INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 03 STOCKOLM, AUGUST 19-21, 2003

DESIGN REQUIREMENTS: CONDITIONERS OR CONDITIONED?

Restrepo, J. & Christiaans, H.

Abstract

The development of information systems for designers require a better understanding of the interaction between designers and such systems and all the aspects that might influence this interaction. This paper discusses two aspects that have influence on the information seeking behavior of designers and the influence they have on each other. These aspects are namely; the way the problem is interpreted early in the design process (early representations) and the generation of design requirements during the design process.

Keywords: Requirements, Information Processing, Fixation, Early Representations

1 Introduction

Considering how information systems for designers should be like, it is important to understand how designers enrich their knowledge during the design process. What triggers the queries, what strategies do they use and what factors influence their behavior in relation to information seeking? What influence has the information accessed on, e.g., the generation of design requirements or the final design?

There is ample evidence that the strategy designers choose in their problem framing is rather idiosyncratic, based on prior experience and/or preferred way of working. By asking designers, e.g., to write their interpretation of the problem shortly after having received the design brief, it can be seen that even in that early stage of the process they express different mental representations of this same brief. These differences have been observed to have a great influence on the information seeking behavior of the designers and the quality of the results [1]. Moreover, the generation of design conditions or design requirements during the process seems to be affected by this as well.

The objectives of this research are twofold. Firstly, it intends to find whether and how early representations of the design assignment condition the design process. Secondly, it intends to find out what aspects in the information presented, enable a design team to generate important design requirements for the given assignment. How do early representations influence information seeking behavior? How do information seeking behavior and the generation of design requirements influence each other?

In two studies, the role of early representations will be analyzed. The first study regarding the design of a flexible workspace will be focused on how differences in early representations influence the information seeking behavior, the quality of the results and the generation of design requirements. The second study regarding the design of a luggage carrier for bicycles shows the relationship between information seeking behavior and the generation of design requirements. In order to operationally define the concepts of ‘early representation’ and ‘design requirements’ both will be described first.

1.1 Early Representations

Designing can be understood as the production of mental representations and the means to communicate such representations [2]. Being faced with a design problem, a designer starts to interpret and to build up mental representations regarding the problem, the solution or both. Early representations are considered, for the scope of this paper, 'a first sight of the way a designer interpret the design assignment after a first confrontation'. When the assignment is given, the designer will construct a mental representation of the situation at hand. This mental representation will be based on his goals and preferences, expertise (prior knowledge), knowledge of the situation, precedents and rules of thumb.

Inevitably, such an early representation is based on available information that is considered somehow relevant for the problem at hand. Early representations, being a personal interpretation of the assignment based on the expertise and (retrieval) abilities of a designer, determine the boundaries of the so-called 'problem or solution space', i.e., the metaphorical space in which a designer looks for a solution to the problem [3, 4]. These representations necessarily limit the problem/solution space in a way that they could help in framing the problem and steer the information seeking behavior. According to Schön [5], a designer will frame a problematic design situation by setting its boundaries, selecting particular things and relations for attention, and imposing on the situation a coherence that guides subsequent moves.

Sometimes information intake will be hampered if the designer becomes fixated by past experience. The phenomenon of fixation can be seen as the negative effect of an early commitment to a design problem [6, 7], or as a blind adherence to a set of ideas or concepts limiting the output of conceptual design [8, 9, 10]. However, prior knowledge and experience will not always have this negative, limiting effect on the scope of the designer. We would prefer to speak of 'conditioning' effects. Conditioning is a phenomenon that can be seen as the creation of the set of premises upon which the design activity will be carried out, that will condition the performance of the designer and the output of the process.

If the designer's early representation of the assignment is predominant, it is hypothesized that he will stick to this representation, which in turn, will affect the way the designer process information. For example, a conditioning effect of a narrow focused early representation could be that information consulted from (new) external sources will never become knowledge (internally processed) and thus will never be applied to the current task. Nevertheless, if this early representation covers a much broader perspective on the design brief, the representation might for that very reason elicit willingness to process external information.

A way of making the early representations explicit is to let designers write down their interpretation of the design assignment after a first short reading of it. Differences in interpretations between designers should be an indication of the validity of this assumption. Next, the influence of the interpretation on the following design process will give further proof of the conditioning effect by this early representation. It is expected that this early representation will condition the way the designer tackles the design assignment, his 'open-mindedness' regarding his solution-seeking behavior and his choices in the design process including the final solution.

1.2 Design requirements

Design requirements are an important part of the design assignment, but also an important part of the exploration of the design space. Design assignments do not always come with a

complete set of requirements; instead, assignments are very often rather incomplete and diffuse. Requirements are used to specify the design assignment (expanding the problem space) and to describe and explore aspects of the desired solution (exploring the solution space). They are dynamically generated during the design process and are used by designers to express what they consider the most important aspects of the given assignment. This creation of design requirements on the fly seems to be triggered by either prior knowledge or by knowledge acquired during the design process.

There is very little research on the generation of design requirements during the design process. Suwa et al. [11] have discussed how different types of design requirements are generated during the design process by means of what they call unexpected discoveries. In their study, they show how sketches contribute to this process of "invention" of design issues or design requirements and conclude that in about half of the design process (of the studied architect) there were bi-directional relations between the design issues or requirements "invented" and the "discovery" of features in the sketches that were not intended when drawn. Other elements however, contribute to the generation of design requirements as well, e.g. prior knowledge, self-conversations, interaction with external information sources and dialogue with teammates. In fact, it is sometimes only when a solution has been devised that a designer is able to detect and understand important issues and requirements of the given problem [11].

Requirements prescribe (or describe, depending on how it is seen) characteristics the designed artifact should comply with, imposing conditions on the solution. However, design requirements also indicate certain characteristics that other objects (environments) and humans (users, producers, etc.) that establish relations with the artifact should have in contexts we deem as important. Design requirements are made explicit during the process by either writing them down (1st and 2nd studies) or discussed with team mates (2nd study). This paper discusses only those put on paper.

2 The Empirical Studies

2.3 First Study: The design of a Flexible Workspace

This study was originally designed to assess whether the type of information presented to the designers has a direct influence on the creativity of the design solutions and whether this effect is mediated by the nature of the designer's solution space. There are several publications reporting on this. See e.g., Snoek et al. [3]. The influence of early representations on the quality of the results and on the information seeking behavior was later reported in Christiaans and Restrepo [1]. A detailed description of the experimental procedure is reported in these references. In this paper, a second analysis on the data will be reported, with a focus on the relation between the early representations of the problem by the designer, the information accessed, and the design requirements described.

Participants for this study were 23 graduate students from the faculty of Industrial Design Engineering (IDE) at Delft University of Technology. They were selected on their marks for their design courses. In order to stimulate them to participate and to work on the assignment, the experiment was announced as a contest organized by a company in office furniture.

The design assignment given to the participants was 'Design a new concept for a modern and flexible office environment'. This assignment was further explained by a text of about 500 words. The core of the design assignment was formulated as: "The problem is that an employee must have at his disposal the things he needs for his specific task at any time and in

any place. Also, he wants to be able to adapt the desktop to make it his own personal work station at any time and in any place." For this task, participants were given one and a half days.

In order to assess the early representation of the designers, they were asked to express their conception of the design problem, i.e. to draw, sketch and/or write down everything about the problem they already had in mind on as much paper as they needed (Task 1). Before this task was given, they read the design brief, followed by a small “distracting” activity (solving a common logic problem). Next, for task 1 they had a fifteen minutes time limit. After half a day, participants were asked to write down their problem conception (Task 2). For this task, the time limit was 20 minutes. This procedure was repeated after the second half day the next morning (Task 3). Judges assessed the quality of the solution, as well as the type of representations presented in the three tasks.

All designers had access to a computerized information system. The system contained two types of information, traditional 'industrial design' information, and 'contextual' information. Traditional information was defined as information that is directly and obviously related to the problem domain (examples of office products, information on flexible workspaces, office furniture companies, materials, etc). The contextual information was defined as information that is not directly and not obviously related to the problem domain (information on mobility, life styles, changes in the labor laws, etc.). Context information required active interpretation in order to apply it to the situation at hand. All database activities were logged in a file.

2.3.1 Results

The problem conception (early representation) of all 23 participants was expressed in written language, without any sketch or other graphics. The content of these documents show a great variety, ranging from short statements about ‘a product-to-be-designed’ to extensive considerations on the problem context.

There were two types of early representations. One focuses on descriptions of the problem as it is interpreted by the designer (problem-oriented). These refer to the context of the problem, e.g., the difficulties of having a desk for every employee even when they are not permanently at the office, or the difficulty of giving the work environment a more personal appearance when it has to be shared. The other type of representations deals with a description of the product that has to be designed (solution-oriented). Some of the participants favor the use of nouns (“design of a unit that...”, “Design of a product...”, etc.), whereas others favor verbs and adjectives (“flexible work stations”, enhance work environment”, etc.). Interestingly, the solution-oriented participants produced less design alternatives and produced as a final concept something very close to what was described in their first and second concepts (Tasks 1 and 2). In other words, they stuck to the solutions that came to their minds in the early stages without further exploring different alternatives. Moreover, these participants used in a less intensive way the information system provided, visiting each page for a time that is not long enough to read its content. The participants who start designing from a more abstract problem-oriented perspective, are able to produce more alternatives, explore more possibilities and produce solutions that are more distant from existing products.

In relation to the production of explicit design requirements, some differences can be observed as well. For instance, the solution-oriented designers produced a larger and more complete list of requirements during the first hours. These requirements are in some cases so specific as to include dimensions, colors, and so on. In contrast, the problem-oriented designers expressed very few requirements if any at all. To illustrate the influence of early representations on the design process, a sample of five participants is shown in table 1. These

five cases are representative for the whole sample of 23 participants and were selected randomly.

Table 1 Type of early representation, list of requirements and quality of the solution for 5 participants. P refers to participant number

P	Early Representation Task 1	Type of Orientation	Requirements	Assessment
23	...design a universal workstation…	Solution	Long list of requirements e.g.: must be adjustable, maintainable, hygienic. max. en min. dimensions Changes must be fast and easy Other requirements on modes of use, etc.	Low quality of the solution, yet distant from existing products. Low feasibility of the concept
4	...a concept which enhances flexibility.	Problem	Very basic requirements explicitly expressed. Mostly use of guiding keywords.	Original and distant from existing solutions. Low feasibility. Fair quality of the concept.
10	Flexibilise the physical workplace. Workplace: everything which is needed to do your job	Problem	No explicit indications of Design Requirements in the assignments or in the sketches.	Very good quality of the concept, distant from existing products, feasible and original.
11	Design a product solving the problem of the need for flexibility in office spaces	Solution	Lots of Requirements in the assignments 2 and 3 and in the sketches, e.g. must be foldable and flexible, there should be space for trolleys, must be recognizable, etc.	Poor quality of the concept. Similar to existing products, feasible
13	.. a (concept) for a flexible workspace that must have a desk, computer and telephone.	Solution	Lots of requirements Dimensions (with values) Screen must not be positioned near windows There must be a PC on every desk, etc.	Low originality, very similar to existing products, feasible.

2.4 Second Study: The Design of a Bicycle Luggage Carrier

Observations regarding the flexible workspace study show a relation between the way designers initially represent a problem, the information seeking behavior and the quality of the results. Additionally, the way design requirements were treated seems to be related to these observed behaviors as well. However, is the information seeking behavior being driven by the design requirements generated during the design process? Are those requirements being triggered by particular aspects of the information presented? With the data collected in the first study, it was not possible to define which aspects of the information looked for

contributed to the generation of these design requirements or if, on the contrary, it was the generated design requirements what drove the information seeking behavior. In this second study, the objective is to observe this interactive process of looking for information and the generation of particular design requirements.

Participants were 11 students from the faculty of IDE. In contrast to the previous study in which participants worked individually, here participants worked in triads (with the exception of one team that was a dyad). In order to reduce disruptions caused by having to work with unknown teammates, members of existing teams of the courses Design 4 (3rd year) and Design 6 (graduates) were invited to participate. They all had finished those courses and had worked together for periods of about 17 weeks.

The design assignment given to the participants was 'Design a product for users of 55+ years old that allows them to transport luggage on Giant Bicycles.' This assignment was also expanded by a text of about 500 words with some information about the company for which the design should be made and the target group of user. The Participants were asked to write a list of requirements for their designs and to develop a concept for a solution. In this case, they had 4 hours to complete the assignment.

After the assignment was given to the participants, they had an introduction to the use of the database. Analogous to the previous study, they were asked to individually express their conception of the problem on as much paper as they needed. Only after completion of this assignment could they start working as a team. Each participant had access to their own computer and they were instructed to browse/search individually but to work on the development of the concept as a team. All the process was videotaped and all activity on the database was logged in a log file. The produced concepts were later evaluated by judges on originality, conformance to the given problem and feasibility.

For this study, participants had access to a more sophisticated information system. Information in this database system was classified as products general (bikes, bikes parts, accessories, etc.), products specific (examples of other solutions for the given problem), users general (accidents on bikes, saddle pain, etc.), users specific (ageing, income, education, leisure activities, etc.), companies general (bikes and accessories manufacturers) and companies specific (information on the company for which the product should be designed). A search engine and a site map were included. Participants were also able so save articles considered important in a "personal collection". Articles saved in the personal collection by a user were visible to the whole team making easy the interchange of information among the team members.

2.4.1 Results

Early Representations

The first visible result was that the differences on the first interpretation of the design problem replicated what was observed in the previous study. Some participants were more problem-oriented and some more solution-oriented ("Design the possibility of transporting luggage…" vs. "The objective is to design a product with which …"). Since the assignment here was developed as a team, it was difficult to observe what influence this might have had on the developed concept, on the information seeking strategies or on the formulation of design requirements. What was interesting, however, was to observe that the more experienced designers (graduate students: groups 1 and 4) formulated more abstract problem-oriented interpretations whereas the less experienced (design 4: groups 2 and 3) expressed more object-oriented.

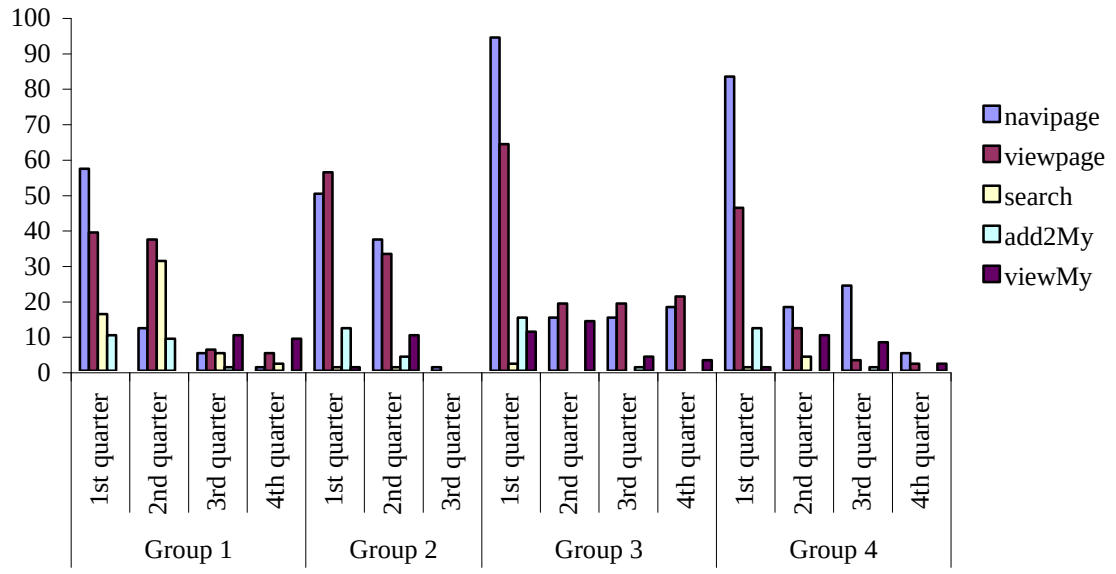

Figure 1 Usage of the database

Database usage

The strategies used by the teams to look for information were quite different. Figure 1 shows the usage of the database by the teams. There are five possible actions, navipage (navigation pages), viewpage (viewing an article), search, add2my (adding an article to the personal collection) and viewmy (viewing an article from the personal collection). Time was divided in 4 quarters to illustrate how the use and the strategies changed as the design activity progressed. Searching and using the indexes available, as opposed to browsing through the pages was used as a strategy only by team 1. They identified three issues and started searching on them (rack and bicycle, consumers and the company). This strategy proved to be the most effective as it resulted in the greatest number of pages added to the collection.

Regarding the use of the database, it is interesting to see that all teams read about the same amount of articles in the database, and added about the same amount of pages to the team's collection. There are no significant differences in the amount of information consulted. What was very different was the type of information they accessed. (See figure 2)

Design Requirements and content of the information accessed.

Observations of the first 30 minutes of the tapes reveal interesting differences in the way the problem was approached by the teams. Group 1 started with a discussion of the important aspects to consider in a very broad way (client, user, racks and bicycles) and begins browsing the database. Each member of the team had the task to search on one of these topics. As they go through the database, they mention to the others elements they consider interesting (and that might add to the list or requirements, but not in a explicit way). For instance, the identity of the company (young and sportive), forces needed to ride a bike and to take luggage off the rack (arthritis), a universal click system, etc. Group 2 starts discussing the initial list of requirements given in the design brief, discusses possible solutions and begins browsing the database. After 20 minutes of browsing, they start working on the list of requirements. Team 3 starts immediately defining the list of requirements mentioning storage, transport, discharge, material, ergonomics, target group, etc. They browse through the database trying to find information to fill in these categories. Group 4 starts browsing the database in an unstructured way without referring to the requirements or what they have to look for.

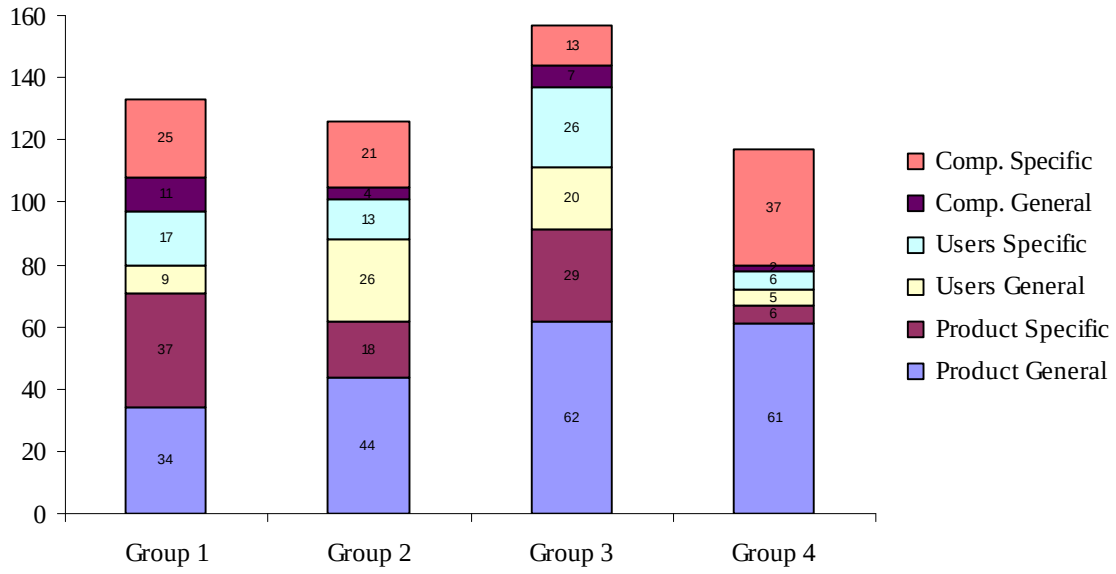

Figure 2 Distribution of the information consulted.

The resulting lists of requirements differ from each other in different aspects. One aspect is the specificity of the requirements. Groups 1 and 4 generate broad requirements that do not give the impression of belonging to a specific solution whereas groups 2 and 3 are very specific. For instance, when group 1 writes, “it is desirable that different types of products can be attached to the bike”; group number 3 writes, “The click mechanism should be safe for hands and fingers”.

Timing, as mentioned before, is another important difference. Whilst teams 1 and 4 developed the list of requirements throughout the entire session, teams 2 and 3 finished the list of requirements before starting the development of the concept. In fact, team number 2 did not succeed in completing a concept because they spent too much time on the list of requirements. These reveal a completely different approach to the issue of design requirements by the teams. While teams 1 and 4 generated most of their requirements through discussions that happened during the design process, teams 2 and 3 did so almost exclusively during the browsing of the database. Groups 1 and 4 used the identified design issues to guide their use of the database and groups 2 and 3 used the information on the database to generate the design issues.

Another aspect of difference is the level of detail to which the requirements are specified. Teams 2 and 3 specify the requirements including values. For instance, they mention the maximum width the accessory can have according to the norms (0.75 m), the maximum weight empty (2 kg.), etc where teams 1 and 4 do not mention specific values (with one exception on team 1). Most of these values were taken directly from articles in the database.

3 Discussion

From the observations made, two distinct approaches can be identified (object oriented and concept oriented). There also appears to be a relationship between the way designers represented the design task and the produced results, the requirements prioritised and the use of the information systems. This does not necessarily mean that there are two types of designers, as the observed behaviour can change in different situations.

The first study shows an interesting relation between the way the problem is initially represented and the information seeking behavior, and the quality of the results [1]. By looking closer, it is possible to see that there are also some differences in the way design requirements are made explicit. It was mentioned before that the generation of design requirements is an important aspect of exploring the design and solution spaces, and that this mechanism of generating design issues is associated to the creative output of the process. Why is it then that in the first study participants who generated more requirements ended up with less creative solutions? Those participants that generated a long list of requirements did so very early in the process. It can be seen already in the first and second tasks and in very early sketches. This can be seen as another indication of the commitment of these designers to a solution very early in the design process. For the other participants, the fact that design requirements are not explicitly written down or do not appear stated in their sketches cannot be taken as an indication that such requirements were not generated. They might have been taken into consideration but we do not have access to that data.

In the second study, we cannot relate the early representations to the performance of the teams, as the early representations were written individually and the rest of the process was performed as a team. There are, however, elements that indicate that there is a relation between the design requirements, the level of expertise and the information seeking behavior. Teams 2 and 3 (the less experienced) produced a specification of the problem very early whereas teams 1 and 4 did so during the entire process. The level of detail of the design requirements can be related to the findings in the first study where the solution-oriented designers also generated requirements that are more detailed. In this study, less experience designers rely much more on external information than the more experienced ones. For them, external information becomes the driving force of their design process.

There are other interesting questions rising from this study. For instance, is the tendency to represent design problems in a conceptual way something idiosyncratic to the designer? Is it depending on the situation? Would the same designer behave consistently throughout different design situations, showing therefore the same information-seeking behavior? Design studies have been concentrated so far on multiple designers in the same design situation. What would the result be of longitudinal studies creating situations where we can observe whether the behavior is inherent to the designer or to the situation?

References

[1] Christiaans, H. and Restrepo, J. (2001). "Designer Conditioning By Early Representations" Proceedings of the Third International Workshop on Strategic Knowledge and Concept Formation

[2] Restrepo, J; Christiaans, H. and Rodríguez, A. "The Finality Argument on Design Methods: A Theoretical Approach From the Social Sciences" Proceedings of Design Plus Research, Milan, 2000, pp 109-115

[3] Snoek, H. and Hekkert, P. "Directing designers towards innovative solutions." Managing new product innovation. pp.167-180). London: Taylor & Francis, 1999.

[4] Snoek, H., Christiaans, H., and Hekkert, P.M.M. "The effect of information type on problem representation." Proceedings of the 4th International Design Thinking Research Symposium on Design Representation., 1999, Cambridge, pp. II-101-112.

[5] Schön, D. "Designing: Rules, types and worlds". Design Studies., Vol.9, 3, 1988, pp 181-190.

[6] Purcell, A. and Gero, J. “Design and Other Types of Fixation.” Design Studies, 17, 1996, pp 363-383.

[7] Purcell, A.T., et al. “Fixation effects: Do they exist in design?” Environment and Planning: Planning and Design, Vol.20, 1993, pp 333-345.

[8] Jansson, D.G., & Smith, S.M. “Design Fixation.” Design Studies, Vol.12, 1, 1991, pp 3-11.

[9] Smith, S.M., Ward, T.B., & Schumacher, J.S. “Constraining effects of examples in a creative generation task.” Memory & Cognition, 21, 1993, pp 837-845.

[10] Christiaans, H.H.C.M., and Van Andel, J. “The effects of examples on the use of knowledge in a student design activity: The case of the 'Flying Dutchman'”. Design Studies, Vol.14, 1, 1993, pp 58-74.

[11] Suwa, M; Gero, J and Purcell, T. “Unexpected discoveries and S-invention off design requirements: important vehicles for a design process”. Design Studies, Vol. 21, 2000, pp 539-567.

For more information please contact:

Ir. John Restrepo. Faculty of Industrial Design Engineering.
Delft University of Technology. Landbergstraat 15 2828CE, Delft, The Netherlands.
Tel +31 15 278 5146 Fax +31 15 278 7179 e-mail j.restrepo@io.tudelft.nl