→S: working from a solution type C and applying rules to realise the brief P and a conceived starting situation S.
The **analogic** designing style as described by. Broadbent means deriving means, visual forms from existing ones by analogous thinking: for instance symbolic (a church plan in crucifix form); direct and organic (a forest of columns) or personal (giving shape to a buttress like a man supporting a vault) and translating those by analogue (shapes in sketches, drawings, scale models and other representations re-interpreted). In our designing code, this is the pattern C→S→R. the deployment of shapes derived from nature or culture as possible models of the end result C and working back from there to the start situation S and the brief P.
The **canonic or syntactic** approach leads to deploying geometrical proportions and modular grids as shape decision rules (for instance shapes and dimensions according to the Modulor). In our code, this is P→S→C: deriving a concept C from a fixed set of syntactic rules and the principal's brief P applied on the starting situation S.
To make the names of the six types of designing strategies complete, Hettema proposed 'convergent' for S→C→P and 'feasibility,' for P →C→S.
'Convergent' means that the setting of different conceptions of the starting situation S are put side by side and the rules are applied to generate different solutions as end results C to be evaluated and chosen in accordance to the brief P.
'Feasibility' concerns the application of a program P as a set of rules to possible end results C delivering different conceptualisations of the start situation S.

A closer look at the six identified design strategies reveals that they belong to three fundamental styles of reasoning. A typical reasoning style of designers and artists is abduction: the jump to a concept or solution from a scarcely explored program and situation **(concept centered:** a shape generic approach) followed by backward reasoning [7]. Abduction in science is seen as the jump from facts to hypotheses by the following type of reasoning: (1) the fact F is observed; (2) if the hypothesis H is true F would be obvious, (3) therefore it is sensible to suppose that H is true. Thereafter deductive implications about other facts than F can follow and be tested for confirmation. Abductive design thinking has a similar pattern. The design strategies C→S → P and C →P → S are typically concept centered and therefore oriented on abduction (situation and performance follow, conceived form). If a designer is not concept but **situation centered** (interpretation oriented), he has an inductive thinking style. This style is well known in empirical science where -given some observations of design cases in particular situations - a general rule, hypothesis or theory

[7] Roozenburg en Eckels (Eckels and Roozenburg 1991) deny that design reasoning can be seen as abductive (p. 69). They see design reasoning as going from the general to the general, whereas abduction goes from the particular to the particular. But then, they have defined the central problem of designing as the transition from function description to form description (pp. 51 e.a., 69). This is in fact a normative definition of designing, corresponding to the working styles where P is pre-eminent. It precludes other working styles as either non-designing or lesser kinds of designing. The form of reasoning they see as typical for designing then follows from the definition of what designing is.

is derived. The design strategies S →P →C and S→C→P are situation centered and therefore induction oriented (concept and performance follows situation).

If the designer is neither solution or situation but **program or performance centered** (prediction oriented), he has a deductive thinking style. This style is common to technicians working with known rules, hypotheses or theories and deriving performances out of given design descriptions. The design strategies P→C→S and P→S→C are performance centered and therefore deductive (situation and concept follows performance).

Reasoning type	Strategic style	Broadbent 1973	Broadbent 1988	New terms
Abduction	CPS	iconic	typological	
	CSP	analogy		
Induction	SPC	pragmatic	programmatic	
	SCP			convergent
Deduction	PCS			feasibility
	PSC	canonic	syntactic	

Figure 5
Summary of strategic styles and terminology

The discerned strategies and tactics are also useful for conceptualising **collaborative designing,** not only, for professional practice, but also in an educational context. A balanced design team needs reflective as well as active attitudes within the practical and theoretical steps of designing. When evaluating the composition of a team, one should take into account these aspects, and act in consequence. Up to now, little attention has been given to them. Schneiderman (Schneiderman 1992) -a recognised expert on human-computer interface- offers a checklist of questions concerning Computer-Supported Cooperative Work (CSCW). When he turns to the composition of the team, he regrettably comes no further than "Which jobs may have to be redefined?" and "Is there enough flexibility, to handle exceptional cases and special needs (disabilities)?" In his conclusions on CSCMI, he states: "Theories are sparse, measurement is informal, data analysis is overwhelming, and predictive models are non-existent." This is precisely, what we try to compensate with our research.

Implementation of IPMAD in tools

In the preceding, we saw six specific architectural strategies and six general tactics applied by architects while designing. The experienced architects who were the subjects of the research described used only pen and paper as their tools. When working traditionally, on a complex brief, the architect is compelled to reduce complexity and does so by, choosing a 'parti', and tests whether the brief can be accommodated by the parti. This C(oncept based) strategy is the most efficient in the traditional design process. This is also what students do most of the time when working in the design studio. Many, CAAD tools have been developed to complement those traditional tools, in particular for complex briefs. Within the frame of this article we cannot review the range of CAAD tools and assess whether they do support the described strategies and tactics [8]. We therefore chose to review, a tool created within our research team. The tool, called TRI [9] was developed to translate the brief transparently into a schematic plan. It makes use of a reorderable graphical matrix to create clusters by, manual manipulation on screen. In its own way, it answers Simon's statement that "Solving a problem simply means representing it so as to make the solution transparent." (Simon 1969). This tool supposes a P-strategy, either from the beginning onwards, or by a change of strategy, during the design process.

Such a strategy switch took place in a longitudinal study by, a post-graduate student, where a complete design process was monitored in the real world situation of an architectural office (De Haan 1992). At first his priority, was to develop the concept, then he switched to tackling the brief first. Initially, the brief (for a large polyclinical centre of a hospital) was only, a very short summary. With the given ROP-tool package the designer was able to extract quickly, from the client (the board of directors) the needed information for the brief. The data concerned were the needed activities and their spatial and relational requirements. With the application it was possible to cluster the data visually and interactively on screen and to get immediate feedback from the client about the consequences of the heuristically obtained results. The clusters found in an association matrix were then translated into graphs, bubble diagrams and floor plans and the solutions evaluated against the original specifications. The designer's expectation did come true and much time was spared. Time that he wanted to invest into the fun of developing an architectural concept. But due to the very limited time actually, allowed by external circumstances he used a quick and effective conceptualisation in a sketch design. The developed alternative 'partis' (as suggested by the situation) could be calculated and controlled in respect to the brief and decided upon. The sketch design drawings_produced within the ROP-package could be used unaltered for the preliminary design and design development. This study suggests that the availability, of an adequate tool can contribute to change to another strategy which would be inefficient without the tool.

In terms of state transition mechanisms, TRI functions as follows on the tactical level: for **'reflection',** 'a step back' function is built in. A memory based reconstruction function is used to back-track the executed actions, either by jumping to a known number of steps from the beginning or end or by stepping back and forth continuously, like in an film playing backward or forward.
'Exploration' is supported because clusters and diagonalisations are executed manually and gradually, guided by the pattern recognition capabilities of the human eye and brain, and the heuristics applied. Every, step produces its own sub optimal pattern, often suggesting alternative directions to proceed and explore and, if those steps do not produce promising subpatterns, to step back and choose a new branch to explore.
To support **'uncoupling'** various 'views' are built in. The same data can be represented as a graphical dot matrix, a graph or a dendrogram. All the views can be manipulated directly and the changes translated dynamically to the other views.
'Substitution' is possible because clustering and diagonalisation can be guided entirely by the hidden structure of the data, ignoring for that moment their possible meaning.

[8]The criteria for judging tools have been the subject of an earlier paper (Daru 1992)
[9] We have combined this schematic tool with a CAD package (MiniCad + for the Macintosh) under the name ROP.

The clustering and diagonalisation patterns can also be adapted to the given floor plans, taking into account the restrictions of the floor spaces available.
'Redirection' can be realised by using the step back function and starting afresh in a new direction from a previous branching point, taking into account some preferred patterns the user want to realise as much as possible.
'Persistence' is supported by a success indicator, calculating step by step your relative increase or decrease towards closer patterns of clusters and/or diagonalisations.

IPMAD supportive tools and techniques can be classified according to two types of categories: the designing phase (schematic and preliminary design and design development) and the type of strategic designing task involved (Situation, Performance or Concept related).

While the strategy of a designer could be enhanced by the selection and ordering of special types of tools combined with special training in promising techniques, his tactics can only, be supported by, intensifying functions in the tools involved. The disruption mechanisms distraction (defining another problem), avoidance (ignoring the problem) and extinction (leaving the problem aside) seem in principle not eligible for tool or tool function development. But when disruption is turned into a tactic to postpone action, disruption could be used as safety, valve to return to a more normal situation afterwards. In such a perspective, even tools like computer games have a positive side. In the case of TRI, the user lets the computer take over for a controlled time: he asks for an algorithm to do his work and can sit back while monitoring what happens on screen.

Didactic implications

The empirical research described here has been carried out among experienced architects in order to obtain the largest spectrum of working styles possible. A few pilot experiments with students indicate that their working style is mainly. concentrated around the Concept. This is not only due to their lack of experience, but in the present educational system, also to the short time within which they must produce drawings and maquettes which are ripe enough to be judged. Another point is that the bias towards the concept is encouraged by the criteria used to judge their projects and the priority, given to the 'parti' and to the esthetics, to the detriment of the brief - and to a lesser extent of the integration into the situation. Furthermore, there is a tension between the working style of professionals in their actual practice and what teachers consider to he the ideal working style in an educational context. An important difference between student and experienced architects is also that the latter can largely make use of their routine before having to resort to state transition mechanisms, which means that they can work on a strategic level most of the time.

Gaining experience is leaming to control the designing process by applying state transition mechanisms (i.e. exploration, substitution, reflection, uncoupling and redirection). The didactics of the studio could take this learning process into account by providing tools (among them CAAD tools) to help the students to gain control within these mechanisms. They should amplify the qualities of young adults and as far as possible compensate for weaknesses. Creativity theories and techniques make use of state transition mechanisms. One of the best known classical examples is Alex Osborn's Applied Imagination list (Osborn 1963) where proposals like combining, rearranging, magnifying or minifying, substituting, reversing etc are applications of the state transition mechanisms of substitution, uncoupling and redirection. But many more examples can be found in the creativity, and design methods literature. In some cases, authors even try to turn disruption into a positive designing experience. Up to now, however, computer tools specifically intended for creativity support have alas been rather ludicrous. The new wave of 'idea generation' tools which are emerging appeal to verbal-symbolic capacities. CAAD creativity support at the moment comes with 'unappropriate' use of existing tools. For future developments we must try, to encourage spatial creativity but beware of tools which would lead only to new forms as an esthetic hand-aid.

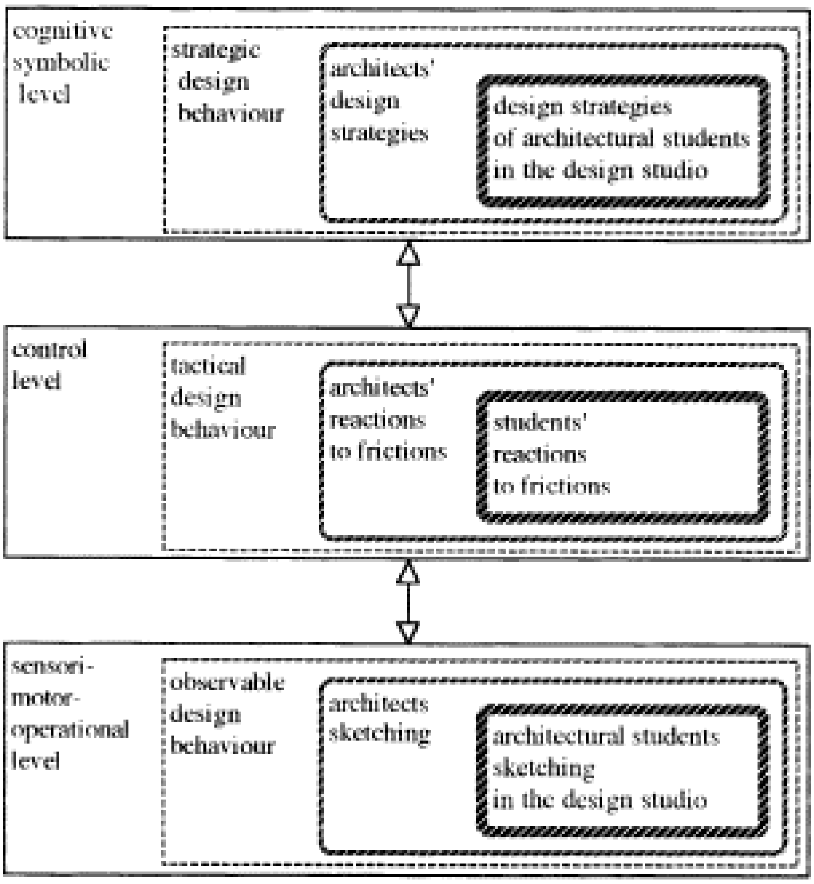

Figure 6
The model as applied to the design studio

We have taken the first steps to implement S, P and C tools in studio exercises and in particular for the schematic and the preliminary design phases. As an 'S tool' in schematic design, we have chosen the implementation of the 'space syntax' approach. The space syntax technique of topological space description stems from the work of Bill Hillier e.a. (Hillier and Hanson 1984). In our department an computerised and modified version is developed by Jan Teklenburg (Teklenburg, Timmermans and Van Wagenberg 1992). The program is used for the analysis of districts and neighbourhoods as a research project, but a studio project is on the way to apply the same program to the

analysis and (re)design of a large building complex and of a number of neighbourhoods.
The C centered approach was experimented with the 'sketch as sketch can' exercise described in (Daru 1991), where students learn manipulating conceptual modelling, analogies and metaphors. Deformation of the chosen 'parti' according to site constraints combines C and S.
We have developed an exercise in 'site sculpturing' which gives attention to the site in the schematic design phase, where spatial site constraints are translated into a 3D image of the site.
The translation of the brief takes place in an exercise with the ROP tool described above.

The didactic implications of the IMPAD do not concern only the individual student, but also student teams and staff members. A better combination of students/staff/projects could in principle be obtained by having students and staff fill a questionnaire which would reveal their preferences in terms of strategic and tactic behaviour. We are quite conscious that the introduction of such a questionnaire can meet incomprehension and misgivings. The cultural problem remains. When trying to break open the domain of working styles in the educational context, one is confronted to the attitudes in schools of architecture and interpretations of creativity as part the myth of the artist. De-sacralisation of it is felt by most of the staff as an aggression against which they react according to all variations of state transition and disruption mechanisms: creativity is best left as a black box. At the same time, computers and CAAD tools are not (yet?) perceived as belonging to the domain of creativity. Because CAAD is still not mastered by a large number of studio instructors, teaching CAAD is still left to specialists considered by, other staff members to be computer buffs, even if they are not. CAAD is on the one hand considered as down to earth technology, and on the other hand as a means of impressing clients with glossy ray-traced presentations. The down to earth approach has often lead to introducing the market leader of computer aided draughting, modelling and rendering at an early stage of the course. The consequence is that students do learn the specific skills needed to master that application, but do not at that moment learn to compare approaches, platforms and CAD applications at a strategic level. When they have come further in the course, their critical judgment is already biased by the use of that one CAD application. One of the problems is that the application has a steep learning curve because it has been developed from the point of view of the system analist, even though it is a commercial success. The time spent learning that one application precludes sampling other ones. The overall result is that CAD is not associated with the concept of easy going creativity.

Conclusion

Empirical results concerning working styles of architects are already, applicable when translated into operational objectives. Six main strategic working styles were found which can be integrated into the formulation of studio exercises, in particular for CAAD exercises. Computers are meant to be enabling tools but they can turn out to he disabling, especially in (architectural) designing if the computer environment clashes with the largely innate and partly learned working style of a student. Design sketching tools are nearly non existent. The architectural drawing, modelling and rendering tools available do not correspond to designing needs at the strategic and tactical level in the early stages of the design process. To guide the development of real designer aided computing tools the concepts of the Interactive Personality, Model in the Architectural Domain (IPMAD) can be deployed. They; would help to evaluate existing tools and to define the brief for new ones. While adequate tools can be developed, their adoption does not so much depend upon their adequacy as their acceptability within the culture of the architectural studio.

References

Akin, Ö. (1986). *Psychology of Architectural Design.* London, Pion Limited.

Alexander, C., S. Ishikawa, M. Silverstein et al. (1977). *A Pattern Language.* New York, Oxford University Press.

Baker, G., H. (1989). *Design Strategies in Architecture, an approach to the analysis of form.* London, Van Nostrand Reinhold.

Baker, G. H. (1984). *Le Corbusier, an analyis of form.* Wokingham, etc., Van Nostrand Reinhold.

Borie, A., P. Micheloni and P. Pinon (1984). *Forme et déformation des objets architecturux et urbains.* Paris, Ecole Nationale Supérieure des Beaux-Arts.

Broadbent, G. (1973). *Design in Architecture. Architecture and the Human Sciences.* London etc, John Wiley, & Sons.

Chan, C.-S. (1992). The Driving Forces of Style in Design. In: H. Timmermans (ed.), *Proceedings of Design and decision support systems in architecture and urban planning,* Mierlo, (in print),

Clark, R. H. and M. Pause (1985). *Precedents in Architecture.* New York, Van Nostrand Reinhold.

Coyne, R. D. and M. Yokozawa (1992). Computer Assistance in Designing from Precedents. *Environment and Planning B: Planning and design* vol. 19, 143 - 171.

Daru, R. (1991). Sketch as Sketch Can. Design sketching with imperfect aids and sketchpads of the future. In: G. E. Pittioni (ed.), *Proceedings of ECAADE 1991. Experiences with CAAD in Education and Practice,* München, TU München,

Daru, R. (1992). The performance of Design Support Tools. In: H. Timmermans (ed.), *Proceedings of Design and decision support systems in architecture and urban planning,* Mierlo, (in print),

Daru, R. and A. C. E. van Gils (1986). Decision graphics (CADG): Criteria for development and evaluation. In. E. A. Warman, K. Bø and L. Estensen (ed.), *Proceedings of CAPE '86 IFIP TC5 2nd Intl Conf. on Computer Applications in Production & Engineering,* Copenhagen, 883-892.

De Haan, H. (1992). Electronic sketching in the Design Process: a Case Study. In: H. Timmermans (ed.), *Proceedings of Design and decision support systems in architecture and urban planning,* Mierlo, (in print),

Eckels, J. and N. F. M. Roozenburg (1991). *Produktontwerpen, structuur en methoden.* Utrecht, Lemma.

Endler, N. S. and D. Magnusson (1976). Personality and person by situation. In: N. S. Endler and D. Magnusson (ed.), *Interactional psychology and personality.* Washington D.C., Hemisphere.

Flemming, U. (1987). The role of shape grammars in the analysis and creation of designs. In: Y. E. Kalay (ed.), *Computability of Design.* New York etc, John Wiley and Sons. 245 -272.

Fonatti, F. (1982). *Elementare Gestaltungsprinzipien in der Architektur.* Wien, Edition Tusch.

Hettema, P. J. (1979). *Personality and adaptation.* Amsterdam, North Holland.

Hettema, P. J. (1989). *Personality and Environment, Assessment of Human Adaptation.* Chichester, John Wiley & Sons.

Hillier, B. and J. Hanson (1984). *The Social Logic of Space.* Cambridge, Cambridge University Press.

Lebahar, J. C. (1983). *Le Dessin d'Architecte.* Roquevaire, Editions Parenthèses.

Osborn, A. (1963). *Applied Imagination.* New York, Scribner's Sons.

Pratt, H. (1984). Case studies in design decision making. In: R. Langdon and P. A. Purcell (ed.), *Design theory and practice.* London, The Design Council.

Rieg1, A. (1893). *Stilfragen: Grundlegungen zu einer Geschichte der Ornamentik.* Berlin,

Rowe, P. G. (1987). *Design Thinking.* Cambridge, Mass., The MIT Press.

Semper, G. (1860 - 1863). *Der Stil in den Technischen und Tektonischen Künsten.* München,

Schneiderman, B. (1992). 2nd edition. *Designing the User Interface. Strategies for Effective Human-Computer Interaction.* Reading, Mass. etc, Addison-Wesley.

Simon, H. A. (1969). *The Sciences of the Artificial.* Cambridge, Mass., The M.I.T. Press.

Simon, H. A. (1970). Style in Design. In: J. Archea and C. Eastman (ed.), *Proceedings of the Second Annual Environmental Design Research Association Conference.* Stroudsbury, Pa., Dowden, Hutchinson & Ross. 1 - 10.

Stiny, G. (1981). Introduction to Shape and Shape Grammars. *Environment and Planning B vol. 7, 323-351*.

Teklenburg, J., H. Timmermans and A. Van Wagenberg (1992). Space Syntax demystified. In: M. Aristides, C. Karaletsou and K. Tsoukala (ed.), *Proceedings of AIIAPS. Social Environmental Metamorphosis,* Aristotle University of Thessaloniki,

Van Bakel, A. P. M. *(1992).* Personality. Assessment of Design Strategies. In: H. Timmermans (ed.), *Proceedings of Design and decision support systems in architecture and urban planning,* Mierlo, (in print),

Walker, J. A. (1989). *Design History and the History of Design.* London, Pluto Press.