Synopses of some recent published studies of the design process and designer behaviour

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This series of synopses first appeared as Appendix II in 'Design decision making and recommendations for design aids' a report commissioned by the British Building Research Establishment. It was felt that this special issue on Designing for Behaviour provided a unique opportunity to republish these extremely relevant summaries to reach a wider audience of interested and involved parties. These synopses might also reveal to environmental design human behaviour researchers some of the problems that designers have in incorporating findings in their design processes and may perhaps suggest ways in which research publications might overcome these barriers to the transfer of information.

LABORATORY EXPERIMENTS

Eastman[2] at Carnegie-Mellon University was one of the first to monitor designers under controlled experimental conditions. He used an information processing theory of cognition to study and explain the design process. Six subjects were monitored solving each of two problems. In the conclusions from the study he draws attention to the significance of various types of representation used by the designer to represent, compare and manipulate information:

- words
- numbers
- flow diagrams
- plans
- sections and perspectives

and reports that there was a correspondence between the kinds of constraints identified and considered and the representation used. For example, only when a section is drawn through a bathroom does a child's ability to reach the taps become an issue. Having been given a bathroom layout to replan and a set of constraints or requirements, the designers nevertheless identified new constraints as the design proceeded. In the data provided by one designer, the final solution ignores one of the original set of constraints. Between major reviews of constraints the three main moveable elements of the design—bath, toilet and vanitory unit—were located sequentially on a trial and error basis. The order was then reversed, the vanitory unit being located first, then the toilet, then the bath; then the bath, the toilet and the vanitory unit. Other elements—mirror, medicine cabinet and towel rack—were placed directly without trial and error. Eastman also found consistently that[2]:

> instead of generating abstract relationships and attributes, then deriving the appropriate object to be considered, the subjects always generated a design element and then determined its qualities.

Foz[3] at Massachusetts Institute of Technology monitored four designers of differing levels of skill during a two hour sketch design or *parti* for a small lecture hall building. He looked for the origin of form ideas and solution path alternatives, the mode of exploring data and proposals, the origin and use of test criteria and the cues which suggest pursuit or abandonment of a line of enquiry. The designer assimilates the briefing instructions, and responds to these requirements by inventing a form proposal. He then tests how far the proposal meets the requirements, and readjusts his problem definition, proposals or tests and, if necessary, begins another iteration through the cycle. During the first few steps the source of useful content and decisions is the designer himself. As he proceeds, his input is less and less to inject fresh initiative into the process, but rather to respond to what has already been established.

Foz's most skilled subject

- called on a large number of varied precedents he already knew
- made many more form proposals
- performed more tests
- used more analogies more deliberately
- was much more explicitly aware of his creative process than the other subjects

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He felt the organization of the building to be a trivial problem and considered the urban planning of the plaza, not the building facilities, to be the real challenge; hence he chose to work on the site in great detail. *Parti* design appears to be a way of making decisions about what to do in reality by simulating it. Vizualisation facilitates manipulation. Increased accuracy and vividness of the simulation generates more varied and apt alternative solutions and facilitates decision making. There is a distinct progression in the vividness of graphic simulation with designer experience. Most experienced subjects manipulated 3D graphic representations as if they were reality and saw more possibilities and suggestions in them than did the others.

All subjects followed the basic strategy of locating building site, defining functional relationships of the building, translating these ideas into floor plans, then 3D forms. They evaluated the merits of proposals

- by comparison with existing known examples
- by testing geometric congruence
- by emotional appeal to the designer
- by comparison with their perceived peer group ideals and standards, eg what other architects would think

They did not generate and test many alternative form proposals, possibly because they may have had too little time, but the more skilled generated and tested many more possibilities. Whatever the designer is confident of being able to produce is put aside until needed. The designer concentrates his efforts on something recognisably unfamiliar. Exploration of the problem evokes previously known solutions. These precedents are used as guides or templates for analysing or developing form proposals in terms of programme requirements. At some point the design develops its own identity. Designers varied features such as location on site systematically in order to select one of the possible outcomes. When the designers come up against problems they direct themselves by consulting precedents for dealing with that kind of situation that are already stored. The designer's guides for what to do next seem to come from long term memory rather than being developed *ad hoc*. There was also evidence of strategy control exhibited by the designers, eg 'I know what I'm going to do next'.

Cornforth[4] at the Royal College of Art, UK monitored five subjects 'thinking aloud' during a two hour architectural sketch design task. He also asked them to complete a psychological scaling exercise known as repertory grid. He then compared the analysis of the video-recorded verbal protocol with the design drawings and with a multidimensional scaling analysis of the repertory grid data. He characterized the sketch design activity as alternating between a specification process and a search process and emphasised that specification continues throughout the activity. His findings support criticisms of those design methods which attempted to define design problems before allowing them to be solved. He also offered evidence to support the hypothesis that search takes place in a hierarchy of problem spaces; in simple terms that the designer first develops a simplified solution which has superficial plausibility and then uses this as a plan to develop a more detailed solution to the problem. This sort of process is repeated until a sufficiently detailed solution to the problem is reached.

On design aids Cornforth makes two suggestions[4]:

- multi-dimensional scaling could be used as the basis of a design aid
  - to encourage designers' self-awareness of their own judgemental processes
  - to elicit clients' and users' judgements for the benefit of designers
- video recording made of the designer might be replayed to him to encourage self-awareness of his own design strategy; video recordings might also form the basis for group discussion

Thomas and Carroll at the IBM Research Laboratory, USA, studied design problem solving in a series of twelve laboratory experiments[5]. Although with one exception they are not concerned with building design, they found similarities in design procedures regardless of subject matter and their conclusions seem worth reporting. They found that design problems were structured (analysed or decomposed) in terms of subproblems. These were then the subject of a design cycle. The cycles varied in duration and extent and do not necessarily follow the strict hierarchical decomposition of the design problem. Subproblems, typically, are derived dynamically during the design and are not completely specifiable at the beginning. The authors also found that a crucial aspect of design is specifying goals[5]:

> the typically implicit goal structure that the designer brings to the design situation will drastically alter his/her design activity and the product of that effort.

Clients do not state their goals explicitly, according to the authors and are probably not even aware of them before interacting with the designer. The authors also have comments on the use of design aids; these are summarized in the part of the appendix describing design aids.

Simmonds[6] of Oxford Polytechnic, UK reports a study based on the observation of twelve graduate students of architecture at an American university. He compared decision making strategies of the students. Three levels of strategy were identified:

- an overall strategic level of operation
- mechanisms for operating the strategies
- the operation of basic design skills

Within the overall strategic level Simmonds found students varied in the way they went about solving the design problem. Simplifying somewhat it may be said that some analysed the problem, generated solutions, then considered implementation. Some generated solutions, derived possible problem definitions from these and tested them against the situation, then worried about implementation. Some began by looking at available resources, implications and constraints, generated a solution within these constraints and then derived an acceptable problem definition from this.

At the second level of mechanisms for operating the strategies, Simmonds reports only on those who analysed the problem, generated solutions and then considered implementation. Again he found a variety of approaches. Some took identified subproblems in order of importance, tackled the most important and generated a solution, then took the second most important and generated a solution within the constraints imposed by the first, and so on. Thus, later decisions were dominated by earlier ones and tended to be unsatisfactory. Also, once an idea had been given a concrete manifestation it persisted through to the final solution. One student, on the other hand, generated a range of alternatives to subproblems and only afterwards concerned himself with how to produce a composite solution into which one solution to each subproblem would fit. Less successful was an attempt at a composite solution where there was only one answer to each subproblem.

At the level of basic design skills, Simmonds reports a tendency to undervalue intuition and a lack of awareness of its role with concomitant attempts to rationalize. Unrecognised and unrespected, intuition was not exploited as an element of a flexible strategy. He also discusses the ability to assimilate new information into existing patterns and to adjust existing patterns to new information. Few students were able to make this latter adjustment. Most students exhibited convergent skills, but only one skills divergent to any extent; that was in the generation of many solutions to subproblems. Students varied in the concrete or abstract approach in which they worked; a persistent problem was the inability of some to reverse the process of concretization as a means of escape from intractable situations and restrictions.

Simmonds reports that the students who produced the most successful design projects exhibited greater range and flexibility in their decision making strategies. They could decide how to make decisions in response to context; other students changed the content of their decisions in response to context, but not the way in which the decisions were made. Furthermore, he highlights the relationship between the strategies used and the designer's concepts and values. There was some evidence that certain strategies were adopted to legitimate strengths and to cover up weaknesses in basic design skills. For example, those who believed in an adequate solution to the carefully investigated needs of client groups felt helpless when confronted by visual/formal design problems.

In conclusion, Simmonds emphasised the need for a full repertoire of basic design skills; in turn, this allows the designer to operate flexibly, choosing his strategy to suit the decision context.

Lera[7] ran a series of experiments at the Royal College of Art to study the effect of designers' value judgements and priorities on their design proposals and their preferences among design alternatives. The experimental subjects were in three groups

- architects
- students of architecture
- non-architects

The subjects all designed school plans on a given site and to a given brief in a three hour intensive design exercise. Before and after the design process, they performed a judgement analysis exercise, devised by Saaty[8]. This was intended to elicit the structure of their subjective value judgements in the form of relative weightings ascribed to valued attributes. The sketch designs prepared were redrawn and, within each of the three experimental groups, were evaluated comparatively by the designers with respect to their valued attributes and for overall merit. The evaluation also made use of Saaty's technique.

The data enabled hypotheses to be made about the individual designer, the effect of the design process on his judgements and the effect of his priorities on his proposals. It also permits hypotheses on the reasoning behind the individual designer's evaluations, and between designers, the levels of agreement between their priorities and between their evaluations, to be tested.

He found that a small set of attributes elicited from the designers in conjunction with the design process could be used to provide explanations of their design proposals, and in particular that the differences between the attributes they valued helped to explain the differences in the plans they designed. Changes in the attributes to which they gave priority resulting from their explorations of what was possible in design were found for some of the non-architects, but the architects seemed better able to predict beforehand the trade-offs they would make among attributes.

In the evaluation of the redrawn plans, the differences between the designers' preferences could be accounted for logically and coherently with reference to differences in the weighting they ascribed to different attributes and the relative degrees of fulfilment of each attribute achieved by each plan.

Successful application of Saaty's technique in an experimental setting prompted the author to suggest its potential use as a design aid. One range of uses would be to elicit clients' or members of the building design team's preference structures, so that relative priorities could be discussed and decided upon in the abstract before designs were attempted. The other type of use is an evaluation aid to provide a coherent framework for the justifiable evaluation of alternative design proposals.

Case studies

Krauss and Myer undertook a case study of the preliminary design[9] phases of a nursery school over a period of eight months at the Centre for Building Research, Massachusetts Institute of Technology, MA, USA.

They report that it was at the space allocation stage that the outline of the primary features of the final design seemed to be determined. A number of assumptions were made by the designers, for example that the building should have two storeys to preserve outdoor play space. The first attempt at a design was an apparently arbitrary placing of the building on the site; subsequent changes were due to evaluations of the designers' sketches.

To illustrate the making of a typical decision, they chart the changes in location of the music room. They group the constraints into three categories:

- geometric constraints imposed by the site
- the relation of one space to another, proximities of various spaces to the entry and orientation to sun and wind
- most important, the relationships read as a whole, the sequence of spaces and the expressive qualities that come from making one space more prominent than another

It seems clear from their description that the designers identify and assume constraints but that according to the possibilities revealed by their manipulations of form

> the designers are dropping old concerns and raising new ones, and they even change their minds again as they create forms and react to them.

The authors conclude by summarizing the implications of their findings.

- The system should be graphic and focus on geometric form.
- The system should permit the designer to select the scale at which to operate, the whole design or its parts; operations and variables should be allowed to be investigated in any order.
- The system should permit the treatment of a large number of variables, most of which become known only after the problem solving process has begun.
- The system should keep the designer in close contact with the problem solving process.

Willey noted in his review of the full report[10] that some of the other recommendations (including helping the designer to find entry points into the problem, allowing the generation of other configurations for the designer to select among valid alternatives and allowing parts of the design to be held fixed while others were manipulated)

> have almost no basis in the reported design case history and have not been borne out by subsequent studies.

Hykin of Imperial College, London, UK, reports eleven case studies in engineering design. His findings also seem to be relevant to building design[11]. In his conclusions he found it impossible to isolate and to identify the simplified strategies typical of the design methods movement. He stressed that the exploration of alternatives led to a clearer understanding of the problem, and that many important subproblems were not recognised or understood, until several solutions had been attempted or pursued to an advanced stage. Therefore, properties and relationships could not be established at the beginning of the process, nor could the strategy be preselected and controlled. Nevertheless, he reports that a well formulated problem is halfway to its solution. He noted a bias towards design solutions that offered certainty over those that offered superiority. Critical decisions, though not irreversible, became so the longer they were accepted as such. Serious errors mostly resulted from changes of personnel without the necessary transfer of information; other errors were usually due to insufficient or incorrect information, only rarely through incompetence.

Interestingly, in at least one case, the designers had to consult Hykin's records of the case study. Although critical of simplified formal design methods, and having found them to be very rarely used, he noted that checklists, priority allocation, family trees and decision networks were used in some informal ways. It was also felt that the majority of designers in the engineering industry would consider design methods seriously if they could be used to monitor and regulate progress. The need was expressed for such methods of recording information, decisions and reasoning. Hykin drew up a list of seven recommendations for design methods, and these have been incorporated in the present author's recommendations.

Mallen and Goumain of the Royal College of Art London, UK, reported to the Science Research Council on 'The analysis of architectural design activity in the working environment'[12]. The aim of their work was to develop models of architectural design behaviour which would both increase general understanding of design processes and provide tools and techniques for improving the design and evaluation of CABD (computer-aided building design) methods.

Inspired by research in artificial intelligence and psychology, the authors used a psychological measurement technique, Kelly's repertory grid, to elicit designers' 'internal representations' of design problems, followed by multi-dimensional scaling to infer structure of the repertory grid data. Drawing copying experiments were conducted to explore the differences between architects and non-architects in the quantity and quality of information each type of subject handled.

From their results, the authors propose SIMDAC, a computer model intended as a simulation of design activity. SIMDAC models three processes:

- problem definition
- problem solution
- solution evaluation

The authors also undertook field studies in design offices, and propose a second computer model SHADO (Simulation of a Hypothetical Design Organization). One case study is reported in some detail. The report concludes by describing the implication of the findings for CABD methods.

Willey and Yeomans undertook a study at the University of Liverpool of the drawings and sketches made by a team of eight student designers while designing a primary school at Liverpool School of Architecture Project Office[13]. A written analysis had been made by a team member to accompany the drawings. The design strategy they identified begins with bubble diagrams which quickly suggest overall plan forms. These appear as sketch layouts. In producing these layouts, the designers became aware of critical planning problems which were then explored by a series of sketches. Overall planning involved alternating between vague sketches and scale diagrams until an acceptable plan was found. Following client criticism, more plans were attempted. The first occupied 32 drawings but fewer than 20 sketches were then required to develop two further plans and the design finally accepted.

The authors note that while initial plan types demand considerable exploration of detailed problem areas, subsequent plans are prepared with relative ease. They record also that the designers' main concerns were with human use and perception of the spaces and their relationships; no costings or calculations were performed. The authors find this a subtle problem that suggests a less important role for supporting machine analysis.

In the planning of the school, evolutionary development of the design was apparent; there is a clear connection between one plan and the next. Faults were recognised and attempts made to eliminate them in subsequent plans. But this evolutionary development was not apparent between the generically different plan forms.

> Indeed the final plan was produced by the team leader out of dissatisfaction with all previous attempts. No comparison was made between these sketch plans. They were not considered in any way as competing alternatives. The beginning of each seemed to signal the complete rejection of previous designs.

The origins of ideas and the criteria used in assessment and final acceptance were not explicit or apparent.

Willey and Yeomans give a detailed account of the use of drawings, which indicates in particular the variety and flexibility of the designer's method. This they characterize as one of learning simultaneously about critical relationships and possible forms as the design evolves. Between generic solutions, planning may be less a search for the best solution than an exploration of the compromises that give sufficient solutions; these explorations may help the designer to appreciate which requirements may be most readily achieved. The authors conclude that the design elements being handled and the properties being examined are very variable in character, and thus that computer aids must cope with this variety.

Wang obtained an extremely detailed collection of design monitoring data by spending three months full time carrying out research at Portsmouth Polytechnic. He observed the development of a junior school through RIBA Plan of Work stages A to D in the offices of an English County Council[14]. Wang had a workstation adjacent to the Job Architect, attended meetings, interviewed personnel and had full access to files and technical information.

The required design was a prototype for five junior schools, to be initially two form entry, with a view to extension to three form entry, built using the SCOLA system. There was no standard brief, but the Education Officer had five main requirements. These included those previously stated, with the additions that it was a compact/two-storey building, that the 2 per cent daylight factor requirement was observed and other points concerning accommodation and cost limits were observed. After the briefing meeting, the Job Architect began by extracting a schedule of accommodation from a set of plans of an existing school. Initial space allocation was made in terms of daylight requirements. He then broke the plan down into four selfcontained parts. The existing plan was influential; the kitchen/servery area was taken direct from the existing set of plans. Teaching spaces were influenced by the DES Bulletin on Middle Schools. The architect at this point took no account of the site nor of the SCOLA system which he felt too limiting at this stage, though he was aware of the 12 ft and 2 ft structural and planning grids. (1 ft is equal to 304.75 mm.)

Six alternative sketches were prepared. They could either form a standard plan suitable for any site by rotation and/or mirroring (rubber stamp), or be used as a set of units linked as necessary to suit each site (design system). One was selected nominally on the economies of plan shape, though there is very little to choose between them. A scale drawing and an axonometric were prepared. The architect undertook daylight calculations at the suggestion of his group leader using the BRS protractor, and found his scheme failed to meet the 2 per cent level required.

Criticism by superiors over the drawing board centred about the scale drawing with respect to the DES Regulations and several inadequacies were pointed out. Later, a total allowable area was obtained from the Quantity Surveyor.

The Job Architect felt strongly about achieving domestic scale in the building and for this reason rejected the large areas of glass necessary to achieve sufficient daylight. Instead he planned more shallow practical rooms where daylight had been poor which resulted in an indented plan profile. He also decided he preferred to develop a standard plan (rubber stamp) as opposed to a set of units (design system), a decision made partly to conform with the policy of the office.

Eighth inch (1/100) scale drawings were begun showing the revised plan, but the same day one of his superiors suggested altering the arrangement of classrooms to omit one staircase. The suggestion was not followed up.

After a short review meeting with the Education Office, who gave the scheme a good reception subject to a few small requested changes, the Job Architect amended the scheme as necessary and submitted the drawings officially to the Education Department for comments and to the Quantity Surveyor for cost analysis.

Alteration of the arrangement of classrooms to omit a staircase was brought up again and the Job Architect was asked to explore its implications. After some sketches were reviewed by his superiors this suggestion was abandoned because it was 'uneconomical', had 'awkward massing' and 'inflexible form for future expansion'.

The Job Architect continued to make some detailed revisions to the scheme and presented it to a design meeting attended by his architectural superiors, the Education Officer, and a School Meals Adviser. While the Education Officer reacted favourably to the scheme, the others criticised the kitchen, the service access, the elongated form and the enormous length of external wall resulting from the indented plan. Although the Deputy County Architect wanted to see a single storey compact scheme explored, in contradiction of a principle of the original brief, the meeting ended with clear definitions of areas for detailed studies and gave the impression that provided the cost was within limits the scheme would be approved. No cost plan had ever been drawn up and the only cost information was the rule-of-thumb building unit cost derived from DES guidelines and approximate total allowable area for the school.

Despite persuasion by the Group Leader to simplify the plan shape, the Job Architect preserved the general overall configuration but revised the details to try to satisfy the recommendations made at the design meeting. Then formal plans were begun. Shortage of headroom on one staircase was detected by the Group Leader and both he and the Job Architect proposed solutions, the former concerned with reationality and economics, the latter giving priority to the quality of architectural spaces. Though the latter was more expensive, necessitating the addition of a 6 ft bay at the entrance foyer, the Job Architect preferred it in the first instance unless cost proved prohibitive.

Incomplete design drawings were distributed to the Quantity Surveyor M and E and Fire Officer and, at a meeting with the architect's two immediate superiors, general satisfaction with the scheme was expressed subject only to some detailed changes. Plans, elevations and perspectives were completed. Meetings with the Education Officer and County Architect respectively were held; the former gave unofficial approval pending cost analysis, the latter however expressed reservations. When the cost plan was prepared and an allowable area calculated, the architect, in consultation with his Group Leader, decided to reduce the length of building by 6 ft in order to meet the cost limit.

The Design Committee (Architects' Department) met to review the scheme three months after the initial briefing meeting. It was attended by the Job Architect's superiors up to and including the County Architect, and by the Quantity Surveyor and engineers. A number of serious criticisms were made about classroom layout, and costs which were understood by the Group Leader to be all related to doubts about the elongated plan form. Later, the Deputy

County Architect called a meeting, and a decision was made to abort the scheme. His reasons all related to criticisms of the original brief, in which he was supported by the Liaison Architect at the DES: first, that while the brief had called for teaching accommodation on two floors, this was too precise and what was meant was that a compact was required; second, insufficient consideration had been given to the requirement for further extension; third, because the design was to be repeated greater emphasis should have been given in the brief to future building costs. The project was scheduled to be redesigned by the same Job Architect. This time the major design theme was a compact/single storey building which was set by the Architects' Department.

Wang discusses at some length the method of his experiment, perhaps avoiding drawing attention to what to the disinterested reviewer seems an account of almost three months' professional design skill wasted merely through lack of communication of priorities between the Education Department and the Architect's Department in a County Council. One important result is to show how influential the brief was on the designer's proposals and how, given an imprecise brief, a designer is unlikely to be able to satisfy precise demands. Of course, when a brief does contain instructions in contradiction to what is required, the designer's position is a hopeless one. This research also draws attention to the importance of the designer's personal relationships with his colleagues and superiors and implies that such relationships may influence the design process and product. Wang makes no recommendations about design aids.

Bessant and McMahon report on their observations of a major design decision in the plastics processing industry[15]. Though not especially relevant to building design, they do emphasise that 'to some extent every design process is unique'. This implies a contingency theory of design activity, whereby it is recognised that behaviour is dependent on the circumstances in which the activity takes place.

Darke of the University of Sheffield interviewed seven successful British architects about their design process in the course of a project about the design of public housing[16]. She found that:

> designers do not start with a full and explicit list of factors to be considered, with performance limits predetermined where possible. Rather they have to find a way of reducing the variety of potential solutions to a small class of solutions that is cognitively manageable. To do this they pick on a particular objective or small group of objectives, usually strongly valued and self-imposed, for reasons that rest on their subjective judgement rather than being reached by a process of logic. The major aims, called here primary generators, then give rise to a proposed solution or conjecture, which makes it possible to clarify the detailed requirements to see how far they can be met.

She found too that the design concept was arrived at before the requirements had been worked out in detail and argues that such requirements could only become operational in the context of a particular solution. There were no cases in her sample where the requirements and their interrelationships were analysed in detail in advance of any conjectured solution.

Al Wareh and Murta of the University of Sheffield report a study of the design processes of six UK architectural practices[17], chosen because they had won design awards at national level. Generally the research method was to concentrate on one award winning building with each practice, examine the relevant drawings and documents, and interview the project architect.

The authors detected two important phases in the design process. In the first, dominant ideas of the built form are conceived. Often one person, the principal, would be responsible. Even where team design was encouraged, ideas were put forward by individuals and salient points criticised. And where it was the principal, he would submit his proposals to others, such as the partners. This part of the process seems to be one of checking the design against the major constraints of the programme as defined and construed by other people. The source of basic ideas was found to be the designer's preconceptions of what major components the design should incorporate. Part of the design process lies in adapting this to the brief. The basis of the design is established in a surprisingly short time. The brief acts as a stimulation document indicating the operational purpose of the building and the type of response favoured by the client. In only one scheme did the brief contain detailed schedules and planning and social policies of the local authority; the architects said this had positive effects on their design. The appointment of a client representative able to make decisions about the interpretation of the client's needs and views, with short response times, was held to be of great advantage.

In the second stage, the design is developed and refined. A larger team is involved and consultants are introduced. Confidence and a certain skill in management and leadership are necessary to retain the integrity of the initial design through this phase. Constructive criticism can be beneficial, if well controlled, at this stage. Many large scale studies and details were drawn out and some models made to determine materials, choices and constructional feasibility.

THE USE OF DESIGN AIDS

Four studies have been found which attempt to determine the worth of design aids by running experiments to compare the aided and non-aided design products.

Murtha set up a highly artificial experiment at the University of Wisconsin in which the subjects (graduate architectural students) used three different specified design methods in an intensive design exercise[18]. The three design methods were a five-step 'intuitive' method, a ten-step 'key operations' method, and a fifteen-step 'systematic' method. The design problems were to design environments typical of higher education, such as a Faculty office. The design process involved selecting items, concepts, expressions, etc, from a large given information base comprising some 800 items of information. Murtha found that the subjects were highly variable within the strategy groups and that there was no statistically significant evidence of differences in strategy or in the quality of designs resulting from the use of any of the design methods. However, the 'systematic' method was slightly more effective and efficient.

Thompson of the PSA (Property Services Agency) and Wood of the Royal College of Art organized a two day intensive design exercise to study the use of the PSA method of building with a view to possible requirements for computer aids[19]. PSA professionals took part as subjects. Two design projects were prepared separately by two architects, and they shared support from a quantity surveyor , M and E engineer and a structural engineer.

There was also an MoB adviser present, and a client representative. The aim was to encourage throughout the exercise the use of MoB, and to observe and elicit the manner of its use. The results were concerned with the observed uses of MoB and the subjective assessment of its usefulness as a design aid. This latter concern was also explored by follow up interviews at PSA regional offices.

The findings of the exercise may be summarized as follows:

MoB

During the exercise MoB documentation was used only for Early Cost Advice and loadbearing brickwork, though the authors note this might be due to lack of familiarity of the participants. In the interviews some aspects of MoB were in common usage though the report authors note that MoB was not used as widely as they had initially anticipated. The design of the manual was criticised, as was some of the content for attempting to duplicate existing material while not being as comprehensive as the original. Lack of training in the use of MoB was also felt to be a hindrance.

Design aids

Design aids in general use, charts, handbooks and calculators, are documented in the report. The authors also report on a series of design aids for which a requirement was expressed. The most desired were MoB dimensional framework, early planning aids and retrieval of data on MoB components. Tedious additional learning was stated as a disbenefit of some computer based aids.

Team collaboration

One point which emerged strongly was that there was considerable improvement in communication and collaboration between professions during the exercise; intensive design exercises themselves were felt to encourage multi-professional design activity.

Epp *et al* sent out a draft design aid in the USA about shared spaces in housing for the elderly to architects' offices, and followed it up with a survey[20]. They obtained replies from seventeen offices on the utility of the design aid document, and also measured its effect on the design process. They found (hardly surprisingly!) that when the aid was made available *after* a sketch design had been prepared, only minor changes were made to the scheme in the light of the aid. They imply that information received earlier in the process had more impact, though no evidence is actually cited. Graphical representation in the design aid was popular; the research method behind the aid's recommendations was of no interest to the designers. A major amendment to the design aid, resulting from the survey of architects' replies, was to add a design checklist to the aid.

Thomas and Carroll of the IBM Research Laboratory, USA, report the results of three experiments to test aids to solving problems. In the first, a 'structured aid' required the experimental subjects (college students solving a series of problems) to state their goals, objects, transformations and some of the relevant attributes. The experiments were to test the hypothesis that people fail to solve problems because they do not formulate the problems well. The experimenters found that

> if anything, performance in the no-aid group was superior to performance in the experimental group.

From their results they were however able to show why this was the case; the answers that people gave to questions about goals, objects and attributes showed that many did slightly but vitally misunderstand the problems. In the second experiment an 'unstructured aid', comprising twenty pages of quasi-random words intended to stimulate ideas, did result in significantly more 'creative' solutions to two design problems, including chair designs. In the third experiment twenty nine college students designed the conversion of an old church into a restaurant. Half the students were given the unstructured aid described above. After completing their designs subjects filled out a questionnaire which probed their goals, styles and strategies. The designs were evaluated with respect to their creativity, on two measures

- originality
- practicality

The experimenters found that originality did not correlate with practicality. Originality and practicality were unrelated to any measures of the subject's strategy or style. Originality and practicality were related to the subject's retrospectively expressed goals concerning these two factors. The unstructured word list was found to increase significantly scores for practicality, but not those for originality. The style of design and the subject's expressed strategy were unrelated to either practicality or originality.

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