Research and modelling of mental processes in the synthesis of design proposals

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INTRODUCTION

Since the 1950s and 1960s researchers studying the creative processes of design have strived to develop investigative methods to help designers understand the way they think while designing (Rowe 1987). The studies carried out so far about the way designers formulate their design proposals (i.e. design concepts) can indeed be framed within the fields of *cognitive psychology* and the *psychology of communication* (see figure 1).

The first approach is normally present when research is focused on the content of design ideas, that is, the determination – for instance – of whether the designer's mental associations are primarily memory-based or imaginative or whether design ideas are construed using primarily verbal or iconic means. The second approach or that of the *psychology of communication*, on the other hand, works based on the designer's intentions during the formulation of his/her design proposals. This latter is an approach which also involves aspects normally associated with cognitive psychology given that it is practically impossible to study intentions without taking into account the experience and knowledge accumulated by designers throughout the years.

In this respect, the important thing is not to lose sight of the fact that designing is about satisfying the needs of certain users. Therefore, any design proposal does not only need to be appropriately built as a matter of content but also thought to achieve certain effect on its end-users either to generate a radical change in their behaviour or the mere

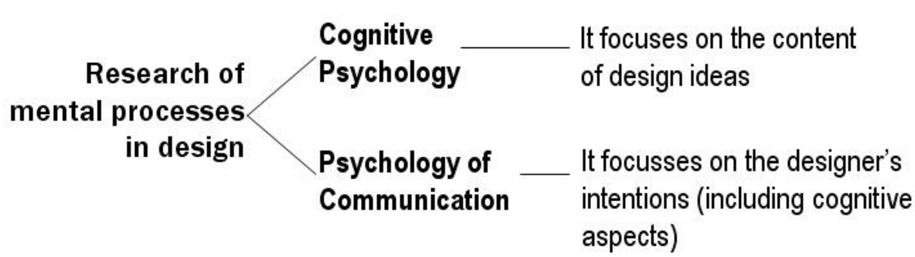

Figure 1 – Differences between the studies developed within the frames of cognitive psychology and the psychology of communication in design according to the author.

evocation of behaviours already known and accepted by them.

Based on the above considerations, the present work is an attempt to provide a retrospective and critical review of the course followed by this sort of investigations and the lessons derived from them. To this aim not only the latest studies on the subject will be referred but also those studies which can be considered as key examples of its kind and seminal works on the subject.

1. Between the Observational and Experimental Methods of Research

In relation to the methods used to study how designers think, the two most popular in design have been the observational and the experimental one, with some instances in which a mixture of both of them has also taken place. In the *observational method* the situations under study are witnessed and registered in video and audio recorders for a period of time (Girbau 2002). These recordings are then transcribed (including the verbal and non-verbal), classified -according to a system proposed by the researcher (for an example see figure 2)- and later quantified in terms of frequency, i.e. the recurrence in the use of words, gestures and sequences of action by the designers under observation. The data so gathered is then processed using a conventional statistical analysis, such as sequential analysis or the comparison between arithmetic means, in order to outline the pattern of behaviour present in the design process under study.

In the *experimental method*, on the other hand, the situations are not merely observed but also modified in order to study them under special circumstances, creating situations different to the way in which they normally happen in some respects (Rivera 1978). To this aim

1. Constraints

Identified Before Trial Sketches Were Made

Given Information (Constraints Given)
CG1 More luxurious bath
CG2 Total design concept
CG3 Wasting space
CG4 Cost = existing + $50
Retrieved Information
C1 "Looks small"
C2 "Functions okay"
C3 Wasted space between toilet and washbowl
C4 Wasted space between tub and washbowl
C5 Round objects are expected to rotate
C6 Blocks of space should have 45% of perimeter common with larger space
C7 Plumbing on one wall

Identified While Making Trial Sketches

C8 Adequate use space for fixture
C10 No exposed bathtub corners
C11 No sightline to toilet from door
C12 Toilet should not fall within 180° radius centered toward sink and one to two feet in front of it
C13 Should have large mirror
C14 Locate towel racks where towels are used

2. Manipulations

Plan
M1 Remove current unit
M2 Rotate designated unit 90°
M3 Move unit to another corner first on same wall then on other walls
M4 Add new unit next to previously manipulated unit
M5 Extend unit around corner
M6 Locate wall next to fixture
M7 Locate over sink
M8 Align spatial metrics
M9 Move unit to align with others

Perspective
M10 Align horizontal edges
M11 Locate along wall

3. Design units

DU1 Counter
DU2 Toilet
DU3 Bathtub
DU4 Mirror
DU5 Sinks (two)
DU6 Tub and wall
DU7 Mirror
DU8 Sink, tub, and mirror
DU9 Window
DU10 Medicine cabinet
DU11 Towel racks

Figure 2 – Example of classification and codification of aspects used to study a design process.
Source: Eastman 1970, p.29.

experiments are devised to take place under "ideal conditions" for the researcher's interest, controlling some of the independent variables or possible causes of the process under study. From these experiments information is gathered and classified according to certain format and finally subjected to statistical analysis (see figure 3).

Bearing in mind the differences between the two methods above mentioned it is important to realise that, within design studies, the observational method does not strictly comply with what is understood as "observational" in other fields of study such as ethnography. Indeed, many observational studies in design share some features commonly associated to the experimental method. The most relevant of these features is perhaps the development of the observations in locations different to those in which designers normally work. That is to say, places different to their actual studios or offices. Thus, designers are observed at work in rooms not only isolated from noises and distractions but also equipped with video and audio recording means of which the designers under observation are totally aware of.

Another important aspect of these studies is the assignment of tasks to the participants purposely adapted to the interests of the researcher instead of observing designers working in any of their actual projects. As a matter of fact, these are tasks that, besides being artificially imposed, should also be accomplished within a limited extent of time which disregards the designer's normal pace of work. Nevertheless, we can still designate as *observational* this kind of studies provided that it is the observation of the design process - strictly as it develops – the main focus of attention.

This latter might be the reason why observational studies have become so popular to unveil aspects of the design process. Most of these studies have been developed around a technique known as *Protocol Analysis*. Such a technique involves the formulation of experiences where a design task is assigned to a subject (either professional or novice) to be solved during a period of time, drawing sketches and thinking out loud every consideration, step and decision taken as part of such task. The whole process is audio and video recorded. Once the observation is finished, the data so gathered is transcribed and analysed, establishing the type, sequence and frequency of use of different sorts of information and the operations applied at each state of the sequence leading to a new state in the formulation of a design proposal. Thus, the researcher establishes what is and what is not consistent with the process that leads to the solution of a design problem.

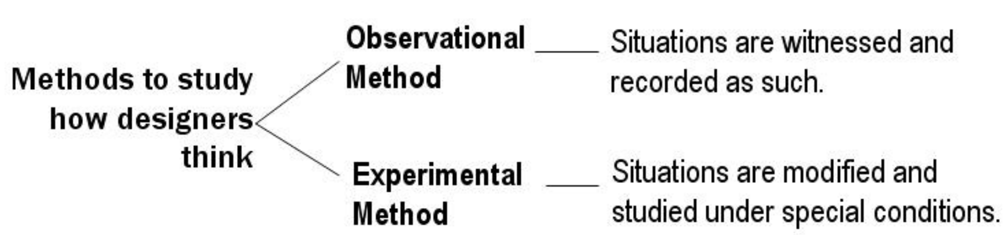

Figure 3 – Basic difference between the methods employed to study the synthesis of design concepts according to the author.

The results of such protocols have been traditionally represented through what are known as *Problem Behaviour Graphs* (PBG). As part of these graphs, the operations carried out by the designer are represented by nodes (dots) joined through lines which run from left to right and from top to bottom, in order to express the sequence of operations comprising each of the mental states involved in the design process under study (see figure 4).

Since the 1990s a graph technique known as *Linkography* has also been used to represent analyses of protocols in retrospect. This has brought about contributions different to those of the Problem Behaviour Graphs for the study of design processes (see figure 5).

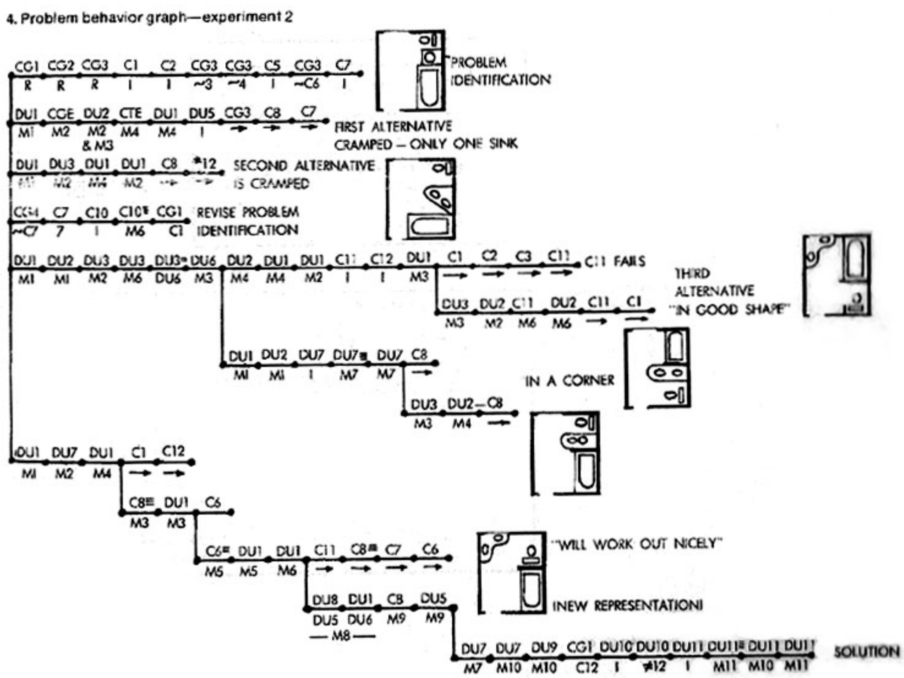

Figure 4 – Example of a *Problem Behaviour Graph* about the design process of a bathroom.
Source: Eastman 1970, p. 25.

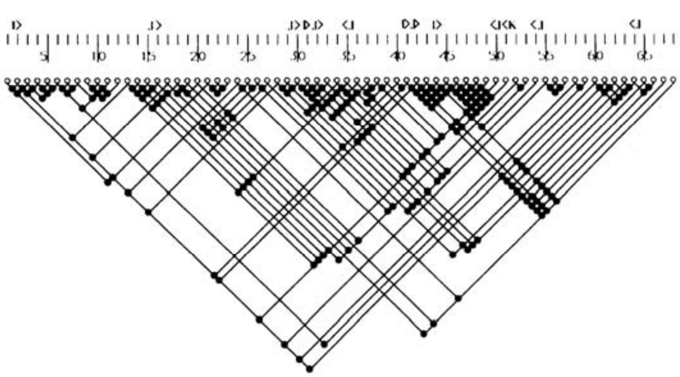

Figure 5 – Example of a Linkograph in which 70 design moves are recorded. The upper scale refers to the number of moves. Each white dot is a move in the design processes, whereas each black dot is a link between moves.
Source: Cross 1997, p. 313.

According to Goldschmidt and Weil (1998), Linkography differs from other graph techniques in that it does not parse the verbalizations of protocols based on time units (e.g. 3-minute units) but grouping them as part of subject matter units, which are in turn parsed into chronologically ordered *design moves* (i.e. steps or operations which transform the design situation in relation to previous moves).

Thus, each *design move* is assessed in relation to the previous moves based on their similarity or closeness of subject matter, and related to those moves located after them in other units. The aim of this technique is to generate a link-pattern to see in what subject-matter units or design episodes of a design process is located the higher productivity of the designer based on the links-per-moves ratio (Goldschmidt and Weil 1998). However, it is important to highlight that, despite of their usefulness, *Linkographs* do not actually explain the origin of the ideas/concepts whose links they help to quantify (Cross 1997).

Regardless of the graph technique in use, *protocol analysis* is useful mainly to look for three kinds of information (Eastman 1970): (1) the physical elements considered within the design process, (2) the design constraints (limitations and attributes), and (3) the way in which those limitations are handled in order to achieve the expected attributes. Thus, besides helping to outline processes, protocol analysis has also contributed to understand the designer's sketching behaviour and the differences derived from the designer's level of expertise during concept ideation.[1] Some authors have even asserted that protocol analysis is the observational method for researching about the act of designing that "…has received the most use and attention in recent years" (Cross, Christiaans and Dorst 1996 in Goldschmidt and Weil 1998: 87). Nevertheless, this method has not escaped criticism.

Among the most relevant criticisms about protocol analysis is the idea that thinking out loud interferes with the cognitive processes of designing and the fact that not all the cognitive operations present in the act of designing can be properly expressed in terms of words. Both criticisms, however, have been discarded by the advocates of protocol analysis who have argued that this method does not affect all subjects in the same way. Therefore, it should be only applied in those cases where the cognitive processes of those involved do not experience interferences.

On the other hand and regarding the possible difficulty of words to reflect what is going on during the act of designing, the advocates of protocol analysis have substantiated that even though the verbalization of acts and decisions cannot reflect the process as a whole, it is the closest monitoring technique to do it nowadays (Goldschmidt and Weil 1998). Beyond this, it is clear that the extremely elaborated nature of protocol analysis is its main drawback. To such an extent that most of the observational experiences carried out with this method to study design processes have generally involved only one designer (e.g., Do et al. 2000) and in some cases no more than six (e.g. Popovic 2004). This situation has indeed its consequences in relation to the validity of the findings of protocol analysis to achieve generalizations about the way designers think, bringing about questions such as to what extent the findings in the creative processes of very few designers can reflect the way in which all designers work?

This situation has turned design researchers toward the use of modified versions of *Protocol Analysis* (i.e. modified versions of the observational method), including research on team behaviour (Cross and Cross 1995) and a few unstructured studies (Ingram 1980) among others. Some of these studies even turn away from what observation is about, since their recordings are carried out after the design task has been accomplished instead of during its execution. Among these *retrospective techniques of protocol analysis* we ought to mention the use of questionnaires, interviews, analysis with predefined categories, and even self-introspection.[2] Many of them also involve the analysis of sketchbooks, mostly in qualitative terms.

However, there are also forms of protocol analysis in which sketchbooks have been the main focus of attention; especially those carried out during the 1980s and 1990s about the role of sketching within *Collaborative Design* (Garner 2005). In this respect, even a new research technique -known as *Analysis of Graphic Acts*- was created for studying the contributions of individuals in design-team tasks. Within this technique a *Graphic Act* is defined as the sketching and writing contribution that a member of a design team can make to a design task, which is separated by pauses or interruptions of less than one second of duration. Therefore, to carry out this type of analysis the contributions of each member of the team have to be done using interconnected computers which register their individual contributions while they are video recorded.

Finally, we ought to mention a protocol analysis study developed in 1999 in which *gestures were used instead of sketches* to explore the communicative power of the former in relation to the latter (Athavankar 1999). In such a study, a blind-folded designer was asked to explain his design proposal to solve a particular problem using gestures while he was video recorded. Then two different designers -who were absent during the recoding of the video- were asked to reconstruct the design proposal previously recorded by watching the video. The results of this study showed that gestures have a communicative power similar to that of words to explain design processes, especially when one cannot or does not want to use words to explain them.

In relation to the experimental method, design studies have been developed for the characterisation of how designers think during the solution of specific tasks not necessarily linked to design, to outline the presence of individual styles of design problem solving, to determine how the level of expertise among designers –i.e. between freshman and senior design students or between design students and design professionals– influences their capacity to tackle design problems, to explore the particular contribution of designers as part of interdisciplinary teams, to assess the designers' use of drawings/sketches during designing, and even to study the use *memory and imagination mental images* during their generation of design proposals.[3]

Other experimental studies have focused on the designers' capacity to criticise and grade design proposals, and some others on quantifying the creativity (i.e. originality) as well as the practicality present in such proposals.[4] The data recollected in these experiments is quantitative (number of drawings, number of words, number of solutions, etc.) and therefore, also subjected to statistical analysis.

2. Some Interesting Findings

Despite of the differences between the method at use and the research focus of interest, both kinds of studies (observational and experimental) have provided crucial information for our understanding of how designers think and, particularly, about how design concepts/proposals are generated. Among the most relevant findings derived from observational studies we ought to mention:

- Design concepts/solutions often evolve through proposed solutions (Galle and Kovács 1992).
- Instead of departing from abstract relationships and attributes, designers first generate design proposals and then determine their qualities (Eastman 1970).
- During the concept design process, designers invent requirements in a way situated in the environment in which they design as a means to illuminate their decision-making (Suwa, Gero and Purcel 2000).
- For the creation of their proposals designers fix their attention on a particular objective or in a small group of objectives which are strongly-valued and self-imposed (Darke 1978).
- 90% of the designers' patterns of action are plan-like behaviours (Akin 1979).
- The greater the designer's experience, the more information he/she is capable of handling (Foz 1973).
- And, most major design decisions are made in a very short period of time (Kraus and Myer 1970, Cross 1997, Goldschmidt and Weil 1998).

Among the findings regarding teamwork for designing it is worth to mention (Cross and Cross 1995):

- Leadership roles are taken by different members of the team throughout the design process.
- Laughter and jokes are used to avoid conflict.
- Generally there are mis-understandings about apparently shared concepts.
- And as part of the teamwork dynamics, some disagreements are normally left unresolved for the sake of achieving the proposed goal.

Finally, we have a different type of findings stemming from the experimental studies on the generation of design proposals. Among them we should mention:

- It is possible to measure the level of creativity of a design proposal based on concepts such as practicality and originality (Thomas and Carrol 1979).
- Effectiveness in the ideation of design proposals can be measured in terms quantity (number of ideas generated), quality (feasibility and closeness to design specifications), novelty and variety (Shah, Smith and Vargas-Hernandez 2003).
- In the sketching of design proposals the presence of two mental processes becomes evident: restructuring and combining ideas (Verstijnen et al. 1998).
- The individual style of each designer influences the course of his/her design process and his/her success in problem-solving (Eisentraut 1999).
- The interaction between verbal and visual codes in the generation of

design solutions is far more complex than we tend to think (Ulusoy 1999).

- And, designers solve problems carrying out strategies which are based more on the proposition of solutions than in the actual discovery of the structure of the problems at stake (Lawson 1979).

3. Five Lessons from the Study of How Designers Think

As a result of all these studies, some important aspects have been realised. Among them we ought to mention the following:

3.1. The time employed to accomplish design tasks

In observation-based studies with no limitation of time subjects have used about four hours to solve a design problem (Chan 1990), even though in some studies only 40 minutes has been allowed to carry out this kind of tasks (Cf. Eastman 1970, Foz 1973).

For the case of observation-based studies of teamwork, two hours have been the time generally established to formulate a design proposal (Cross 1997). In contrast with this, experimental studies about general problem solving (i.e. no design problems) have been carried out with no time limit (Lawson 1979). Nevertheless, when the task is a design problem, an average of three to four hours seems to be the normal time needed to produce a design concept, even though there are experimental studies where pilot testing has shown that 30 minutes is enough time to produce *"Thumbnail Sketches"* but disregarding some of the constraints normally taken into account as part of a design proposal (Dahl, Chattopadhyay and Gorn 1999).[5]

In retrospective studies based on real commissions instead of laboratory tasks/problems for research purposes, the designers interviewed have asserted to have employed from ten days to fifteen weeks to accomplish the conceptual phase of their designs (Rodgers, Green and McGown 2000).[6]

In order to understand the presence of such differences one must bear in mind that no all design problems have the same level of complexity neither they are of the same kind (well-defined, ill-defined or wicked problems). Indeed, the sort of problems commonly used in observation-based or experimental studies is rather different than those of real practice in many respects besides the time needed to solve them. Bearing this in mind, we can contend that an appropriate length of time to develop a design concept under either observational or experimental conditions goes from two and a half to five hours. This is a length of time that subjects participating in experiments can tolerate. On the other hand, it allows subjects to consider what they think to be the most obvious constraints of the problem they are asked to solve.

3.2. The number of participants involved

The experiences developed with protocol analysis have defined a maximum of six participants for observation-based studies, even though there are cases with nine participants.[7] This number will depend upon the level of detail of the observations to be performed. Differently from this, in experimental studies the number of subjects involved has in some cases reached the number of 140 (Dahl, Chattopadhyay and Gorn 1999).

Nevertheless, it is known that this latter number of participants definitely affects the level of elaboration of their responses (e.g. sketches disregarding the normal constraints), the time programmed for each experiment (e.g. around 30 minutes), and the physical conditions under which these experiments take place (e.g. sometimes respondents are asked to work on small desks instead of using drawing tables). Furthermore, studies with such numbers of participants need to involve undergraduate design students instead of professional designers, given that it is hard to gather in a single place and at the same time such a large number of professionals.

Thus, depending on the matter under study (e.g. level of expertise, manipulation of information, cognitive style, etc.), it is always preferable to devise experiments involving between fifteen and forty participants when concept ideation and the design process are the matters under study. Indeed, these are the number of participants used in many successful experiments carried out to date.[8]

3.3. The motivation of respondents

This is a point rarely referred in most research reports published in design journals, even though it is a fundamental factor for the success of any inquiry about the synthesis of design concepts. Indeed, it is well-known that among the motivations involved in the development of design proposals are the desire to change the way things are, the satisfaction derived from having designed something already in production/built and used by many, and the presence of an economic reward (payment) for the work done.

This sort of motivations are, however, quite difficult to be incorporated as part of any observation-based or experimental study. Therefore, there is the need of finding different ways to motivate the participants in these studies to help them accomplish the tasks so assigned in a satisfactory manner. In this direction, a detailed reading of reports on observation-based studies can lead anyone to conclude that, given the small number of participants involved, one of the motivations playing a definitive role here is the possibility of casting some light on the participants own way of dealing with design problems.[9]

For the case of retrospective protocol analysis, besides the aspect above mentioned, there is also a sort of personal gratification in the participants derived from the fact that their peculiar ways of designing are taken as referents to define such an activity.[10]

Differently from these studies, in the experimental ones it is perhaps more complex to deal with the motivation of their participants. First of all, because there are not main protagonists in the studies given the number of participants involved. Secondly, because it is much harder to convince a relative large number of designers to be part of an experiment than a few ones. Therefore, researchers should devise strategies to deal with this situation. One well-known strategy is to pay certain amount of money to the participants (Dahl, Chattopadhyay and Gorn 1999). However, this is a strategy with more receptivity among design students than professional designers (perhaps due to ethics or ego issues).

Another strategy used is the implementation of experiments with design students as if such experiments were part of a class or a workshop exercise (Cross and Cross 1995). Thus, the grades (marks) or place achieved by the participants in these exercises (or competition, if it is envisaged as such) become the main motivation to do the activities requested in the best possible way.

In this latter respect, the best way to motivate the respondents of an experiment devised as a class exercise is to conceive its activities in terms of *meaningful tasks* (Newman 2002). In other words, focusing the participants' attention on what they can learn out of such an activity and the practical implications of the experience or knowledge they will gain for their professional future. The disregard of this particular aspect in experiments with students has indeed brought along, in some cases, a significant desertion of participants before the study can be finished (Ulusoy 1999).

Finally, we also ought to mention that, in higher education, another possible source of motivation for respondents can come from devising the experiments in terms of providing the researcher with findings that help improve the way in which certain subject matter is taught to design students (Atman et.al. 1999, Popovic 2004). As a matter of fact, this has been particularly relevant in studies about differences in styles of problem-solving (Lawson 1979, Eisentraut 1999).

3.4. The reasons behind data collection

A key aspect of any study is the definition of the sort of data to be gathered as well as the way in which such data will be processed and interpreted. In this respect, observational studies about the act of designing tend to focus more on procedural data (i.e. information on design steps and routes of decision), whereas the data collected in experimental studies normally varies according to the matter under study.

Thus, while observational studies such as those derived from protocol analysis generally register chains of words and changes in sketching activity as part of phases leading to design decisions (e.g. general constraints, acts of manipulation, and design units); experimental studies tend to concentrate more on aspects such as the features prevailing in design sketches, the time employed by the participants to accomplish a design task, and the semantic implications of the words used as part of sketches beyond procedural matters. In this respect, observational and experimental studies both collect verbal and graphic data but each of them encodes and processes such data differently.

3.5. The units and scales of measurement

The kind of units and scale of measurement varies according to the nature of each study. Nevertheless, two things should be kept in mind. First, we have come to a point where aspects seen as hard to quantify in the past are now measurable. Indeed, the distinctive *problem-solving style* of designers has been measured by studying the number of correct trials use by designers to achieve a solution for a problem and such number has been even compared with that of professionals from other fields of knowledge (Lawson 1979).

The *practicality* of design products, on the other hand, has been measured matching design proposals against sets of "functional requirements" where *practicality scores* derive from the ratio of met requirements to the total requirements initially formulated (Thomas and Carroll 1979). Similarly but standing on Information theory, the measurement of *originality and novelty* of design proposals has been determined from the presence of the less-probable design features among those present in groups of design proposals generated for the same product (Thomas and Carroll

1979, Shah, Vargas-Hernandez and Smith, 2003).

Following this sort of comparative studies, *variety* has been measured by grouping the set of ideas comprising different design proposals for a single product and comparing their differences two by two (Shah, Vargas-Hernandez and Smith 2003). This latter procedure is not new at all, having a clear antecedent in the studies carried out by Abraham Moles (1975) to establish the *Semantic Distance* among objects, i.e. the degree of similarity (functional, syntactic and semantic) between two different objects in the eyes of the public.

The second relevant thing that should be mentioned has to do with the measurement scales used to assess design proposals. In this respect, we can say that there are two basic types of scales: those determined after the assessment of design proposals has been made as part of the presentation of results -which we may call *analytical scales*- and those scales prepared in advance to the development of the assessment of design proposals or *rating scales*.

Analytical scales are characteristic of studies where the results are calculated based on some kind of formula or mathematical procedure, e.g. the scales of studies about the originality, practicality or variety of design proposals above mentioned. In these scales the number of points or ranks may vary with the results of each study. *Rating scales*, on the other hand, are commonly used in methods of inquiry such as questionnaires. Examples of this type of scale are those used to establish the hierarchy or relative relevance of different aspects of a design proposal, Likert scales, and mixed scales (quantitative + qualitative) such as those used in the Semantic Differentials technique and the Semantic Distance Matrixes[11] (see figures 6 y 7).

	Cup	Dish	Spoon	Table	Book	Paper	Jug	Chair	Telephone	Bread
Cup	0									
Dish	1	0								
Spoon	1	1	0							
Table	2	2	2	0						
Book	3	4	4	2	0					
Paper	3	5	5	2	1	0				
Jug	3	2	3	2	2	4	0			
Chair	4	5	6	1	2	4	5	0		
Telephone	4	5	6	2	2	3	4	3	0	
Bread	3	3	4	2	5	3	2	4	6	0

Example of an assessment of Semantic Distances based on a scale of 7 points: 0, 1, 2, 3, 4, 5, 6.

Figure 6 – Scale in a Semantic Distance Matrix.
Translated from: Moles 1975, p. 21.

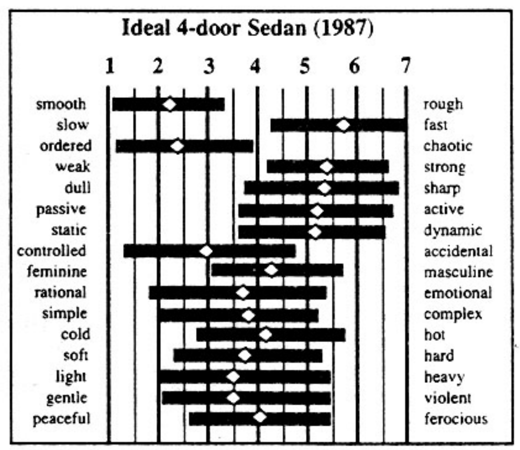

Figure 7 – Semantic Differentials scale to assess the concept of a vehicle.
Source: Coates 1988, p. 7.

In these scales the number of points or ranks should not exceed the number of seven. This is due to the fact that, either by learning or by the design of our nervous system, people cannot discriminate more than 6.5 categories with an absolute clarity (Miller 1956). Indeed, there is scientific evidence stating that the more points or ranks we add to the scale, the more difficult it becomes for respondents to make accurate

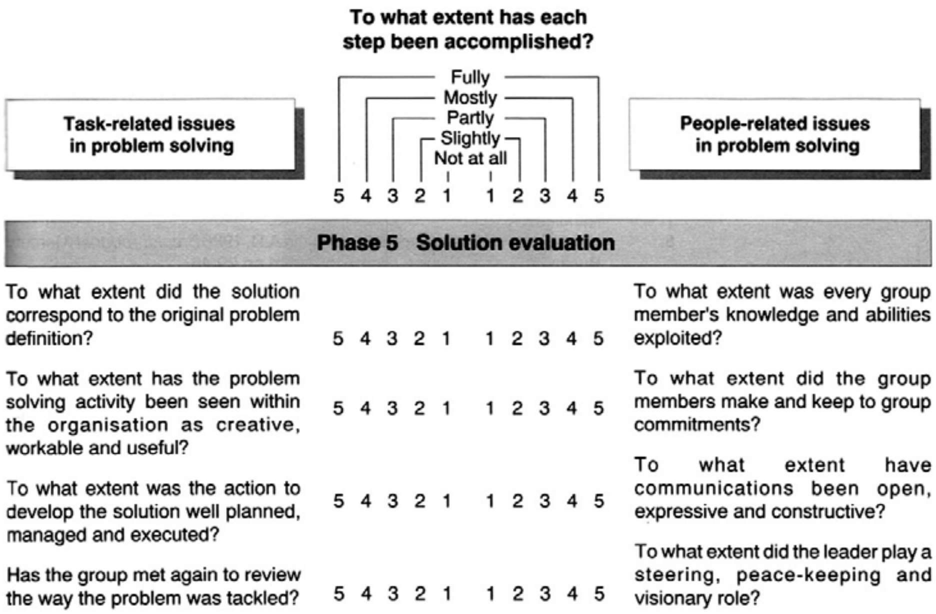

Fig. 8 – Example of a PIPS assessment scale.
Source: Baxter 1995, p.97.

judgements. This may be the reason why techniques such as Semantic Differentials and questionnaires do not exceed the use of seven points in their scales, as well as the reason why some researchers intuitively prefer three-point and five-point scales.[12]

There are even double rating scales for problem-solving evaluation working with two five-point scales simultaneously. Such is the case of PIPS (Phases of Integrated Problem solving) evaluations where each aspect is simultaneously assessed in terms of the tasks and the processes involved (Baxter 1995) (see figure 8).

CONCLUSION

It is interesting to see the level of development achieved by studies on the mental processes leading to the ideation of design solutions. The Observational and Experimental methods have both contributed with relevant findings to clarify this subject despite of the particular preference and validity assigned by researchers to each of them. Nevertheless, we ought to bear in mind that each of these methods obey to different kinds of searches. Insomuch that they do not actually serve the same purpose. Furthermore, one should not forget that even though one may be working with the same type of method, the timing, number of participants, motivations as well as the units and scales to be used may vary according to the researcher's interest. Therefore, before deciding whether to use an observational or an experimental method in order to establish what and how data will be collected, codified and assessed, the most important thing is to have a clear idea about what the subject of study is and the ways already known to do such kind of inquiry.

On the other hand and even though the above studies have set the basis for a particular way of looking at and understanding how designers think, their contributions have mostly focused on aspects of the design process. This has unleashed –since more than a decade ago- the researchers' concern for investigating more about the results/products of the design process, that is, the design concepts themselves. As part of this new search design proposals/solutions are envisaged as mental constructions capable of showing not only the designer's own view of the world but also the sort of ideas he/she wants to inculcate in the end-users of his/her designs.

Therefore, we should not be surprised by the increase of studies centred on how the end-users understand the designers' creations (e.g. Espe 1992, Jordan 2002, Govers, Hekkert and Schoormans 2004). It is perhaps a way to compensate the remarkable disregard of the users in past studies that, given their communicative nature (psychology of communication), should also involve the receivers of these messages/design concepts.

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NOTES

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1 Cf. Scrivener, Ball and Tseng 2000, Kavakli and Gero 2001, Suwa and Tversky 2001.

2 Cf. Kraus and Myer 1970, Darke 1978, Galle and Kovács 1992, Visser 1995, Oxman 1997, Suwa and

Tversky 1997, Suwa, Purcell and Gero 1998, Dorst and Cross 2001.

[3] Cf. Lawson 1979, Eisentraut and Günther 1997, Verstijnen et. al. 1998, Atman et.al. 1999, Chattopadhyay and Gorn 1999, Rodgers, Green and McGown 2000, Dahl, Austin et.al. 2001.

[4] Cf. Malhotra, Thomas and Carroll 1978, Ulusoy 1999, Chattopadhyay and Gorn 1999, Shah, Vargas-Hernandez and Smith 2003.

[5] See also Thomas and Carrol 1979, Akin 1979.

[6] See also Galle and Kovács 1992.

[7] Cf. Foz 1973, Tovey, Dorst and Cross 2001, Porter and Newman 2003.

[8] Cf. Thomas and Carroll 1979, Eisentraut and Günther 1997, Atman et.al. 1999, Austin et.al. 2001.

[9] Cf. Eastman 1970, Kraus and Myer 1979, Akin 1979, Chan 1990.

[10] Cf. Darke 1978, Galle and Kovács 1992, Visser 1995, Dorst and Cross 2001.

[11] Cf. Moles 1975, Coates 1988, and Jordan 2000.

[12] Cf. Ulusoy 1999, Govers, Hekkert and Schoormans 2004.