Design and Other Types of Fixation

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Abstract

Design educators often comment on the difficulties that result from a premature commitment by students to a solution to a design problem. Similarly practitioners can find it difficult to move away from an idea they have developed or precedents in a field. In the psychology of problem solving this effect is called functional fixedness or fixation. This refers to the observation that people find it very difficult to see, for example, that objects with well known uses or functions can be employed in new or unusual uses to develop an innovative solution to a problem or to solve a problem that requires innovation. Given that fixation refers to situations where innovation is blocked, it is not surpassing that these effects should occur in design problem solving. Design problems are essentially ill-defined problems. As such they inherently contain the opportunity for innovation. However, while these types of issues have been discussed in the context of design, there has been little systematic evidence available about whether or not and under what conditions design fixation does occur. The paper will review the results of a series of recent experiments which begin to addresses these issues. The results of the experiments will then be examined in terms of what insights they provide into the design process, what implications they have for design education and how they relate to the larger and more general area of human problem solving.

Keywords:

Introduction

Through an unusual inversion of everyday ways of thinking, the Gestalt psychologists[1,2] sought to understand innovation and creativity in problem solving by studying problems that most people find it difficult to solve. The basic logic attached to this approach appears to have been as follows. If problems are chosen which require innovative solutions then studying the conditions under which people fail can give insights into why people find it difficult to produce innovative solutions. One of the central concepts to emerge from this approach was the idea of fixation. For example, people appear to be unable to see new ways of using objects which could lead to the innovative solution required, because they are blocked or fixated on well learnt uses or properties of the object. A typical problem where fixation is exhibited requires that two spatially separated pieces of string hanging from the ceiling of a room be joined. The pieces of string are not long enough for one to be simply picked up and carried to the other. Present in the situation are a variety of everyday objects. Many of these objects are capable of being used as a weight which can be combined with one of the pieces of string to form a pendulum. If a pendulum created in this way is set in motion, it is possible to pick up the end of the other piece of string, catch the end of the pendulum and tie the two together. However this solution is rarely spontaneously produced. The reason for this result, it is argued, lies in the way that the well established, everyday functions of objects prevent the problem solver from seeing this unusual and innovative use. This basic idea is appealing because it taps experiences common to many people and to problem solving in many domains.

The area of design is no exception. Here a common and often commented on form of fixation is the premature commitment to a particular problem solution, observed in students and practitioners alike. As in other domains, the designer appears trapped by the characteristics of a possible solution that has been developed or an existing precedent solution. However, in the design domain, the majority of the discussion of this phenomena is essentially anecdotal and not based on either principled argument or the results of empirical research. Design would also appear to offer a particularly suitable domain for this approach to studying these aspects of problem solving. It is well recognised that design problems are inherently ill-defined[3]. Consequently every design problem has the potential for innovative and creative solutions removing the necessity for specifically developing problems that have these characteristics.

While all discussion of fixation in design has been largely anecdotal, recently experimental methods have been developed for examining both whether or not the phenomena exists and, perhaps of more interest, the basis for the effect. The aim of this paper is to review the available research results and then to draw out the implications of these results in three areas. First what do the results tell us about the design process? If there are insights into the design process what are the implications for design education? Finally what do the results contribute to the general literature dealing with complex human problem solving?

Design Fixation

Jansson and Smith[4] were the first to develop an experimental approach to the problem of fixation in design. They argued that showing designers a picture of a potential design solution to a problem prior to a design session should result in fixation. In effect the picture would act as a precedent blocking access to other ways of solving the problem. They also extended the argument about the basis of fixation. They suggested that the process of design involves operating on effectively two types of mental representation of the problem. One representation they refer to as the conceptual space which consists of abstract knowledge about principles, concepts and rules which can be used to solve the problem. The other representation takes the form of particular physical objects and elements which could form the physical realisation of a solution to the problem. This representation is referred to as the object space. Jansson and Smith argue that the location of the fixation induced by a pictorial representation is the object space and that innovation is prevented because the designer cannot move to the conceptual space which is where they consider that innovative changes can occur.

In order to test this hypothesis Jansson and Smith used three different types of design problem and had advanced undergraduate and practicing mechanical engineers engage in solving the problem. The experimental design was quite straight forward. For each of the design problems two groups of designers were used. One group (either a student or an expert group) were simply given a statement of the problem and acted as a control group. Separate groups corresponding in level of expertise to the control groups were given the statement of the problem together with a picture of a possible solution. The example solutions were specifically designed so that aspects were included which were incorrect given the problem statement. A set of features which characterised each pictorial example was developed and the designs produced were scored for the presence or absence of the features. The design sessions lasted for one hour and the designers were allowed to produce as many sketch designs as they liked. It would be expected that, if fixation resulted from exposure to a pictorial representation of a possible design, more features of the example should occur with the groups shown the example. This was found to be the case. For each of the design problems and for student and expert designers, more features associated with the example, including incorrect features, were found with those who had been shown the pictorial representation.

Exploring the Design Fixation Effect

The potential significance of this effect is apparent because of the role of precedents, generally presented in the form of pictorial and other forms of visual representations, in the teaching and practice of design. A number of significant issues relating to the effect can be identified. Does the effect occur when pictorial representations of different possible designs are presented prior to a design session? Is the effect associated specifically with pictorial representations or would similar effects occur if verbal descriptions of possible design solutions were made available? Does the effect occur with other disciplines and levels of expertise? In order to begin to explore the basis for the design fixation effect we Purcell and

Gero[5] carried out an experiment using one of the Jansson and Smith problems - the design of a bicycle rack for a car. Five different design solutions were identified and these are shown in Figure 1. Pictures of three of these designs were using as fixating examples (a, b and c in the Figure) and for two of these solutions a verbal description was developed (the verbal description of one of the designs is presented in Appendix 1). Novice students in architecture and industrial design participated in the experiment using the same experimental design as Jansson and Smith. Separate groups of students were shown the example design were told that it was to illustrate what was meant by a sketch design with corresponding control groups being given only the statement of the problem. Lists of features of each design were developed and the designs produced by the experimental and control groups were scored for the presence or absence of the features. In addition the number of designs developed by each participant was recorded and the participants answered a number of questions at the completion of the session.

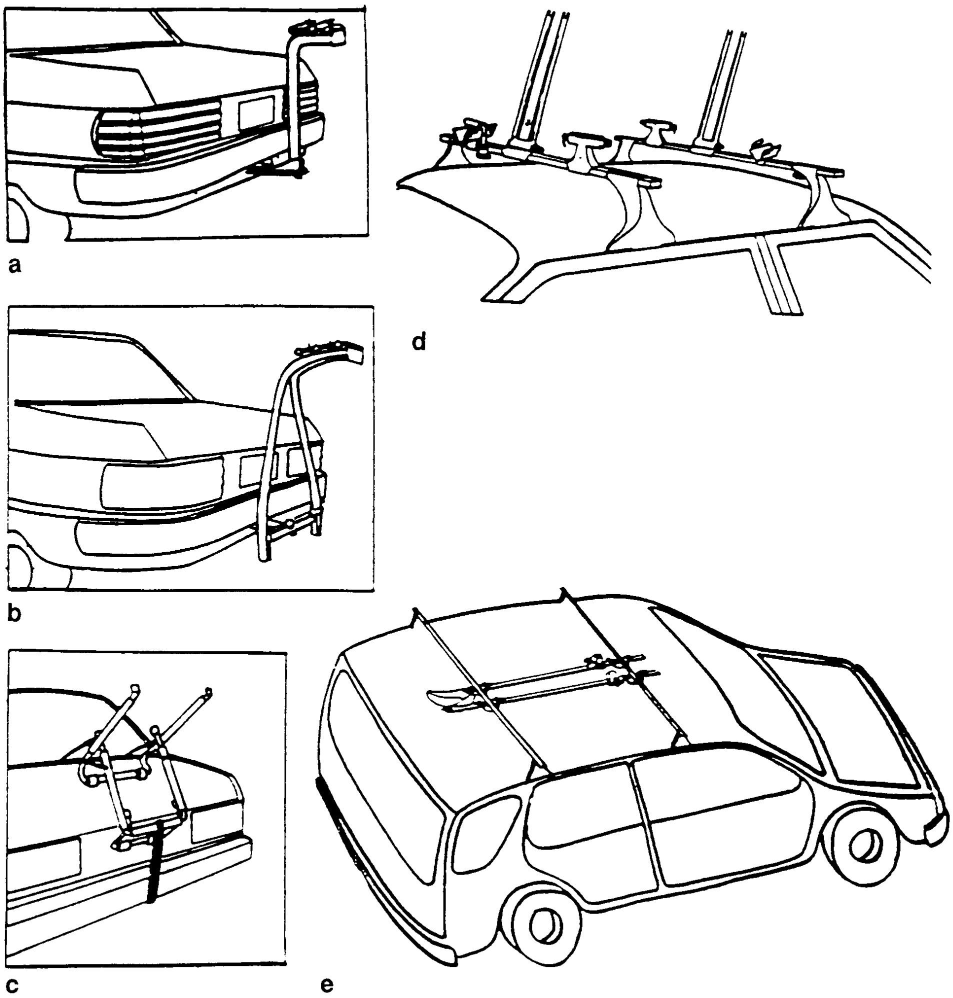

Figure 1. Five types of bicycle-rack design; (a) single-post, (b) A-frame, (c) boot, (d) upright, (e) seat-and-wheel

Figure 1. Illustrations of five bicycle rack designs.

Differences in the frequency of design features were statistically analysed and part of the results are presented in Table 1. Effectively no evidence of fixation was found with the exception of one of the pictorial examples for one feature. The fixation effect, on the basis of these results, does not appear to be associated with simply the presentation of a pictorial example nor does it occur with a verbal description of a possible design. Where evidence for fixation was found with one of the examples, an analysis of the results of one of the questions asked at the end of the design session indicated a somewhat different possible basis for the results obtained. Participants were shown the drawings of all of the examples shown in Figure 1 and asked how familiar they were with each. Tabulation of the responses to this question revealed that the most familiar example was also the example where some evidence of fixation was obtained (see Table 1). What appears to be a fixation effect could as a result simply reflect familiarity with the example. Subsequent enquires with bicycle retailers and a group representing bicyclists demonstrated that the most familiar example was also the type of bicycle rack that predominated in sales. Interestingly this type of design was also different to the rack design that had produced fixation in Jansson and Smith's work.

Table 1. Probability of the difference in frequency of occurrence of four bicycle design features between experimental and control groups.

Group	**Location of rack**	**Car attachment**	**Bicycle support**	**Bicycle attachment**
Control versus single-post picture	0.36	0.38	0.53	0.17
Control versus single post description	0.83	0.88	0.72	0.06
Control versus A-frame picture	0.79	0.64	0.21	0.02
Control versus A-frame description	0.3	0.13	0.61	0.12
Control versus boot picture	0.89	0.99	0.86	0.26

There is however significant differences between our work and the original Jansson and Smith experiments. They had used advanced student and practicing mechanical engineering designers and we had used novice designers from two other disciples. A possible interpretation of the effect obtained could therefore be that novice designers from these other disciplines, lacking any domain specific knowledge, simply relied on their general, everyday knowledge which was triggered when shown the drawing of the example. This possible explanation is reinforced by the absence of any effects with the drawings of the other types of designs. This result also indicates that the effects obtained with the most familiar example do not simply involve copying as it would have been equally easy to copy each of the other types of design.

The Role of Design Discipline and Expertise in the Design Fixation Effect

Our next experiment attempted to examine some of these issues. We again used one of the Jansson and Smith problems - the design of a device to be used by the blind in measuring quantities for cooking. We chose this design problem because it would be unlikely that our designers would have either designed or seen an example of a design for such a device in contrast to the bicycle rack problem. In this way we were able to minimise the effects of familiarity with existing design solutions. Advanced student designers in mechanical engineering and industrial design in their final year participated in the experiment. This choice was made both because we wanted to use the designers from the same discipline as in Jansson and Smith's work and because we wanted to examine whether or not the effect occurred with different disciplines while using designers with a similar level of expertise to those in the original Jansson and Smith experiment. Industrial designers were chosen as a second discipline because the two disciplines can deal with similar types of problems. This removes a possible effect resulting from using a design discipline, such as architecture, which deals with qualitatively different types of design problems to the problem we had chosen. We also pursued the question of whether or not fixation would be found with other examples to that used by Jansson and Smith. In Australia there is a organisation which represents the blind and we approached them to determine if there were examples of such a device available. They market a device for this propose and the pictorial representations of the two examples are shown in Figure 2.

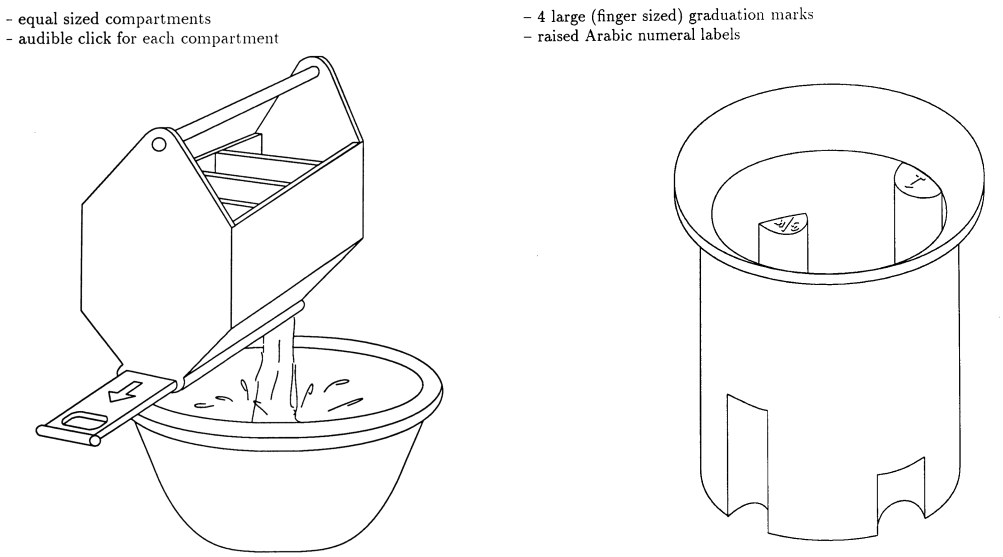

Figure 2. Illustrations of the two example designs of devices for use by the blind in measuring quantities for cooking.

Again the same experimental design was used as in previous design fixation work. We did however introduce a change in the way the designs were analysed. In previous work features characteristic of each design were identified and each design produced was scored in terms of these features. However, in reflecting on the results of these experiments, it appeared to us that features could be of two types. One type would represent the actual details of the features present in the design example. However it is possible that a design feature could represent the same concept as was present in the design example without having the same detailed characteristics. Consequently for each design two lists of features were developed to reflect this distinction (for details of the features of each of the designs and the results of the analysis see Purcell, Williams, Gero and Colbron[6]).

In brief the analysis demonstrated that fixation did not occur with the industrial design groups for either of the example designs. However fixation was apparent with the mechanical engineers but only with the example design used in the original Jansson and Smith experiments. This appears to indicate that fixation may occur only where the combination of the design discipline and the example design used are the same as in the original Jansson and Smith experiments suggesting that the effect may only have limited applicability. The presence of fixation in the mechanical engineers and not in the industrial designers could for example reflect differences in approaches to education in the two disciplines. While this would be an interesting result, it would diminish the general significance of the effect. However an examination of the two example designs in Figure 2 suggests another possible basis for this finding. The Royal Blind Society example is a particularly simple device that essentially uses an everyday cup with three dimensional markers identifying discrete quantities. By contrast the Jansson and Smith example is a more complex device which, significantly, appears to involve principles that could be thought of as typical of the mechanical engineering discipline. This suggests the possibility that the fixation effect is not simply discipline specific but involves the use of an example that embodies principles that are specific to a particular domain of knowledge.

Domain Specific Knowledge and Design Fixation

In order to test this hypothesis we sought the assistance of experts in mechanical engineering and industrial design. Our aim was to develop a new design problem which would again be the type of problem that could form a part of the practice of each discipline but where it would be unlikely that groups of advanced undergraduate students would have been involved in designing or have seen examples of solutions. We also wanted a problem where there were a number of existing solutions which both involved principles which would be typical of mechanical engineering and also examples which the experts considered unusual and innovative. The problem we identified was the design of a device for assisting the elderly into and out of a bath in a domestic setting. There are a number of existing solutions to this problem four of which are shown in Figure 3. To initially examine our hypothesis about the role of domain specific knowledge being embodied in the pictorial representation of a design, we chose the example, the Autolift device, labelled as (c) in the Figure. We had asked the experts in mechanical engineering to assess whether or not the examples involved typical mechanical engineering principles. In their judgement this example involved the use of such principles and should therefore produce fixation.

Our experiment followed the same design as previously. Advanced undergraduate students in their final year in mechanical engineering and industrial design participated in the experiment with two groups from each discipline. Both groups in each discipline received the verbal description of the problem with one group in each discipline also being shown the drawing of the example design. Lists of features related to the principles