INFLUENCE OF TASK INFORMATION ON DESIGN IDEA GENERATION PERFORMANCE

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1. Introduction

In regards to conceptual design, past research has been primarily concerned with idea generation and evaluation. However, these steps are preceded by problem formulation activities, which have received relatively little attention. A design project is usually initiated from a user need that has yet to be satisfied. The design brief is the object through which this problem is carried over to the design team. The design brief is basically a description of what is to be designed. In addition to the need statement, the design brief includes additional information that is found purposeful for an applicable final design.

As will be discussed in this paper, a trade-off may arise between the depth and breadth of idea generation in regards to whether the design brief emphasizes the essential problem or the immediate value of the solutions in light of a pre-defined set of requirements. The general objective of this paper is to demonstrate the coupled nature of problem formulation and conceptual design activities. We present a design experiment that highlights the importance of brief structuring, by demonstrating how changes in design brief content affect succeeding idea generation. More precisely, we study the effects of two information-objects: the requirements list and visual description of use context.

The next section presents the framework of the study and the underlying logic behind the research hypotheses. This section is followed by a detailed description and analysis of an experiment that was conducted to test the hypotheses.

2. Framework and hypotheses

A central assumption that drives idea generation is that the number of different ideas is positively correlated with finding a high-quality solution [e.g. Diehl and Stroebe, 1987]. The objective of an early idea generation session is to ensure an overview of possible design directions, rather than to directly arrive at a single solution [Benami and Jin 2002]. In metaphor, one must find the branches before designing the leaves. A rule-of-thumb is that the more abstract a design problem is, the more creative solutions may be found. In contrast, design process theory usually suggests that the design brief should include a list of requirements and a careful consideration of the use context.

A requirement is defined as a characteristic, which a designer is expected to fulfil through the eventual design [Chakrabarti et. al, 2004]. The early adaptation to the established requirements is seen to assure that the final design satisfies the needs of all stakeholders, since the set of requirements determines which solution in a solution space is considered best [Maher and Tang, 2003].

When design is viewed through an information processing perspective [Newell and Simon, 1972], the effects of problem formulation become one of the essential factors to best-practice research. We believe that the most significant trade-off that needs to be understood is the effect of omitting/including solution requirements in the design brief. Next, we discuss how the contents of the design brief establish the (mental) boundaries of the design problem space.

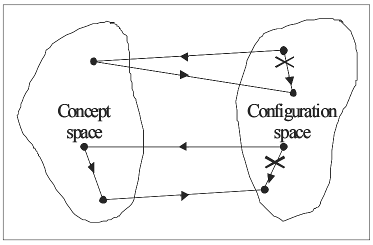
The idea of two distinct spaces, and an iterative search between them, has been a fundamental basis for reasoning about design. This movement between the problem and solution space is essential as a discovery process to reveal new aspects about the problem and potential solutions [Jansson and Smith 1991]. Jansson and Smith (1991) argued that a movement in the configuration space rarely takes place without a movement to concept space and then back to another point in configuration space (Figure 1a). Although Jansson and Smith used different terms, these spaces are analogical to more general concepts of problem and solution space.

Configuration space is determined as an imaginary space, which contains physically realizable configurations, or more specifically, the mental presentations of configurations, such as sketches. And concept space contains elements (ideas, relationships, other abstractions), which may later become the basis for elements in the configuration space. Jansson and Smith (1991) used the framework to describe the occurrence of design fixation, defined as a blind adherence to a limited set of ideas in the design process. The occurrence of fixation is characterized by the inability of a designer to move between these two spaces.

Further assertion has led to rationalizing design as a co-evolutionary process (Figure 1b), in which, the solution and problem space change and become defined through mutual interaction [Poon and Maher, 1996; Maher and Tang 2003]. Dorst and Cross (2001), following the co-evolutionary theory, concluded that creative design is not a matter of first fixing the problem and then searching for a satisfactory solution concept, instead, it is more a matter of developing and refining together both the formulation of a problem and ideas for a solution.

Hatchuel and Weil (2003) have also come to similar conclusions with previous theories in their C-K theory. C-K theory defines design dynamics as an expansions and continuous movement within and between the concept (C) and knowledge (K) spaces. This movement has four operators: two external (concept to knowledge and knowledge to concept) and two internal (concept to concept and knowledge to knowledge). These operators compose the “design square”, which represents the structure of design process.

1a)



2b)

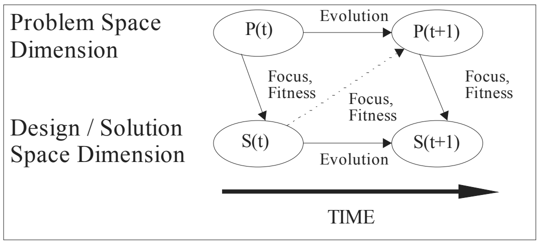


Figure 1. Two problem and solution space expositions: 1a) a model of conceptual design, adapted from Jansson and Smith 1991. 1b) a model of co-evolutionary design, adapted from Poon and Maher (1996)

The task information that is given to the designer may even have an impact on the design strategy that a (s)he employs to solve a problem. There are two main categories for problem solving strategies: problem and solution driven [Kruger and Cross 2001; Christiaans and Restrepo, 2001], which are divided according on how one approaches the problem. There are several studies that aim to explain this procedural differentiation; it has been accounted that these different approaches originate from e.g. education or experience, but differences have been observed in respective homogenous groups [Christiaans and Restrepo, 2001].

An interesting matter, in addition to what causes the application of a particular strategy, is the effect of the chosen strategy on idea generation performance (Table 1). For instance, in design idea generation, the central matter is to generate many different ideas, and thus, the solution driven strategy should be more useful.

Table 1. Expectations about design strategies, adapted from Kruger and Cross 2001

	PROBLEM DRIVEN STRATEGY	SOLUTION DRIVEN STRATEGY
Solution ideas	Few	Many
Requirements identified	Many	Few
Activity emphasis	Data gathering	Solution generating
Creativity score	Low	High
Overall score	High	Low

The theoretical implications arising from these models is that one's perception of the problem space will become more constrained as a function of task information carried in the design brief. Therefore, if a designer is presented with a set of requirements and a fixed context, (s)he may first produce a few basic solutions and then begin to refine and elaborate them, instead of focusing on generating a number of solutions that differ significantly from one another i.e. constantly moving between the problem and solution space. The difficulty with abstracting the design problem is that idea generation may lose its focus, so that ideas may become inappropriate for the actual problem. Moreover, in practice, there may be occasions where it is more appropriate to try to find an idea that satisfies some threshold criteria, instead of spending time on performing more saturate solution searches, or vice versa. Either way, this link has yet to be empirically verified. Based on the theoretical implications the following is hypothesized:

H1: Including a requirements list in the design brief decreases the quantity of ideas generated.

H2: Including a requirements list in the design brief decreases the variety of ideas generated.

H3: Including a requirements list in the design brief increases the average elaboration of ideas.

The second information-object under investigation is the effects of providing a description of use-context along with the design brief. The reason for providing external stimuli is that they may enhance the evocation of new ideas by providing designers with different kinds of 'sources of inspiration' [Bonnardel and Marmeche, 2004]. The stimuli chosen for this experiment (pictorial description of use context) is unrelated since it does not imply a solution, but may provide favorable cues that aid in the generation of ideas. Regarding effects of the particular visual stimuli, the following is hypothesized:

H4: Including visual stimuli in the design brief increases the number of ideas generated.

H5: Including visual stimuli in the design brief increases the variety of ideas generated.

The design and analysis of the experiment that was designed to test the hypotheses is presented in the next section.

3. Methodology of Study

3.1 Subjects

Thirty-two fourth to fifth year mechanical engineering students at the Helsinki University of Technology participated in the study. The students were predominantly male (94%). The mean curriculum phase was 128 study credits completed (out of 180). The experiment was performed during a product design course event, and therefore the subjects did not receive extra credit from participation.

3.2 Experiment design

The experiment was concerned with the effects of the contents of the design brief on succeeding idea generation performance. The experiment was a full 2x2 factorial design with two factors: 'Requirements list' and 'Pictorial descriptions of use-context' (Table 2). The levels of both factors were binary: the information-object was either included in the brief or not. There were eight subjects per experimental cell.

Table 2. Experiment matrix: additional information in design brief in addition to the need statement

PICTORIAL DESCRIPTION OF USE CONTEXT	REQUIREMENTS LIST: Yes	REQUIREMENTS LIST: No
Yes	x	x
No	x	x

3.3 Procedure and assignment

Participants were randomly assigned into the four experimental groups so that there were eight persons in each cell. Subjects were asked to generate concepts for a single design task under a time limit of 40 minutes. The participants used another five minutes to get acquainted with the design task and materials prior to idea generation. This was done to ensure that each subject understood the assignment and attained to the information that was given. All experimental cells were run at the same time in the same facility. Subjects were not allowed to speak during the experiment.

The assignment was to generate as many design solutions as possible for a 'beverage cup holder' under the pre-defined time limit. The need statement was given in writing on a separate sheet to each participant, accompanied with the additional information. The need statement was as follows:

'Transportation of a beverage container in a car within the reach of the driver, so that (s)he may concentrate on the driving'.

Prior to the experiment participants were asked to fill out a form that included questions about their background and personal skills. The manner of presenting concepts was standardized, so that, each participant was provided with an answering sheet that contained general instructions on how to present the ideas and separate frames in which to draw them. The instructions were that sketches, together with textual support when needed, should be used and the concepts should be drawn so that the mechanical solution principle and the main components were identifiable.

3.4 Materials

The pictorial descriptions of use context (later. stimuli) consisted of four pictures of varying car interiors taken from different angles. The pictures were given on two sheets of paper, so that, there were two pictures per sheet. It was also stated (textually) that the solution should not be limited to the specific interiors; the pictures were only intended to 'awaken thoughts'.

To establish the requirements list, six product development researchers were asked to come up with a set of ten quality criteria for the design of the beverage cup holder. The PD researchers were acquainted with design-for-quality practices, and therefore, were found appropriate for determining the criteria. After receiving the initial criteria, the authors of this paper made a synthesis of the responses and made a set of solution neutral requirements from the criteria. The final requirements list is shown in Table 3.

Table 3. Requirements list used in the experiment

CATEGORY	REQUIREMENT
Functionality	The holder should hold the container steady during ‘normal’ driving.
	The holder should be able to hold different containers, at least: carton coffee-cup, 0.33 liter aluminium-can, and 0.5 liter plastic bottle.
	The holder should not break easily.
Usability	The container should be easy to place and remove from the holder.
	The container should be within drivers reach at all times.
	The holder should be easy-to-clean.
Safety	The use of the holder should not distract the driver.
	The holder should not prevent the use and functioning of control and safety devices.
Others	The holder should be appealing.
	The holder should be inexpensive.

3.5 Performance measures

Measures used to assess individual performance were quantity, variety, and elaboration of ideas. The variables are based on a set of Ideation effectiveness metrics proposed by Shah et al (2003). We excluded originality and quality from the analysis, since they are not directly related to the research objectives. We also added elaboration, which refers to the subject’s focus on details within their ideas. To score elaboration, a point was given for each detailed feature that a subject had described in a particular idea. Quantity was the total number of ideas drawn in separate frames. Variety was the total number of different solution types for sub-functions: (1) where (2) and how the holder is attached to the car interior, and (3) how the container is secured to the holder.

Figure 2 presents two ideas produced during the experiment and their respective scores for variety and elaboration. The first idea (‘a beverage-bag’ hanging from the driver’s seat) gets three points for variety and two points for elaboration. The second idea (a beverage holder mounted to the steering wheel) gets three points for variety and one point for elaboration.

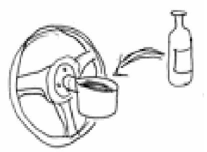
	VARIETY			ELABORATION
	How the container is secured to the holder?	Where the holder is attached to the car interior?	How the holder is attached to the car interior?	
	Pouch	Driver’s seat – headrest	Hung on driver’s seat	(1) Mouthpiece with antispilling features (2) Clip that holds the tube at right place
	Sheath	Steering wheel	Screw fastened	Precision bearings hold the container in upright position

Figure 2. Examples of ideas and their scoring. Note that the idea presentations included additional textual clarifications, which are not shown here

4. Results and analysis

Table 4 shows the mean averages and standard deviations of quantity, variety, and average elaboration of ideas per experimental cell.

Table 4. Means of quantity, variety, and average elaboration of ideas produced by subjects in different experimental groups (n = 32). Standard deviations in parentheses

PERFORMANCE MEASURES	ADDITIONAL INFORMATION IN BRIEF			
	No requirements list		Requirements list	
	Stimuli	No Stimuli	Stimuli	No Stimuli
Quantity	9.50 (3.85)	8.00 (3.82)	4.88 (2.10)	7.88 (2.30)
Variety	14 (4.28)	8.25 (2.71)	7.63 (1.19)	9.38 (2.56)
Avg. elaboration	3.63 (1.60)	3.50 (2.67)	4.88 (3.00)	5.50 (3.07)

A 2x2 Analysis of variance (ANOVA) showed that 'Requirements list' had a significant main effect for quantity ($F(1, 31) = 4.62$, $p = 0.040$) and variety of ideas ($F(1, 31) = 6.56$, $p = 0.016$), and a suggestively significant effect on average elaboration of ideas ($F(1, 31) = 3.01$, $p = 0.094$); including a requirements list led to a decrease in the quantity and variety of ideas, but increased the average elaboration. 'Stimuli' had a suggestively significant main effect on variety ($F(1, 31) = 3.81$, $p = 0.061$. There was also a significant interaction effect (Stimuli x requirements list) on the variety of ideas ($F(1, 31) = 13.39$, $p = 0.001$) and a suggestively significant effect on the quantity of ideas ($F(1, 31) = 4.14$, $p = 0.051$): showing pictures of car interiors with the requirements list led to a decrease in performance in terms of quantity and variety of ideas.

5. Discussion

The design brief encapsulates the essential information concerning the design problem to which a designer seeks a solution. The design brief consist of any information, such as technical parameters, functionality, cost, performance etc. that are relevant quality criteria for the final design. Therefore, the brief can be complex and include variety of viewpoints. This research was conducted to investigate the effects of brief structuring on design idea generation performance. An experiment was designed and conducted, where the brief was manipulated, so that, together with a textual description of the problem, designers were also given additional information: a requirement list and/or pictorial stimuli. The results of the experiment clearly demonstrated that design idea generation performance is affected by the information contents of the design brief.

Individual performance in terms of quantity and variety of ideas generated was influenced so that, excluding the requirements list led to superior responses. However, the elaboration of concepts was lower respectively, which signifies a trade-off between the number and average elaboration of ideas in accordance with whether a requirements list is included in the design brief or not. Therefore, hypotheses H1, H2, and H3 were supported. Pictorial stimuli had a positive influence on the variety of ideas. There was also a simultaneous interaction effect of the two information objects on the variety and quantity of ideas generated. The effects of including pictorial stimuli were crossed in coincidence with whether the requirements list was included or not.

The relating interaction main effect occurred so that superior responses were observed for including the pictorial stimuli together with only the 'need statement'. Whereas, presenting the pictorial stimuli together with the requirements-list resulted in a further decrease of the subsequent quantity and variety of ideas. For this reason, hypotheses H4 and H5 were partially supported. The first effect, i.e.

stimulating effects of pictorial stimuli, was anticipated. However, the latter finding of low performance when stimuli and requirements list were both included, was not expected. Including both of the elements may have caused subjects to follow a problem-driven strategy [Kruger and Cross, 2001], which is somewhat inappropriate for an early idea generation session. After seeing the use-context, subjects may have become more aware of the criteria, causing early convergence towards a few solutions, as a result of focus on fulfilment of single attributes. These implications are tentative at this point, and a more thorough explanation would naturally require further studies.

6. Conclusions

The dichotomy between detailed task information, which constrains the solution space, and the freedom required for idea generation is a challenge for design theory and practise. In this paper, we presented a design experiment that discovered how changes in design brief content affected succeeding idea generation performance. We believe that the experiment gave valid evidence that questions the appropriateness of including excess information in the design brief of an early idea generation session, since it may limit idea generation performance in terms of the number of different ideas generated.

Nevertheless, as discussed earlier, excluding central information objects (e.g. requirements list) from the design brief may cause the idea generation process to lose its focus, so that, the ideas produced may become unsuitable for the actual problem. Still, in the early stages of product design, the scope and creative freedom afforded by the 'openness' of the design brief should be stretched to its limit. Designers should be encouraged to push assumptions and expectations in search of new and unexpected solutions.

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