STUDYING DESIGN FIXATION WITH A COMPUTER-BASED TASK

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Abstract

The term 'design fixation' refers to a phenomenon where designers unknowingly limit the space within which they search for solutions. In an attempt to study this phenomenon experimentally, researchers typically set participants open-ended design problems, prime them with an example solution and measure their performance through subjective metrics. This gives rise to various problems, including limited data capture and highly subjective evaluation of design behavior. To address these problems, we studied design fixation with a computer-based task inspired by psychological paradigms used to study 'mental set'. The task consisted of a game-like activity requiring participants to design a bridge within a specified budget. The use of a digital environment facilitated continuous data capture during the design activities. The constrained task (and direct quantitative measures) permitted a more objective analysis of design performance, including the occurrence of fixation. The method used and the results obtained show an exciting alternative for studying design fixation experimentally and promote a wider exploration of the variety of design activities in which fixation might occur.

Keywords: Design cognition, Creativity, Human behaviour in design, Design fixation, Computer-based task

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1 INTRODUCTION

Design Fixation is a phenomenon in which designers unknowingly limit the space within which they search for solutions (Jansson and Smith, 1991). That is, they become ‘‘blinded’’ to solutions other than the ones they are considering. This can be a problem in professional practice (Crilly, 2015) and in educational settings (Chrysikou and Weisberg, 2005).

Research into design fixation is generally important for developing our understanding of design cognition, and particularly important for understanding the relationships between information, inspiration and creativity. However, like other aspects of human behavior, the knowledge we have about design fixation is dependent on the quality and variety of the methods we use to study it (Greene, Caracelli and Graham, 1989). From that perspective, the existing studies of design fixation are quite homogenous in the experimental approach adopted (there is little methodological diversity) and that approach has some specific features and limitations. For example, the traditional approach has an almost exclusive focus on the ‘idea generation’ stage of the design process, the adoption of ill-defined design problems and the use of subjective metrics to measure design behavior.

To address methodological issues with the established approach, we propose an alternative or additional method: studying design fixation with a computer-based task inspired by psychological paradigms used to study mental blocks (e.g. Bilalić, McLeod and Gobet, 2008; Luchins 1942). This permits better data capture (because the design work is digital), a more objective analysis of design behavior (because the design task is partially constrained) and less variability in participants’ performance (for the same reason). We also hope that reporting on this method will promote a wider exploration of the possible ways in which fixation might be studied and a greater appreciation of the variety of design activities in which fixation might be manifest.

2 FIXATION RESEARCH

For many years, psychologists have been describing and studying the kinds of blocks that can impede insight, often resulting from the counterproductive effects of prior knowledge (e.g. Kohn and Smith, 2011). This phenomenon and its variants have been demonstrated in a number of now-classic experiments, including Maier’s (1931) and Duncker’s (1945: Ch. 7) demonstrations of how people’s ‘attachment’ to the conventional function of artifacts inhibits their capacity to see new possible functions – referred to as ‘functional fixedness’. Related to this are Luchins’ (1942) demonstrations of the ‘Einstellung effect’, where people become mentally ‘set’ in a particular approach to solving problems.

The concept of ‘design fixation’ was developed from these early psychological studies, with the term initially being used to refer to “a blind adherence to a set of ideas or concepts limiting the output of conceptual design” (Jansson and Smith, 1991: p. 3). This definition described what Jansson and Smith found in a number of experiments with participants engaged in creative design tasks. Designers, working individually, had to generate ideas in response to different problems (i.e. design a car-mounted bicycle rack, a measuring cup for the blind, a disposable spill-proof coffee cup). Alongside the design briefs, some of the participants were also presented with pictures of existing solutions. Jansson and Smith identified the occurrence of fixation in their experiments when it was observed that the designers exposed to those pictures tended to repeat key features of the solutions that were represented. This behavior persisted even when participants received instructions to avoid repeating particular features of those example solutions. As these features were intentionally problematic (e.g. they contradicted the brief) this feature repetition was taken to be inadvertent and counterproductive.

Since 1991, the basic approach taken in Jansson and Smith’s study has been adopted by many other researchers whose studies have manipulated different variables to provide a better understanding of why design fixation occurs and how it might be mitigated (e.g. see Linsey, Tseng, Fu, Cagan, Wood and Schunn, 2010; Purcell and Gero, 1996). These studies are now sufficient in number that literature reviews have recently been published focused solely on design fixation, investigating the concepts of interest (Youmans and Arciszewski, 2014), the findings obtained (Sio, Kotovsky and Cagan, 2015) and the research methods used (Vasconcelos and Crilly, 2016).

The established approach to study design fixation has greatly contributed to improve our understanding of what induces fixation and how its effects can be mitigated (e.g. Viswanathan and Linsey, 2012; Youmans, 2011). However, as previously mentioned, studies of design fixation often suffer from a number of limitations, including an almost exclusive focus on unbounded early stage ideation and the use of subjective metrics to measure design behavior. In order to address these methodological problems, alternative experimental paradigms might be considered, and these might be applicable not just to the early-stage design activities that have been studied to date, but to other types of design activity also (see Crilly & Cardoso, 2017). Design fixation research originally took psychological research on mental blocks as useful precedent (Jansson and Smith, 1991), and we can look to this area of research for alternative approaches. In particular, although the concept of design fixation perhaps inherited its name from functional fixedness, the effect of interest is really more like mental set. This is because design fixation is not normally studied as a block to seeing new possible functions in existing structures (functional fixedness), but as a block in imagining new structures for specified functions (especially where an existing structure is known). Considered broadly, these 'new structures' might not just be products that realize a function, but also solutions to a problem or the approach, process or method by which those solutions are determined. A block to seeing new approaches is explained by mental set, and as such, experimental paradigms for studying mental set provide a valuable starting point for studying design fixation.

Mental set refers to the development of a mechanized state of mind, which occurs when previous experience with a successful problem-solving approach prevents alternative approaches being considered. This phenomenon was first demonstrated experimentally by Luchins (1942; 1951) water-jar task, sometimes referred to as the 'three jars' studies. In these studies, Luchins presented participants with a series of water-jar problems that could all be solved by the same complex sequence of "pouring" operations. Then, participants were presented with a problem that could be solved directly by simply pouring the contents of one jar into another. Despite the simplicity of the solution, the vast majority of participants persisted with the sequence they had used in the previous problems (even though it was now inefficient). Then, Luchins gave participants a problem that appeared similar to the previous ones but which could not be solved by the same method (the 'extinction' problem). Many participants said it was insoluble. The fixation of thought displayed by these people was demonstrated by a control group who were given only the extinction problem. They solved it quickly, showing that the problem was not intrinsically difficult. The experimental group failed to find the solution because the similarity of the final problem to the previous ones brought the usual (and now inappropriate) method to mind, preventing them from considering alternatives (for similar results see Bilalić et al., 2008).

3 THE PRESENT STUDY

With the objective of developing a mental set paradigm for studying design fixation, we developed a computer-based design task that would address some of the main limitations of previous design fixation studies, especially the exclusive focus on unbounded ideation, limited data capture and the use of subjective metrics to evaluate the design outcomes.

The task consisted of a game-like design activity requiring participants to design a bridge that could support a specified load using the available budget. By having participants complete a number of trials, we were able to structure our experiment according to the traditional paradigms used to study mental set (e.g. Luchins, 1942). In particular, we observed the performance of an experimental group, whose previous experience with a single approach to the design task was expected to block their recognition of alternative approaches. The performance of this group was compared to that of a control group, whose experience with different approaches was not expected to prevent the occurrence of mental set.

Adopting a mental set approach to design fixation allowed us to explore fixation effects as they might occur in later stages of the design process (once the overall concept is defined), thus complementing previous research on fixation in early-stage ideation activities. Mental set paradigms also offered the opportunity for the fixating solution to be one which the participants arrived at spontaneously (e.g. their first solution), rather than one which was directly provided by researchers (e.g. an example solution). Finally, mental set paradigms offered the opportunity to observe how fixation effects occurred during the design process, rather than just inferring those effects from the design solutions that were generated.

In addition to the benefits arising from the adoption of a mental set paradigm, the use of a digital platform to record the design behaviour allowed better data capture (because the design work was all digital), a more objective analysis of design behavior (because the design task was partially constrained and numerically tested) and less variability in participants' performance (for the same reason).

3.1 Participants

Forty participants (11 women) with an engineering qualification were recruited into the study by responding to posted advertisements; they were all drawn from the Department of Engineering of the University of Cambridge. Their average age was 25.19 (SD = 3.66) and they had an average of 5.97 (SD = 2.60) years of university education. The data from four outlier participants was later removed from the analysis because their performance (total time taken to complete the task) varied by two or more standard deviations from the mean of the group. The final sample therefore consisted of 36 participants. All participants gave informed written consent prior to the commencement of the study and received a small honorarium for their participation. The study procedures were approved by the local ethical review committee.

3.2 Materials and Procedure

The platform for the experimental task was an adapted version of the computer game 'Pontifex' (Chronic Logic, 2001), in which players must design a truss bridge that spans a river. Participants were required to design a series of bridges that could each support a specified load using the available budget. The game included two modes. The 'Design' mode allowed participants to plan the bridge structure by arranging and modifying the structural elements, considering the required span (to cross a river) and the 'anchor points' that could be used to support the bridge (e.g. the banks of the river, or a rock at mid-span). The 'Test' mode allowed participants to load the bridge (by driving a train across it) and assess its performance. To capture the participants' activities during the game and the utterances they made, we used screen recording software called 'Fraps' (Beepa, 2013). This recorded every design and test cycle, including the placement, deletion and resizing of the structural elements, as well as the resulting cost of the bridge and its performance under loading.

The task consisted of a series of trials varying in the length of the gap that the bridges were required to span, and the number and location of the anchor points that could be used to connect the various structural elements. In each trial, the participants were required (and incentivized) to design the lowest cost bridge that would support the load. In particular, there were ten trials:

- • five *single-approach* trials, in which successful bridges could only be designed by using all the available anchor points (otherwise the bridges would fail to support the load);
- • four *dual-approach* trials, in which successful bridges could either be designed by using all the available anchor points or by not using all the anchor points (both types of design could be within budget and support the load, but those designs that used all the anchor points would cost more to construct than was necessary);
- • one '*extinction*' trial, in which successful bridges could only be designed by not using all the available anchor points (otherwise the budget would be exceeded).

Importantly, each of these approaches resulted in a set (or 'family') of design solutions for each trial, with different numbers and sizes of elements and different associated costs. To account for the variety of possible designs, in almost all the trials (except the extinction trial) the available budget was at least double the budget required to construct the optimal solution. This allowed participants to design any bridge structure that they were likely to attempt, regardless of the cost.

Participants were randomly assigned to two experimental groups, which only varied in the order of the trials. In the experimental group, the trial order resembled the order of the jars problems in Luchins' (1942) study (see Table 1). Participants completed five single-approach trials, then two dual-approach trials, then an extinction trial, and finally two additional dual-approach trials. In the control group, participants received the same set of trials in a different order. Crucially, they started the task by completing the extinction trial and the single-approach trials were not grouped together. This experimental manipulation was expected to avoid the development of a mechanized state of mind because the initial trial did not require the use of all the anchor points but some subsequent trials did.

Each participant was tested individually in a private meeting room, seated at a computer screen. An initial introduction explained that they would be playing a computer game and answering some questions about their performance. Before starting with the experimental task, participants received a brief training session in order to familiarize themselves with the game platform. Their task in the training session was to design and test a tower, which familiarized them with both the Design and the Test modes. Once the participants were able to interact with the game platform without further assistance from the experimenter, they were provided with the written instructions concerning the experimental task. The overall aim of the task was to design the lowest cost bridge possible that could withstand the load of a train moving across it without suffering any damage (i.e. broken structural elements or connections). To reduce the influence of participants' background and/or previous experience with similar design-activities, they were told that they would be constructing the bridges in an imaginary world (e.g., anchor points could be in mid-air, and not just on the ground). In all the trials, participants could iterate freely between the Design and Test modes in their attempts to design the least expensive bridge possible with each iteration later being counted as one 'design-test cycle'. There was no time constraint to complete the task.

Table 1. Characteristics of the trials and the trial order in the two groups.

Trial type	Required bridge span	Trials order in experimental condition	Trials order in control condition	Number of anchor points provided/ minimum/ maximum	Cost of the optimal design solution if…	
					…using all the anchor points	…not using all the anchor points
Single-approach	160m	1	3	3/3/3	$18,272	Bridge fails
Single-approach	240m	2	9	5/5/5	$26,672	Bridge fails
Single-approach	240m	3	10	5/5/5	$27,672	Bridge fails
Single-approach	320m	4	6	6/6/6	$37,478	Bridge fails
Single-approach	320m	5	4	5/5/5	$37,544	Bridge fails
Dual-approach	160m	6	2	4/3/4	$18,772	$18,272
Dual-approach	320m	7	5	7/6/7	$40,044	$37,544
Extinction	80m	8	1	4/2/2	Budget exceeded	$6,400
Dual-approach	240m	9	8	6/5/6	$27,672	$26,672
Dual-approach	240m	10	7	8/6/8	$28,606	$26,606

At the end of the experiment, participants were also required to indicate whether they had constructed the bridges in an automatic way or if they had thought about the different possibilities. In addition, they were asked to guess the aim of the study. The total testing time was about one hour per participant.

4 RESULTS

4.1 The effect of mental set on the design solution

To quantify the extent to which the occurrence of the mental set moderated the participants' design solution, we compared the experimental and the control group in terms of (a) the number of participants who designed the bridges using the more expensive approach in the dual-approach trials (even though an alternative, less-expensive approach was possible), and (b) the proportion of dual-approach trials solved following the more expensive approach.

When designing the bridges in the dual-approach trials, more participants in the experimental group used the more expensive approach compared to the participants in the control group, $\chi^2(1) = 5.90$, p = .01, $\varphi = .40$ (see Table 2). Similarly, the proportion of dual-approach trials solved with the more expensive approach was larger in the experimental group compared to the control group, $\chi^2(1) = 13.93$, $p = .000$, $\varphi = .31$. Because of these tendencies, the total cost of all the bridges designed by those in the experimental group was higher than those designed by the control group (experimental group: M =

$30,077.39, *SD* = 2,701.22; control group: *M* = $27,461.11, *SD* = 1,999.76), $t(34) = 3.3$, $p = .002$, d = 1.10.

Table 2. Number of participants using all the anchor points in the dual-approach trials and number of dual-approach trials solved using all the anchor points (percentages in brackets).

	Number of participants solving the dual-approach trials using all the anchor points	Number of dual-approach trials solved using all the anchor points
Experimental Group	15 (83%)	34 (47%)
Control Group	8 (44%)	13 (18%)

4.2 The effect of mental set on the design process

To evaluate whether, and to what extent, developing a mental set influenced the participants' design process, we compared the experimental group and the control group with regards to (a) the total time taken to design the bridges, (b) the number of structural elements used through the various design-test cycles, (c) the number of design-test cycles, and (d) the behavior exhibited when attempting to construct the least expensive bridge possible.

On average, the experimental group spent more time designing the bridges for each trial (experimental group: *M* = 102.46 seconds, *SD* = 43.41; control group: *M* = 74.44 seconds, *SD* = 36.19), $t(34) = 2.10$, $p = .04$, $d = .70$, and used more structural elements during the design process than the control group (experimental group: *M* = 26.49, *SD* = 8.79; control group: *M* = 19.61, *SD* = 7.21), $t(34) = 2.57$, $p = .01$, $d = .85$. In contrast, the experimental and the control group did not differ with regards to the number of bridge designs tested (experimental group: *M* = 2.44, *SD* = 0.83; control group: *M* = 2.23, *SD* = 0.83), $p = .45$.

Looking at the participants' behavior allowed us to make observations about the ways in which they were designing, not just the design outcomes they arrived at. In particular, when comparing the first and last design-test cycles (across all trials) run by the participants in the two groups, we observed that the first designs tested by participants in the experimental group were more expensive overall than the first designs tested by participants in the control group, $t(34) = 3.18$, $p = .003$, $d = 1.06$. Crucially, as shown in Figure 1, the cost of the first designs tested by the control group was also lower than the cost of the optimal design solution, which demonstrates how participants in the control group often started with very low cost solutions, even though those solutions were not functional.

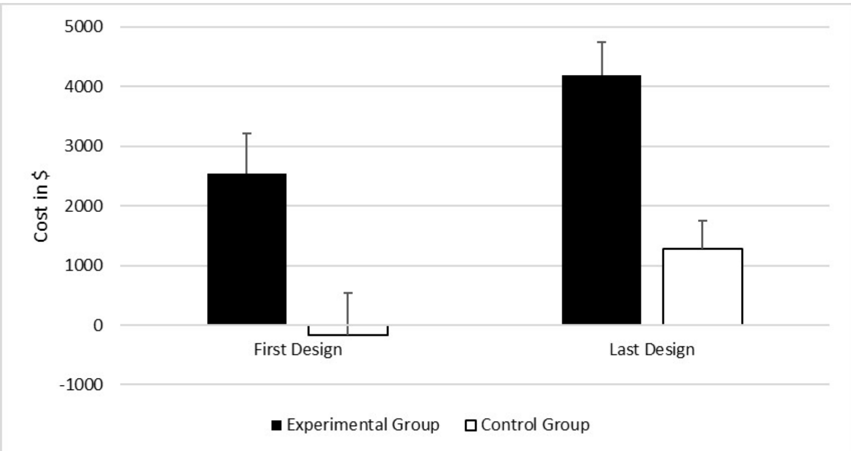

Figure 1. Mean additional cost (and Standard Error) of the last design tested compared to the first design tested. In each case, the additional cost is relative to the cost of the least expensive possible functional solution.

Following this observation, we compared the cost of each tested bridge design to the cost of the optimal design solution (see Table 1). This allowed us to classify the participants' design behavior:

- *'stop if it works'* – designed and tested only one bridge without any further design-test cycles (design cost ≥ optimal design cost);

- *‘strong then cheap’* – started with a functional design that was more expensive than the optimal design solution, and then reduced costs by eliminating structural elements through one or more design-test cycles (initial design cost > optimal design cost);
- *‘cheap then strong’* – started with a low cost design that did not support the load, and then strengthened the structure by incorporating additional structural elements through one or more design-test cycles (initial design cost < optimal design cost).

While the experimental group and the control group did not differ with regards to the frequency with which they exhibited the ‘stop if it works’ behavior (see Figure 2), opposite results were found for the ‘strong then cheap’ and ‘cheap then strong’ behaviors. In particular, the control group more frequently exhibited the ‘cheap then strong’ behavior than the experimental group, $\chi^2(1) = 15.33$, $p = .000$, $\varphi = .32$. Importantly, compared to the ‘strong then cheap’ behavior, adoption of the ‘cheap then strong’ behavior led participants to design less expensive bridges overall, $t(143) = -3.35$, $p = .001$, $d = .55$.

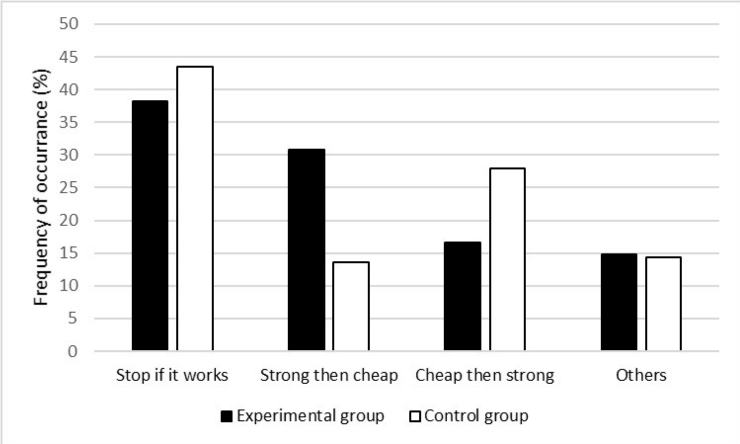

Figure 2. Proportion of trials in which the participants exhibited the ‘stop if it works’ behavior, the ‘strong then cheap’ behavior and the ‘cheap then strong’ behavior. ‘Others’ refer to all the cases in which the behavior could not be classified in one of previous categories or resulted from a combination of them.

4.3 The role of mental set in moderating the subjective experience of the task

To assess the role of the mental set in moderating the subjective experience of the task, we compared how the two groups differed with regards to (a) their awareness of how they had completed the task (i.e. in an automatic vs. reflexive way), and (b) their ability to guess the hypothesis of the study.

More participants in the experimental group (9 out of 18, or 50%) stated that they had designed the bridges in an automatic way compared to those in the control group (only 2 out of 18, or 11%), $\chi 2$ (1) = 7.34, $p = .007$, $\varphi = .46$.

Most of the participants (23 out of 36, or 64%) were unable to guess the general class of phenomena that we were investigating (fixation, bias, mental blocks, etc.). Interestingly, the sub-group that was best able to guess the aim of the study mainly consisted of participants belonging to the experimental group (10 out of 13, or 77%) and they were those who had been the most stuck during the task (participants who guessed the aim of the study accounted for 65.72% of the measured ‘fixated’ designs).

5 DISCUSSION

In line with previous psychological research targeting mental set (e.g. Luchins, 1942), we found that, when working on the dual-approach trials. In comparison to the control group, those in the experimental group more often failed to notice the possibility of a less expensive design approach; they instead continued to design structures following the more expensive approach used in the previous single-approach trials. In other words, the development of a mechanized state of mind fixated the experimental group on a particular design approach (using all the available anchor points), thus preventing the consideration of alternative, lower cost solutions. In addition, participants in the experimental group more often stated that they had constructed the bridges in an automatic way compared to the control group. This provides additional support for the claim that mental set occurs as an automatic repetition of familiar behavior (e.g. Bilalić et al., 2008; Luchins, 1942).

Importantly, and contrary to previous design fixation studies, the fixating solution in our study was one which the participants arrived at spontaneously, rather than one which was directly provided by researchers (e.g., in the form of an example solution). Indeed, although external forms of inspiration have often been identified as sources of fixating knowledge, they are not the only such sources; previous experience with a particular task can also impact subsequent design behavior. In particular, the solution concepts developed in the early stages of the design process can have a limiting effect on later ideation as effort is expended on defending the early direction rather than exploring new ones (e.g., Crilly, 2015). Ball and Evans (1994) regarded this behavior as indicating a fixation on initial concepts, and a reliance on a simple 'satisficing' design strategy in contrast to any alternative more 'well-motivated' process of optimization. Along similar lines, many researchers have reported evidence for the existence of an 'opportunistic' design behavior leading designers to base their decisions on familiar and suddenly-recognised aspects of the task rather than on a hierarchically-structured top-down approach (Bender and Blessing 2004; Cross, 2004; Guindon, 1990; Visser 1994). From this perspective, our findings complement and enlarge previous research into the effect of external inspiration sources on the design outcome by providing new insights into the role of an 'internal' source of fixation taking the form of a premature (and unconscious) commitment to previously explored solution patterns.

While examining design outcomes allowed us to evaluate the role of mental set in moderating the design solution, looking at the process of designing gave us the possibility to make observations about the nature of fixation episodes and the conditions in which they occurred. This was possible thanks to the use of a digital platform which captured design behavior throughout the task. We found that the occurrence of mental set in the experimental group led those participants to include more structural elements in their designs, and to spend more time designing the bridges. More interestingly, we observed that participants in the two groups showed different behaviors in their attempts to design the least expensive bridge that would support the load: the experimental group more often demonstrated a 'strong then cheap' behavior whilst the control group tended to demonstrate a 'cheap then strong' behavior. In light of this observation, we hypothesize a different role for 'functional objectives' (i.e. structural support) and 'resource constraints' (i.e. available budget) in moderating the design behavior of the two groups. While the behavior of the experimental group was mainly driven by the objective of designing a functional structure, the control group was more focused on the constrained resources, designing the least expensive bridge possible. The occurrence of these different patterns of behavior may have been induced by the different order of trials for the two groups, leading participants in the control group to approach the post-extinction trials by adopting a step-by-step approach (i.e. a step-wise increment of the bridges' strength), ultimately resulting in more efficient designs.

Our observations of the participants' design process can be connected to Fricke's (1999) accounts of early stage design strategies. He distinguished between a "function-oriented" strategy, in which the design operations are carried out for one initial function until a satisfying level of concretisation is reached, and a "step-wise process-oriented" strategy, which follows a hierarchical and sequential plan of action, executing basic design operations step by step. In his study, Fricke noticed that, compared to the stepwise "process-oriented" strategy, the "function-oriented" strategy resulted in the generation of fewer solution variants. When combined with our findings, Fricke's observations suggest that the strategy designers use while working on a problem impacts the type and variety of solutions they generate. This highlights a need for design fixation research to investigate (a) the influence of different design strategies on the occurrence of fixation episodes, and conversely (b) the influence of fixation episodes in determining the adoption of different design strategies (see Snider, Dekoninck, and Culley, 2016).

In summary, we believe that our method promises a number of advantages over traditional design fixation studies:

- • observation of design fixation beyond the context of idea generation;
- • more objective analysis of design behavior (because the design task is partially constrained and outputs can be tested automatically);
- • clear evaluation of the effects of objectives and constraints on design performance (because the objectives and constraints are well defined and performance is directly measured);
- • evaluation of design fixation episodes occurring during the design process (because using a digital platform allows researchers to conveniently capture and record design activities, not just the outputs).

In addition, providing feedback on design performance (through the possibility to switch between the Design and the Test mode) allowed us to simulate an important part of design activities that allow for rapid testing or simulation. Finally, our observation that having experienced fixation during the design activity increased participants' awareness of the occurrence of this phenomenon highlights some potential for using a variant of our method to encourage designers to recognize fixation effects and possibly overcome them (for a review of research on computer-based game-like tasks as a means to promote behavioral and attitudinal changes, see Michael and Chen, 2006).

Despite the differences between our study and a conventional design fixation experiment, in some ways it is also quite similar, especially with respect to the characteristics of the participants (inexperienced, unspecialized), the duration of the task (short) and the discipline of design (Engineering). Whilst these features might all pose problems for generalizing our results to other kinds of design practice, that is not our objective here. We only seek to make claims about methodological options, and the type of method we demonstrate is equally applicable to expert designers working on long-duration tasks. Of course, our particular task only relates to structural design, but future research might explore mental set in different types of design activities. All those design practices that involve repeatedly solving similar but different design problems might be subject to mental set, including design work that produces plans for similar but different structures, mechanisms, electrical circuits and software routines. In such cases, it could be that an implicit assumption leads designers to repeat a category of solution or the means by which that solution is reached. Investigating mental set in engineering practice might either reveal differences in how fixation is manifest in different problem types, or might reveal that the phenomena of interest are in fact quite similar, and that researchers should select their experimental tasks based on the methodological opportunities those tasks offer rather than on some similarity to specific design practices.

6 CONCLUSION

Over 25 years, design fixation has provided researchers from a variety of backgrounds with a compelling, important, and uniquely cross-disciplinary design phenomenon to study. However, to date, studies of design fixation have been quite homogenous in the experimental approach adopted. That approach suffers from a number of methodological limitations related to the way in which the occurrence of fixation episodes is identified (i.e. at early stage ideation), the characteristics of the design problems (i.e. ill-defined and ill-structured problems), the type of data that are collected (i.e. participants' final design ideas) and the way in which the data are analysed (i.e. through various subjective metrics). The method we propose here provides a promising future direction for fixation research, offering a more objective, repeatable and comparable description of the various phenomena of interest. In conclusion, although design fixation research has already made good progress with a very limited set of experimental techniques, there are great opportunities for developing other approaches. Applying a broader range of experimental methods might be expected to generate richer insights into fixation, how it occurs and how it might be mitigated.

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