Environment and Planning B: Planning and Design, 1993, volume 20, pages 333–345

Fixation effects: do they exist in design problem solving?

A T Purcell, P Williams, J S Gero, B Colbron
Department of Architectural and Design Science and Key Centre for Design Quality, Sydney University, Sydney, NSW 2006, Australia
Received 1 March 1992

Abstract. Designing involves the use of a number of different types of knowledge which vary from abstract knowledge to knowledge about physical forms and their attributes. Previous research had demonstrated that pictorial representations of an example design presented as part of the statement of a design problem resulted in designs that exhibited the characteristics of the pictorial example. This effect was referred to as design fixation. However, subsequent attempts to replicate the effect were largely unsuccessful with what appeared to be fixation under some conditions being closely related to familiarity with existing examples of the design problem. There were, however, other differences between the two experiments, particularly in terms of the level of experience of the designers and the design discipline of the participants. In the experiment reported, familiarity with existing examples of solutions of a design problem was controlled by choosing an appropriate problem from the set of problems used in the original research and designers of the same discipline and level of experience were used together with designers from different disciplines. In addition to the pictorial representation of a design solution used in the original research, an additional pictorial example was included. The results demonstrated clear fixation effects when both the discipline of the designers and the pictorial example were the same as those used in the original experiment. However, no effect of the pictorial example occurred with designers of different disciplines or the other pictorial example for designers from any discipline. Possible reasons for these results are discussed, with particular reference to the effects of a match between the principles used in the design solution and the discipline of the designers.

Introduction

Designing an object involves the use of a number of different types of knowledge. Typically we think of knowledge as consisting of facts and principles that can be expressed, for example, in linguistic or symbolic form. However, objects are made up of physical elements consisting of particular materials which have properties, such as shape, with the elements arranged in particular ways to form the complete object. These characteristics of objects constitute another possible form of knowledge (perceptual rather than abstract) that can be used in the design process.

The relevance of this type of knowledge to design is apparent if the relationship between the statement of a design problem and the outcome of the design process is considered. Generally the description of what is to be designed is expressed in linguistic or symbolic terms. A consequence of this is that the response to the problem can be satisfied by a variety of possible physical forms. This is because the facts and principles used to formulate the description do not uniquely map into sets of materials and the way they are put together and, as a result, do not specify a single physical form. However, the designer must arrive at a particular form which meets the requirements of the design description. As a consequence, designing involves moving from knowledge about facts and principles which relate to the description of a design problem to physical forms which express particular facts and principles which are relevant to the problem. The designer uses knowledge about facts and principles in order to understand the design problem, combined with knowledge about physical forms and their properties and the ways in which they can be aggregated in order to move from the description of the problem to potential physical solutions.

The experiment to be reported is concerned with the relationship between these two types of knowledge in the process of design. Jansson and Smith (1991) refer to these types as conceptual and configurational knowledge. They investigated the relationship between the two by asking different groups of advanced undergraduate or practising mechanical engineers to solve a number of design problems under one of two conditions. The control group were given a typical statement of the problem in verbal form, whereas the other group were given the statement of the problem together with a drawing of a potential solution to the problem. The drawing was presented in the guise of a guide to the format in which they were to present their designs. The control group obtained conceptual knowledge about what was to be designed and the other obtained this conceptual knowledge together with configurational knowledge of a possible solution.

Jansson and Smith found that the groups shown pictures of possible design solutions produced more designs with the characteristics of the pictured examples for all of the problem types attempted than the control group. In a number of the design problems, the pictured example deliberately included design features which were inappropriate given the verbal statement of the problem and even these features of the designs were produced more frequently than in the control group. They refer to this effect as design fixation, to highlight the relationship between the effect and fixation effects shown in other, earlier work in the general area of problem solving (Duncker, 1945; Luchins and Luchins, 1957).

Given the potential significance of this effect in design education and practice, in part of their extension of this research Purcell and Gero (1991) used pictorial representations of a number of different possible design solutions to a single problem. One of the Jansson and Smith problems, the design of a bicycle rack for a car, was used, with different groups being shown one of the possible design solutions. One of the pictured designs had no effect on the designs produced, one of the examples was associated with an increase in the number of designs, and one of the examples was associated with what appeared to be a fixation effect with aspects of the example being produced more frequently than in the control group who were given only a verbal statement of the problem.

Although this result can be seen as indicating that it is not simply the presentation of a pictured example which produces design fixation, there were a number of other aspects of the experiment which could have influenced the result. Although each of the pictured examples was based on an existing design, there were wide differences between the examples in terms of the numbers of each of the designs sold. This difference was replicated in judgments of the familiarity of the different examples made by the participants after they had completed the design session. The example which had no effect on the designs produced was infrequently purchased and judged as unfamiliar by the participants, whereas the example which was associated with fixation-like effects was the most frequently purchased type and was judged to be highly familiar by the participants. As a result, the effect obtained could reflect the use of existing knowledge (with the picture triggering reminding) about the physical characteristics of the example, based on frequent experience with the example represented (further weakening support for a fixation effect).

In addition, there were other differences between the two experiments which could account for the differences in the results. The Jansson and Smith experiments had involved advanced undergraduate and practising mechanical engineering designers, whereas Gero and Purcell had used architectural and industrial design students at the beginning of their design education. The Gero and Purcell experiment,

therefore, differed in terms of the design discipline involved and the level of experience of the designers. The aim of the experiment reported here was to assess the possible role of these differences between the two experiments in producing the inconsistent results by
(1) using designers with the same background (mechanical engineering) as in the Jansson and Smith experiment together with a group with different design backgrounds (for example, industrial designers);
(2) using a problem where the likelihood of prior experience (on the part of the participating designers) both of the problem and of existing design solutions is low;
(3) using a Jansson and Smith example design together with another design for the same object as the fixation material.

Method

Selection of the design problem

One of Jansson and Smith's (1991) problems involved the design of a device for use by the blind to measure quantities in cooking. Although such devices do exist, they would not be frequently experienced as a part of everyday life or as a part of an individual's design experience. The design example from the original Jansson and Smith experiment was used, together with a drawing of a quite different design based on an example obtained from the Australian Royal Blind Society (RBS).

The Jansson and Smith example [see figure A1(c) in appendix] consists of a compartmentalised box with a carrying handle on top and a slide on the bottom which is withdrawn in order to release the contents of the compartments. The compartments are of equal size. The basic operating procedure is to fill all of the compartments to the brim and then, holding the device over the receptacle, to release the contents from the number of compartments required to make up the desired volume by pulling on the slide. To facilitate this action (for blind persons) the slide produces audible clicks as each compartment is emptied.

The design of the RBS example [see figure A1(d)] consists of a clear plastic cup with four large graduation marks on the inside. Each of these is labelled with raised Arabic numerals to indicate the proportion of a cup which corresponds to a graduation. The cup has a broad lip to facilitate pouring in any direction. The presumed method of operation for this cup is to place it on a flat surface, find the appropriate graduation mark, place one's finger on it, and commence filling the cup with a liquid or powder until it can be felt by the finger on the graduation mark. The cup can then be emptied into the intended receptacle with one hand, leaving the other hand free to assist in locating the receptacle. The broad relatively high brim lessens spillage problems during the dispensing operation.

Procedure

The basic methodology used was the same as in previous design-fixation experiments (Jansson and Smith, 1991; Purcell and Gero, 1991). The participating designers came from four distinct populations (described in the next section). Each of these populations was arbitrarily divided into between two and three separate experimental groups (see table 1). In all cases one of the groups was designated as the control group (ξ_C) and were given a simple (verbal) description of the problem. The other (experimental) groups (ξ_J for the Jansson and Smith example and ξ_R for the RBS cup example) were given the same description of the design problem together with a picture of the relevant example. For those receiving a pictured example, the verbal instructions included a single additional sentence drawing attention to the pictured example as an illustration of the level of detail with which designs were to be presented. The facing pages of the (A4-sized) instruction sheets used for the control and other groups are replicated in figures A1(a) and A1(b), respectively. The reverse pages of the instruction sheets used for the Jansson and Smith example and RBS example groups are in figures A1(c) and A1(d), respectively. The reverse page of the instruction sheets given to the control groups was blank. Participants were randomly allocated to an experimental or control group and the design session lasted for 45 minutes. Participants were supplied with sheets of A3 paper on which to do their designs.

Table 1. Allocation of subjects to experimental conditions.

Population description	Symbol	Number in group[a]			Total
		ξ_C	ξ_J	ξ_R	
Third-year mechanical engineers	ϕ_1	15	10	12	37
Fourth-year industrial designers	ϕ_2	8	7	7	22
Fourth-year interior designers	ϕ_3	4	7	6	17
Fourth-year mechanical engineers	ϕ_4	8	7	0	15
Total	Φ	35	31	25	91

[a] ξ_C control group; ξ_J group given Jansson and Smith example; ξ_R group given Royal Blind Society example.

Participants

Third-year and fourth-year undergraduate designers from mechanical engineering participated to equate both the design background and the level of experience of the designers to those in the original Jansson and Smith experiments. In addition to using designers from the same design discipline and with a similar level of expertise as in the Jansson and Smith experiments, fourth-year undergraduates from industrial design and interior design participated to provide a test of the generality of the effect across design disciplines. Industrial designers were chosen rather than, for example, architectural designers because the size and scale of the problem being attempted would be quite atypical for architectural designers but typical both for industrial and for mechanical engineering designers. The interior designers were included as an opportunity arose which provided them as another design discipline for comparison. The total numbers of participants from each population and their allocation to experimental and control groups are tabulated in table 1 together with the symbols used to represent each population.

Measures of design fixation

In their series of experiments, Jansson and Smith (1991) used two related types of measures of design fixation. The first involved direct physical similarities between the pictured design and a design solution and the second the reproduction of design flaws or mistakes present in the pictured example. Physical similarities between designs can take a number of forms. Perhaps the simplest involves the reproduction of the pictured design; that is, the direct copying of the example design. Jansson and Smith appeared to be assessing this type of similarity in their measure which involved judges assessing the overall similarity of the designs. Another type of similarity can involve the reproduction of elements of the design: that is, parts or configurations of parts can be recognised in the designs produced. A third type of similarity can be termed analogical similarity. Here the same design principles as the pictured example are used in the design without the physical form being the same.

The measurement of flaws in the design also has a number of aspects. Jansson and Smith (1991) assessed what they referred to as intentional design flaws: that is, flaws deliberately introduced into their example designs. However, analysis of their example designs in terms of the requirements for the design problem reveals a number of unintended design flaws. For example, in the design problem used in this experiment—the design of a measuring cup for use by visually handicapped individuals—the intentional design flaws were that only discrete quantities could be measured where the description of the design called for continuously variable quantity selection and that no provision was made in the device for overflow. The unintended design flaws are the following.

(1) The device [see figure A1(c)] requires two-handed operation and deprives the blind person of a prime sensor (touch) when attempting to position the device over the receptacle into which the contents are to be dispensed.

(2) The action of pulling the slide is highly likely to result in the movement of the whole device, exacerbating the problem of positioning the device over the receptacle.

(3) The long array of openings increases the criticality of positioning the device over the receptacle.

(4) The requirement to fill the compartments to the brim, in addition to creating the requirement for an overflow system, introduces the problem of maintaining the device level during operation, which would be difficult for a blind person in spite of the lateral stability, because of pendulosity.

(5) The action of pulling the slide will exacerbate the balance problem.

(6) The only way to determine when the compartments are full is to test for overflow by direct use of a finger.

(7) The device is bulky and awkward to use.

There is also another problem with Jansson and Smith's intentional design flaws. For example, not providing for overflow is an error of omission and it is difficult to claim that flaws are being transferred into designs just because the same omissions occur. Rather, it is necessary to demonstrate the carry-over of committed errors, that is, design flaws actually present in the pictured example such as the unintended errors discussed above.

A similar analysis can be made of the other example design used in this experiment. The method of filling the device to the required level has the undesirable requirement of using the finger as a direct sensor to detect the level of the contents. In addition powders have a tendency to form piles when poured and this would cause the sensation of the powder on the finger to be an inaccurate indication of the quantity of the powder in the cup. [This problem is also present (to some extent) in the Jansson and Smith example.] Arabic numerals are unlikely to be easy for blind people to read with their fingertips even when raised and the provision of Braille labels would be more useful. In common with the Jansson and Smith (1991) design, this design allows only the measurement of discrete quantities.

From this discussion three sets of measures of design fixation are possible—measures of similarity, measures of intentional design flaws, and measures of unintended design flaws. The specific implementations of these measures used in this experiment are described below and tabulated in table 2 together with the symbols used to represent them in various figures.

Measures of similarity

The measures of similarity used were

(1) judgments of direct physical similarity of the designs to the Jansson and Smith example (J_s, design feature 4 in table 2) and the RBS cup (R_s, design feature 15);

(2) judgments of the analogical similarity of the designs to the Jansson and Smith example (J_a, design feature 5) and the RBS cup (R_a, design feature 16).

The symbols for these features are given in column 3 of table 2.

Intentional design flaws

For the Jansson and Smith example these were

(1) a design that makes no provision for overflow (J_1^δ, design feature 3);

(2) a design that makes no provision for overflow, conditional on the design being inherently reliant on overflow in its normal operation (J_2^δ, design feature 7), obtained by testing for design feature 3 on condition that design feature 1 is already satisfied;

(3) a design that only measures discrete quantities (J_3^δ, design feature 12).

The symbols for these features are listed in column 4 of table 2.

No known deliberate design flaws were present in the RBS design.

Unintended design flaws

For the Jansson and Smith example, these were

(1) a design that contains a large array of output openings (J_3, design feature 8);

(2) a design that requires the use of both hands to operate it (J_4, design feature 9);

(3) a design that requires pulling, pushing, or twisting part of the device during the dispensing action (J_5, design feature 10);

(4) a design that requires that the device be filled to the brim for proper use (J_6, design feature 11);

(5) a design that only allows the selection of discrete rather than continuous quantities (J_7, design feature 12).

Their symbols are listed in column 5 of table 2.

In this set there were two further conditional measures

(6) a design that requires the direct use of the finger to test for overflow where the design inherently depends on overflow (J_1, design feature 6);

(7) a design that makes no provision for overflow where overflow is part of the design (J_2, design feature 7).

Their symbols are also listed in column 5 of table 2.

For the RBS example, the parallel measures were

(1) the design only allows the measurement of discrete rather than continuous

Table 2. Design features.

Design feature	Number	Symbol(s)[a]			
		a	b	c	d
Uses overflow as part of design operation	1				
Direct use of finger to test for overflow	2				
Makes no provision for overflow	3		J_1^δ		
Superficial Jansson and Smith similarity	4	J_s			
Analogical Jansson and Smith similarity	5	J_a			
Direct use of finger to test for overflow (conditional on 1)	6			J_1	
Makes no provision for overflow (conditional on 1)	7		J_2^δ	J_2	
Large array of output openings	8			J_3	
Two-handed dispensing action	9			J_4	
Need to pull, push, or twist during dispensing action	10			J_5	
Need to fill the device to the brim	11			J_6	
Only measures discrete quantities	12		J_3^δ	J_7	R_1
Makes use of non-Braille labels	13				R_2
Direct use of finger to sense the level of the substance	14				R_3
Superficial RBS (Royal Blind Society) cup similarity	15	R_s			
Analogical RBS cup similarity	16	R_a			

[a] a, measures of similarity; b, intentional design flaws; c, unintended design flaws (Jansson and Smith example); d, unintended design flaws (RBS example).

quantities (R_1, design feature 12 and shared with the Jansson and Smith example design);
(2) the design uses raised Arabic numerals or Roman letters, rather than Braille, to identify quantities (R_2, design feature 13);
(3) the design requires the use of a finger as a direct sensor when filling the cup to the desired level (R_3, design feature 14).
Their symbols are listed in column 6 of table 2.

Three judges were used to score each of the designs independently for design features 1–5 and 8–16, with the judges then examining areas of disagreement by jointly assessing each design and reaching agreement on the scoring for the relevant design features. Design features 6 and 7 were constructed by the conditional combination of features 2 and 1, and 3 and 1, respectively. Design features 1 and 2 exist purely for this purpose. At the time of judgment the judges were not aware of either the population or the experimental group to which the designer of the design belonged.

Analysis and results

Although the basic data consist of the number of occurrences of each design feature in the designs for the different experimental conditions, there are a number of ways in which these data can be treated. For example, the data can be converted to proportions of designs containing a given design feature. In addition, because participants were not limited to producing only one design, data can be extracted for the numbers or proportions of first designs from each designer which contain a given design feature, the numbers or proportions of designers that produced at least one design containing a given design feature, or for the average number or proportion of designs for each participant which contain a given design feature. Although these are the various possibilities available for this data set, the focus in this paper is on the possible reasons why differences were found between the Purcell and Gero (1991) experiments and the original Jansson and Smith (1991) work. The form of analysis which is most similar to the original Jansson and Smith experiments is to analyse the number or proportion of the designs showing a particular design feature and this was the measure adopted. The symbol $N_{P,X}$ is used to designate the number of designs, taken from designers in the population P and allocated to experimental condition X, showing a particular design feature, and $|\Delta|_{P,X}$ is the total number of designs produced by designers in population P and experimental condition X. The proportion of designs in the sample exhibiting the particular design feature is then given by $N_{P,X}/|\Delta|_{P,X}$. The design features included in an analysis have also been grouped in terms of the four sets of design features that address the different issues discussed in the preceding section.

The measure, t, of statistical distance between two proportion estimates p_1 and p_2 used here is given by

$$t(p_1, p_2) = (p_1 - p_2) \bigg/ \left[p(1-p) \left(\frac{1}{n_1} + \frac{1}{n_2} \right) \right]^{1/2}, \tag{1}$$

where

$$p = \frac{p_1 n_1 + p_2 n_2}{n_1 + n_2}, \tag{2}$$

and n_1 and n_2 are the sample sizes used to determine the estimates p_1 and p_2, respectively. This equation is a reformulation of the equation given by Freund (1979, page 318) as the appropriate statistic for hypotheses concerning one-sided comparisons (such as $p_1 > p_2$, or $p_1 < p_2$) by substituting $p_1 = x_1/n_1$, and $p_2 = x_2/n_2$.

Its sampling distribution is Student's t-distribution with n_1+n_2-2 degrees of freedom. In the experiments presented here the aim is to test the null hypothesis, $p_1 = p_2$, against the alternative hypothesis, $p_1 > p_2$. The proportion p_1 can be said to be significantly greater than p_2 with $(1-\alpha)$ confidence if $Q[t(p_1, p_2), n_1+n_2-2] < \alpha$, where $Q(x, \nu)$ is the probability that a variable drawn randomly from a t-distribution with ν degrees of freedom will be greater than x.

Superficial and analogical similarity
Jansson and Smith (1991) had found that judgments of the similarity of the participants' designs to the pictured example were higher for the group shown the example design. In this experiment two types of similarity were identified—examples showing features directly similar to the physical characteristics of the example design or examples showing physical features which embodied the same principle as the example design but where the physical realisation of the principle was different. These two types of similarity are referred to as superficial and analogical similarity, and in figure 1 we show the comparison between the four groups shown the picture of the Jansson and Smith design and the relevant control group on these two measures. The probability associated with the (signed) difference in the proportions being as large as that observed is shown on the abscissa with the participants from the different populations shown separately. None of the populations exhibits significant differences between the control and experimental groups in terms of the superficial similarity measure although the comparison for the third-year mechanical engineering students (population ϕ_1) approaches marginal significance. This result indicates that there was little effect of the pictured example in terms of the reproduction of overt physical features of the example. However, both engineering student groups (ϕ_1 and ϕ_4) shown the example design produce very significantly more designs that are analogically similar to the example than their respective control groups, clearly demonstrating a fixation effect. By contrast, the industrial design and interior design students (groups ϕ_2 and ϕ_3) shown the example demonstrate only a marginally significant increase over their respective control groups. In figure 2 we present the parallel set of results for the groups shown the RBS design and the relevant control groups. [Fourth-year engineering students (group ϕ_4) did not participate in this part of the experiment.] In this case there are no significant differences with the superficial or analogical similarity measures for any of the types of students. These analyses demonstrate, first, that there was no simple reproduction of the physical attributes of example designs; that is, there appears to be no simple copying of the pictured design.

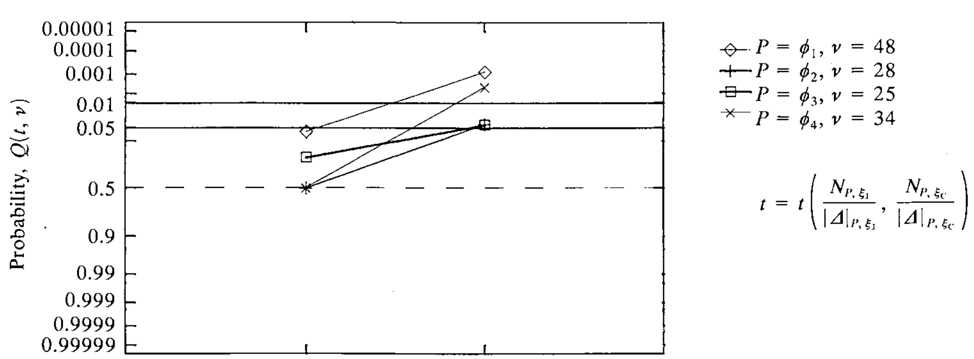

Figure 1. Comparison of adjudged similarities J_s superficial and J_a analogous) to the Jansson and Smith example for the experimental groups shown the Jansson and Smith example (ξ_J) and their respective control groups (ξ_C). (The assignment of the groups is given in table 1.)

Second and perhaps of more interest, is the clear demonstration of a fixation effect in terms of the use of the principles involved in the pictured design, but only with the example design used by Jansson and Smith (1991) and with marked differences in significance levels obtained between the two mechanical engineering populations (groups ϕ_1 and ϕ_4) and the industrial and interior designers (groups ϕ_2 and ϕ_3).

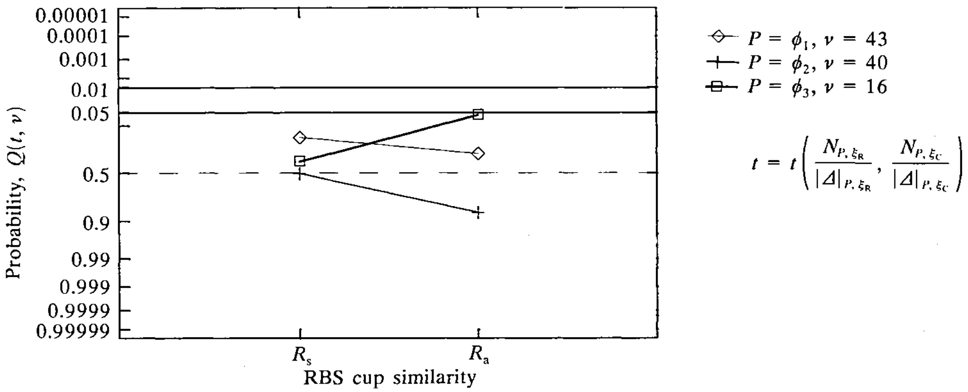

Figure 2. Comparison of adjudged similarities (R_s superficial and R_a analogous) to the RBS (Royal Blind Society) example for the experimental groups shown the RBS example (ξ_R) and their respective control groups (ξ_C). (The assignment of the groups is given in table 1.)

Intentional faults in the Jansson and Smith design

Figure 3 presents the results of the comparison between experimental and control groups for the two intentional faults introduced by Jansson and Smith into the design for each designer population. As discussed previously, one of these intentional faults—the absence of provision for overflow—can be assessed in two ways. It can be either assessed directly or by taking into account whether or not the design inherently relies on overflow for its normal operation—the conditional measure. Jansson and Smith had found design fixation with their intentional design flaws, although it is not clear whether the nonprovision of an overflow device feature was conditional on overflow being a normal part of the operation of the devices. Figure 3, however, clearly shows that in the current experiment it is only with the conditional measure (J_2^δ) that there are significantly more occurrences present and, as with the analogical similarity measure, it is the two engineering groups (ϕ_1 and ϕ_4) and not

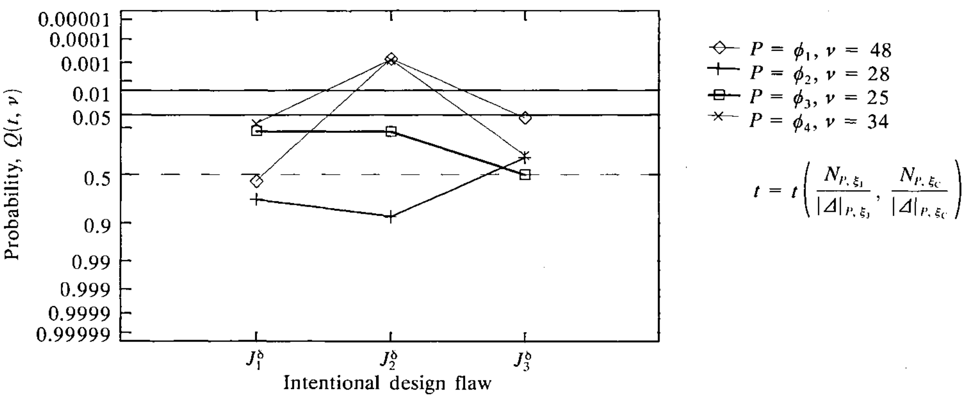

Figure 3. Comparison of occurrence of intentional faults (see table 2) for the experimental groups shown the Jansson and Smith example (ξ_J) and their respective control groups (ξ_C). (The assignment of the groups is given in table 1.)

the industrial design or interior design groups (ϕ_2 and ϕ_3) which show the effect. Although the results shown in figure 3 for the feature J_3^δ indicate no significant difference for any of the populations, it should be noted that the significance Jansson and Smith obtained for this feature was only marginally significant 0.019 (t = 2.109, ν = 86).

Faults of commission in the Jansson and Smith and RBS designs

In figure 4 we illustrate the differences in proportions between the experimental and control groups for the seven design features which represent commission errors in the Jansson and Smith design. For the industrial design (group ϕ_2) and interior design students (group ϕ_3) there are no significant differences between the experimental and control groups for each of the design features. Overall, therefore, these groups do not demonstrate design fixation in the sense of producing commission errors in their designs of the type present in the Jansson and Smith design. These results contrast with the analysis of the two engineering student groups (ϕ_1 and ϕ_4). Here there are very significantly more occurrences in the experimental than in the control groups for both engineering student groups on several design features and most of the others show marginal significance. As a result the two engineering student groups show quite clear evidence of design fixation according to the quite stringent criterion of errors of commission whereas the industrial design and interior design students do not.

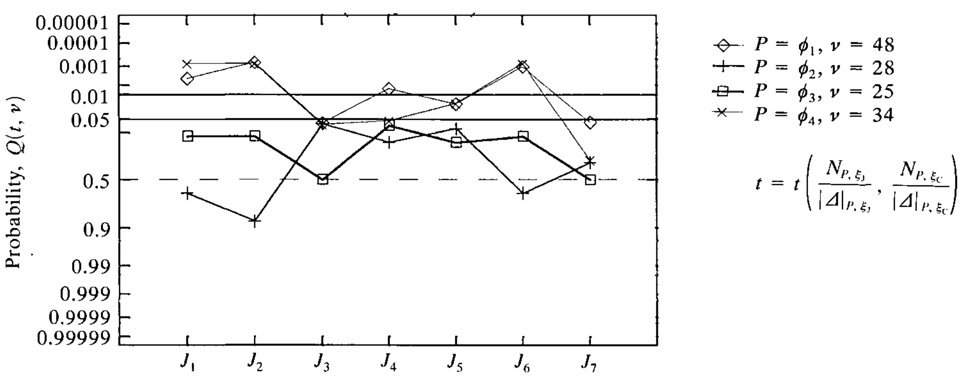

Figure 4. Comparison of occurrence of faults of commission (see table 2) for the experimental groups shown the Jansson and Smith example (ξ_J) and their respective control groups (ξ_C). (The assignment of the groups is given in table 1.)

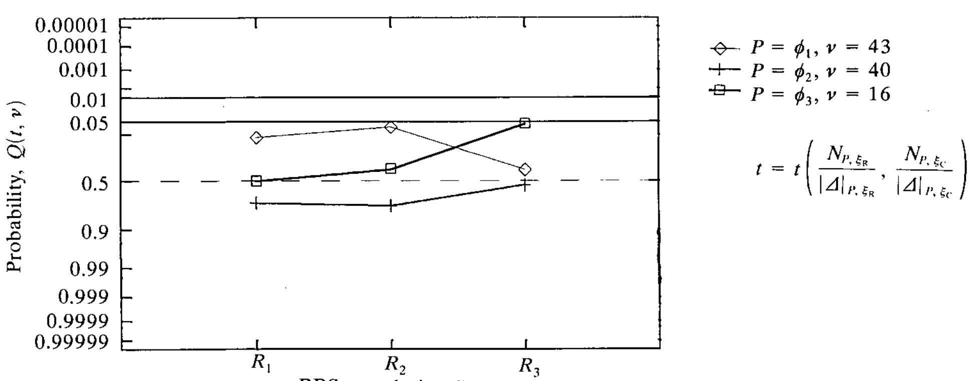

Figure 5. Comparison of occurrence of faults of commission (see table 2) for the experimental groups shown the RBS (Royal Blind Society) example (ξ_R) and their respective control groups (ξ_C). (The assignment of the groups is given in table 1.)

A quite different pattern occurs, however, with the RBS design (figure 5). Here there are no differences between experimental and control groups for any of the features and for any of the groups of designers. Clearly, design fixation is absent for this example design.

Conclusions

In the introduction to this paper it was argued that the failure to replicate the Jansson and Smith (1991) design-fixation results in the Purcell and Gero (1991) experiment could have been caused by three factors—the inexperience of the design students used, differences between the design disciplines of the participants in the two experiments, and familiarity with examples of the problem through everyday experience. In this experiment participants were from the same discipline and at the same level of education as those in the Jansson and Smith experiment. The design problem selected was one of those used in the original experiments, but it was also a problem where it was unlikely that participants would have seen an example. However, the problem was of a scale that would be in the range of experience of the designers. In this experiment clear evidence for design fixation was obtained under the conditions which most closely replicate those of Jansson and Smith (1991). This appears to indicate that the results in Purcell and Gero (1991) could have been caused by the use of designers from a different discipline, given that the selection of the problem in this experiment ensured that it would be highly unlikely that participants would have previous experience with examples of solutions to the design problem and that the scale of the problem was appropriate to the discipline of the designers.

However, in this experiment, design fixation only occurred with one of the example designs—that used by Jansson and Smith—and for advanced student designers from a mechanical engineering background—that is, the same type of background as the participants in the Jansson and Smith experiment. This result poses a number of questions about the design-fixation effect. At first glance, this result might be interpreted as indicating that design fixation is not of much significance because it appears to occur under such a restricted range of conditions. It would also be possible to argue that the conditions where the effect does occur may simply represent a set of conditions where the participants respond to the demand characteristics of the situation and that the effect is not related to the design process at all.

There are a number of aspects of the results, however, which argue strongly against these interpretations. First, the effects were obtained consistently with all three types of measures—similarity, and intentional and unintended design flaws. Further, the significant effects found with the similarity measures were not in terms of superficial or direct similarity but in terms of analogical similarity, and the significant effects found with faults in the design were not only in terms of errors of omission but were also in terms of the more robust errors of commission. In addition, if the results were only associated with the demand characteristics of the situation as they affected engineering students, it would be expected that similar fixation effects would have been obtained with the RBS example design. On the basis of these arguments, therefore, it would seem that the effects are genuine fixation effects.

The key question, therefore, is why does fixation occur with the engineering students but only with a particular example design and not at all with the industrial design students and interior design students? Some possible answers become apparent if the two example designs are examined in terms of the principles involved in their design and correspondingly in assessing design fixation. The RBS design is essentially a single graduated container. By contrast, the Jansson and Smith design is more complex and involves a number of engineering principles which could be thought of as mechanical design principles, for example the dispensing action involves mechanically moving parts. As a result it could be hypothesised that fixation effects occur when a pictured example design contains representations in physical form of principles which are a part of the expertise of the designer involved. Conversely, fixation will not occur when the pictured example does not contain this type of information, either because the principles involved are not specific to a particular design discipline as in the case of the RBS design or do not form a part of the knowledge base of the discipline involved as was the case with the industrial and interior designers. This hypothesis can be tested by the use of design problems where the example designs are based on principles which do or do not match the discipline of the designers. From this perspective, fixation represents the application of principles which are relevant to a particular type of expertise in a situation where application of those principles is inappropriate for the problem being attempted. This in turn provides an additional focus for research in the area by posing the question of why designers fail to identify the requirements of the problem which make the application of the principle inappropriate, in contrast to the question of what it is about the pictured example which produces fixation.

Another possible explanation for why the Jansson and Smith example elicited design fixation whereas the RBS cup did not could simply be the complexity of the example designs. The Jansson and Smith example, being more complex, would require more attention to understand (on the part of the subjects) than the RBS cup which is quite banal. The difference in fixation effect could be related to this difference in attention. This hypothesis can be tested by the use of design problems of graded complexity. This explanation does not address the problem of the differences between the mechanical engineers and the industrial and interior designers.

A possible reason for the differences between the various disciplines could be found in their education. It is possible that the training of mechanical engineers teaches them design methods that are susceptible to design fixation and that of industrial and interior designers does not. Conversely, it is possible that humans have a predisposition to design fixation and the design education of industrial designers and interior designers helps them to overcome it and that of mechanical engineers does not. These hypotheses can be tested by the use of subjects from various levels of education within the various disciplines.

If fixation occurs in design, even under limited conditions, it has the potential to affect the way design is taught. Design is often taught largely by precedence in such disciplines as architecture; what role does fixation play here? This is still an open research question; it is, however, an important one.

Acknowledgments. This research has been supported by a seed grant from the Key Centre of Design Quality and by a grant from the University of Sydney's University Research Grant Scheme.

References

Duncker K, 1945, "On problem solving" *Psychological Monographs* **58**(5, whole of issue 270)
Freund J E, 1979 *Modern Elementary Statistics* 5th edition (Prentice-Hall, Englewood Cliffs, NJ)
Jansson D G, Smith S M, 1991, "Design fixation" *Design Studies* **12**(1) 3–11
Luchins A, Luchins E, 1957 *Rigidity of Behavior* (University of Oregon Press, Eugene, OR)
Purcell A T, Gero J S, 1991, "The effects of examples on the results of a design activity", in *Artificial Intelligence in Design '91* Ed. J S Gero (Butterworth-Heinemann, Oxford) pp 525–542

APPENDIX

Design Exercise:
A Volume Measuring Apparatus for Use in Cooking by the Blind

The aim of this design exercise is to design a volume measuring apparatus for use in cooking by blind persons. The measuring apparatus designed should possess the following attributes:

- easy to operate
- usable with both powders and liquids
- prevent waste of food
- capable of measuring quantities from $\frac{1}{4}$ to 1 cup
- easy to clean
- inexpensive

Detailed and accurate drawings are not required. Simple, rough outline sketches are all that is needed. The sketches may be annotated with written comments as required to clarify your intentions.

You will be allowed forty five minutes to complete the design. If you wish you may complete more than one design.

(a)

Design Exercise:
A Volume Measuring Apparatus for Use in Cooking by the Blind

The aim of this design exercise is to design a volume measuring apparatus for use in cooking by blind persons. The measuring apparatus designed should possess the following attributes:

- easy to operate
- usable with both powders and liquids
- prevent waste of food
- capable of measuring quantities from $\frac{1}{4}$ to 1 cup
- easy to clean
- inexpensive

Detailed and accurate drawings are not required. Simple, rough outline sketches are all that is needed. The sketches may be annotated with written comments as required to clarify your intentions. See figure 1 (on reverse page) for an example of the level of detail required.

You will be allowed forty five minutes to complete the design. If you wish you may complete more than one design.

(b)

equal sized compartments
audible click for each compartment

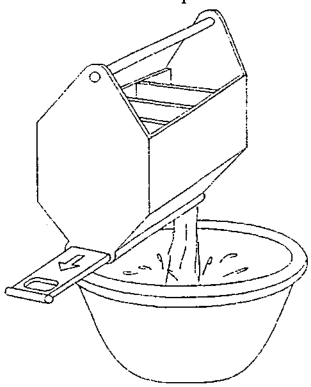

Figure 1. Example Design

(c)

4 large (finger sized) graduation marks
raised Arabic numeral labels

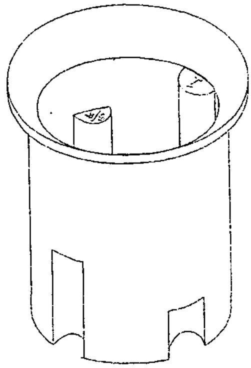

Figure 1. Example Design

(d)

Figure A1. Facing page of instruction sheet for participants in (a) control conditions, (b) other conditions; and reverse page of instruction sheet for participants in (c) Jansson and Smith example condition, (d) Royal Blind Society example condition. (The reverse page for the control group is blank).