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DESIGN FIXATION: A COGNTIVE MODEL

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ABSTRACT
The term *design fixation* refers to the designer's reluctance (or inability, in some cases) to consider multiple strategies to formulate and solve a design need. The design fixation phenomenon severely limits creativity and results in pedestrian design solutions. Design fixation is the direct result of knowledge representation, with human knowledge argued to be organized categorically. These categories are defined by prototypes that exemplify the category. Humans tend to rely upon and use prototypes in their initial approach to design solutions because access to the prototype requires significantly less cognitive effort than does the processing of individual exemplars. The preliminary experimental results support the effects of prototypes in the design process. In the preliminary experiment, engineering students as well as practicing engineers were asked to design a toy for blind children. The results reveal a strong design fixation wherein the subjects failed to consider crucial issues such as non-visual senses (such as hearing), the age and gender of the customer, desired size of the toy, methods of retrieving the toy, and colour. The results also show that the design fixation can occur even during the problem formulation way prior to creating alternative design solutions.

Keywords: New product in existing environment, design fixation, cognitive models.

1 INTRODUCTION
In the consumer-driven market economy, companies are emphasizing innovation to effectively address customers' needs, differentiate their product from competitors, and to gain strategic market advantage. It is difficult to manage the innovation process because such management not only requires the capability to create innovative products, but also to predict the domino effect associated with the manufacturing, marketing, and ultimate use of the product. The focus of this paper is on the process of generating an innovative idea, for which there is no step-by-step procedure. The only certainty in concept generation is that the innovativeness of the outcome is uncertain.

During concept generation, creativity and exploration play a crucial role in the outcome. Design fixation inhibits creativity and exploration by "locking" a designer onto received or pedestrian ideas very early in the concept generation phase. Jansson and Smith [1] defined design fixation as "the blind adherence to a set of ideas or concepts limiting the output of conceptual design." While it could potentially impact the downstream stages of the design process, the researchers have so far focussed on design conceptualization as it has the greatest leverage on product innovation.

2 BACKGROUND
One can view creative conceptual design not as the invention of a new configuration, but rather as a designer's insight into the formulation of a problem in a conceptually new or different way. For instance, Nobel's development of dynamite can be attributed to his observation that kieselguhr, a diatomaceous earth which is porous, absorbed a large quantity of nitroglycerine that had accidentally leaked; and his subsequent insight that he could use kieselguhr to carry nitroglycerine. This insight allowed the invention of an explosive that was powerful but nevertheless safe to handle. This example demonstrates the role of insight in design.

The Gestalt psychologists described the concept of insight as *an abrupt reformulation of a problem leading to a successful solution*. A difficult and well-known example of an insight problem is the nine-dot problem. In this problem, solver must connect the nine dots (shown in Figure 1a) using four straight lines without lifting the pen or retracing any line. This problem challenges the solver to realize the key action for solving the problem. Researchers looked at extending lines beyond the dots [2, 3, 4], drawing lines that did not begin or end on dots [5], and making turns where there are no dots [6, 7] as possible key actions. Once, the problem solver gets the insight, the solution is straight forward as shown in Figure 1b. Similar, well-known examples include the two-string problem [2, 3], the eight coin problem [8], the prisoner and rope problem [9], the moving objects in three-dimensional space task [4], and the mutilated chessboard problem [10]. Cognitive psychology researchers are trying to link the production of the key actions to the cognitive factors that trigger a radical problem reformulation.

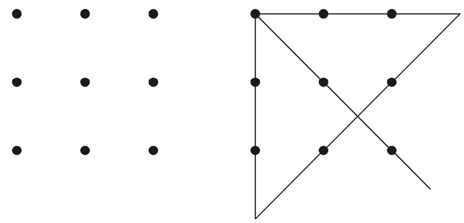

Figure 1. (a) The nine-dot problem and (b) The solution.

While insight plays an important role, a good design is more than a simple insight; it is a *synthesis* of a series of good ideas, or concepts, not just one good idea. Underscoring this point, significant research efforts have been conducted into the configurational aspects of design fixation. Jansson and Smith [1] were the first researchers to document design fixation. Their study involved two tasks: [1] the design of a device for use by the blind to measure quantities in cooking, and [2] the design of a bike rack. The experimental group received the design task accompanied by a drawing of a potential solution. The drawing was presented under the pretext of providing the required format for the solution. The control group received the problem with no example. The participants, senior-level undergraduate and practicing mechanical engineers, were asked to generate as many solutions as possible to the problem. They found that the experimental group generated solutions with features or characteristics embodied in the examples. Even though the examples included features that were inappropriate for the solution of the written statement of the problem, these features were replicated more frequently by the experimental group.

Purcell and Gero [11] tried to extend the research by providing the subjects with multiple design solutions to a single problem. The subjects were architectural and industrial design students at the beginning of their design education. The experiments were unsuccessful in replicating design fixation, raising the possibility that the experience, disciplines, and familiarity of the subjects with the examples affected the role of fixation. But Gero and Purcell [12] did successfully replicate the experiments of Jansson and Smith [1] when the subjects were advanced engineering students with a mechanical engineering background. They concluded that the tradition of teaching design largely by precedence opens up important questions about the effect of traditional design education methods have on the innovative capabilities of students. Chrysikou and Weisberg [13] also replicated Jansson and Smith's [1] experiment using undergraduate students in an introductory psychology course. The consistency of these findings suggests that fixation can occur in inexperienced participants and deters performance.

3 A FRAMEWORK FOR UNDERSTANDING FIXATION - COGNITIVE MODEL

Let us try to understand the natural thought process – that is, the course followed by humans when faced with a design task – and some of the potential pitfalls. We can divide this thought process into two distinct stages:

1. Recognition of the design task
2. Development of the design solution

Recognition of the Design Task

Humans recognize objects by their resemblance to prototypes representing various knowledge categories. For instance, we identify a robin as a bird because it closely resembles the prototype of the bird category. The prototypes closely resemble the typical examples in their category, and can be described as the one member of the category that contains all the defining features of that category. A bird prototype resembles a robin more closely than a penguin. This fact is reflected in the increased time to recognize penguins as birds. A similar recognition process occurs when a designer is presented with a design task.

During the initial stages, the designer categorizes the task based on the prototypes and not on concepts or scientific principles. The recognition process is rapid and may occur even after the designer has read only a small portion of the problem statement. The process is based on configurational issues, since prototypes are configurational in nature. At the end of the recognition process, the designer has conceived a prototype which could be either concrete or abstract, depending on the scope of the problem.

Development of the Design Solution

The development process involves the modification, adaptation, or sizing of the prototype to satisfy the new conditions, constraints, and requirements of the design task. *Design fixation* plays an important role in the development stage by preventing the designer from considering alternative solutions.

In most cases, the core concept behind the prototype remains unchanged during the development process due to the difficulty of accessing the concepts behind the prototype. For instance, the common prototype for manholes is circular while that of airplane wings is swept backwards. However, the fundamental concepts that dictate the geometry may be neither easily accessible nor existent in the designer's mind. Thus, the designer changes small configurational details without gaining a deeper understanding.

Pitfalls in the Natural Thought Process

The natural thought process includes several key pitfalls:

1. The designer develops the solution without proper understanding of customer needs. Such activity results in inferior products that do not appeal to customers.
2. The designer does not consider alternative solutions and develops the prototype into the final solution. Because the prototype resembles the typical examples in the category, the final solution will most likely not achieve innovation.
3. The designer focuses on configurational issues and details. Key issues may not emerge until the testing phase and result in long product realization times.
4. The development activity revolves around sizing, configurational modification, and adaptation, forestalling real synthesis in the creation of the solution.

Jansson, Condoor and Brock [14] provide a more in-depth discussion of the model.

4 EXPERIMENT

Goals

The primary objective of the experiment is to validate the cognitive framework by documenting the thought processes employed by participants. The specific goals include the following:

1. Delineate the methods designers use to interpret a problem statement to determine how they hone in on a configuration.
2. Identify the tenets that inform designers' initial conceptions of a design problem.
3. Determine the influence of knowledge representation on design fixation

Experiment

The proposed experiment will assign the task of designing a toy for a blind child to several practicing engineers and also to students. A mixed expert-novice sample will be used to support our argument that design fixation results from a natural thought process relying upon prototypes, and does not reflect differences between expert and novice designers. The general method to be used in the present study will be consistent for all subjects. All participants will be asked to draw front and side views of their designs. The participants will be asked to verbalize their thoughts while performing this task, with all participants being videotaped so that these "think aloud" protocols can be analyzed later for key themes. No models or sample toys will be provided, although all participants will be provided with the definition of toy from the *Encyclopedia Britannica* to ensure that they understand the concept. All participants will be asked to design as many toys as possible within a one-hour time limit, and will be reminded before they start that they are to verbalize all their thoughts, no matter how mundane, throughout the process. All participants will first practice this think-aloud procedure on an unrelated task prior to the primary design task to ensure they understand the procedure. At the end of the design period, participants will be asked to complete a questionnaire in which they are to describe their creations, the last toy they recall playing with as a child, and the contribution (if any) that this toy made to the design process; they will also complete a check-list of toy features (e.g., texture, color, and other perceptual characteristics) that could have been aspects of their creations. These questions, which will function as a form of retrospective participant reporting, are designed to assess participants' own evaluations of and insight into their personal design processes.

While other methods could support an examination of the design process used by our participants in the creation of the requested toy (e.g., behavioural observation alone, or retrospective participant reporting alone), we chose the think-aloud procedure because it will allow us to directly assess our participants' thought processes as they perform the design task. As it is the thought process itself we are most interested in, this procedure is ideal for this research. The use of videotaping will allow us to make behavioural observations, and the post-design questionnaire will allow for the examination of retrospective participant reporting, giving us three convergent methods for collecting and comparing data. While some have suggested that the think-aloud procedure is unnatural, Ericsson and Simon [15] have argued that this procedure does not interfere with task performance or the thought process.

All protocols will be transcribed after they have been recorded. These transcripts will be compared to the videos of each participant, so that behavioural observations can be noted in the transcripts (e.g., noting that a participant began sketching a design), and to allow for double-checking of the accuracy of the written transcript. Once this transcribing and behavioural observation has been completed, the contents of the transcript will be analyzed to serve in the construction of a psychological model of the design process. Specifically, we will examine three phases of the design process: (1) orientation—how participants extract information from the instructions they are given; (2) execution—how participants analyze the problem and create a solution to the problem; and (3) analysis—how participants evaluate their solutions to determine their fit with the original problem. We expect that these phases will recur as participants reach partial solutions and reinterpret the original problem. Within each of these phases, we will code responses for the degree to which they reflect reliance on categorical knowledge, specifically the categories "toy" and "blind," as defined by the task, by comparing responses to a checklist of features derived from existing category-feature norms for the concepts/categories "toy" and "blind." Each of these features will be ranked in terms of semantic distance from the category's prototype/central features (as determined by published norms); responses will be assigned scores based on these ranks, which will be summed to create a total score for each phase of the design process. We will compare summed rank scores across phases to assess correlations in these scores over the entire design process, with lower summed scores reflecting greater reliance on prototypes/central categorical features. A similar procedure will be applied to the analysis of the retrospective participant reports to allow for comparison across the two types of data.

5. PRELIMINARY RESULTS AND DISCUSSION

Even in the absence of visual cues, the preliminary results have pointed to the presence of design fixation. Design fixation can be inferred from the following two specific observations:

1. All the toys designed by the subjects required the use of hands; none of the subjects thought of using a voice activator or other methods of use. None of the designs considered the possibility of using temperature to stimulate the sense of touch, nor did the subjects consider the colour of the toy. While one could argue that colour is not important to the blind child, it does play a key role to the person buying the toy. The key point to note is that the subjects did not make any conscious decision about colour. The focus was always on the shapes and textures. Sound was prevalent only in designs where sound would naturally exist in precedent designs.
2. Subjects found it difficult to move away from the prototype. For instance, one subject (a practicing mechanical engineer working in an aircraft company as a designer for three years) started out by listing all five human senses and eliminating those that the blind are not able to use. Also, she stated that she wanted her toys to be educational. Then, she went on to create

six designs: (1) an ABC game with 3-D letters and the ability to tell the child whether s/he has selected the correct letter when placing the letters on a station, (2) a Braille piano, (3) a puzzle with scratch-and-sniff shapes that fit into a board by shape and smell, (4) a hide-and-seek ball that emits noises so that the child can find it, (5) a textured guessing game in which the child feels objects and guesses what they are, and (6) a sound recognition game that calls on children to guess song titles after hearing clips played. Despite a conscious effort to avoid the creation of games, the subject ultimately produced designs more closely related to games than toys; in fact, the subject listed the game Monopoly as the last "toy" that she remembered playing with. It was clear that the subject had real trouble attempting to generate solutions even though the design process she followed went through the process of identifying the need and demonstrated her awareness of the difference between the toy and the game category.

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