Inspiration and fixation: Questions, methods, findings, and challenges

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Research into inspiration and fixation has produced a complex web of questions, methods, and findings, making it difficult to know what has already been investigated and learnt, and what to investigate next and how. To address this, we review the literature, focussing on 25 studies that adopt a similar experimental approach. This reveals 14 manipulated variables, relating to properties of the inspiration source and features of the design process. However, whilst these studies follow a similar approach, when scrutinised and compared, they show great variety in the methods used and the results obtained. We discuss this diversity, offering a methodological critique of inspiration and fixation research and providing recommendations for how future studies might be conducted and reported.

Keywords: fixation, creativity, design process, problem solving, design research

Creativity is often associated with better designs in education and practice (Christiaans, 2002) and is considered a prerequisite for invention and innovation (Sarkar & Chakrabarti, 2011). This has motivated design researchers to conduct many empirical studies into creativity. In particular, a number of studies have focused on using external sources of inspiration to stimulate the idea generation stage of the design process. These external stimuli are introduced to the design process and are known to help designers arrive at new ideas that it would otherwise be very unlikely to emerge. As such, many studies highlight the positive outcomes and benefits of using external stimuli during idea generation (e.g. Dugosh, Paulus, Roland, & Yang, 2000; Dugosh & Paulus, 2005; Liikkanen & Perttula, 2008; Nijstad, Stroebe, & Lodewijkx, 2002; Perttula & Liikkanen, 2006a). However, when designers are provided with example solutions to the problem that they are considering, this may unfavourably interfere with the creative process, a phenomenon that has been called 'design fixation' (Jansson & Smith, 1991). In researching this phenomenon, the negative effects of external inspiration sources have been extensively discussed by many researchers (e.g.

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Dahl & Moreau, 2002; Linsey et al., 2010; Perttula & Sipilä, 2007; Purcell & Gero, 1996; Smith, Ward, & Schumacher, 1993).

The prevalence of studies into inspiration and fixation allows authors of such studies to frame their research with a review of other similar work. These studies have also recently been the subject of more extensive surveys, reviewing fixation classifications and types (Youmans & Arciszewski, 2014), and performing a meta-analysis of the results of a set of comparable studies (Sio, Kotovsky, & Cagan, 2015). These two reviews contribute to the literature in different ways: the first is qualitative and classification-oriented, defining what is being studied; the second is quantitative and results-oriented, revealing what has been found. However, there has not yet been a thorough methodological analysis of how the studies are conducted. This makes it difficult to establish an overview of the experimental choices and setups adopted, and difficult to interpret and compare the results obtained. To address this, the present paper reviews the relevant literature from a methods-oriented perspective, focussing on how the studies have been designed and implemented. Whilst the studies typically yield quantitative results, describing the methodology used to obtain such results (and the ways in which it varies) is largely a qualitative matter. As such, we do not aim to integrate results and identify patterns in the literature, but to acknowledge the diversity of results in the field and explain such variety based on methodological factors. We highlight where results conflict, provide some reasons that could explain this, and suggest what other concerns researchers should have about the literature. In doing so, the paper contributes towards a better understanding of the different ways in which inspiration and fixation can be studied, and how the results should be interpreted. Our objective is to help the field to clarify some of its current issues and to plan its future directions.

The rest of the paper is structured as follows. To establish a broader context for our analysis, Section 1 reviews the early psychological research related to fixation and compares it to empirical design research, presenting an overview of how fixation is interpreted and studied. Section 2 reviews the research questions asked in the literature, the variables manipulated to address those questions, what those experiments have found and where those findings conflict. The studies are grouped with respect to the aspects they examine, a grouping that is not obvious from the literature because the relevant variables by which the studies can be interrogated and compared are often only implicit. Section 3 reviews some challenges to interpreting the current research, especially methodological details that vary between experiments. These include potentially important variables that have not been systematically manipulated, differences in what is measured and how, and possible explanations for the measured effects. Finally, Section 4 makes recommendations for how research into inspiration and fixation could adopt a more consistent approach to conducting and reporting experimental studies, whilst also incorporating non-experimental methods. The paper thus offers useful information and perspectives for those new to the field and also for those who are already expert.

1 What is design fixation?

The term fixation usually refers to an effect originally described in the experimental psychology literature, an effect in which an individual might unconsciously focus on certain aspects of an object or a task, whilst leaving others aside. For instance, the term functional fixedness, first introduced by Duncker (1945), refers to the way an individual becomes fixated on one particular function of a product (also see earlier investigations by Maier (1931)), acting as a block to creatively reinterpreting the function of an object with which one is familiar (e.g. thinking of pliers as a pendulum bob). Similarly, mental-set or the *Einstellung* effect, proposed by Luchins (1942), refers to the way an individual becomes fixated on a particular process, acting as a block to finding different ways to solve a problem (e.g. finding a simpler path instead of repeating the one previously used). Originally, functional fixedness was studied with respect to long-standing associations, whereas mental set was studied with respect to an experience immediately preceding the problem-solving attempt (Smith & Blankenship, 1991). However, whether someone is fixated on a function or a process might be independent of whether that fixation is caused by long-term or short-term associations.

The investigation of fixation effects in design activities followed on from more general investigations of functional fixedness and mental-set. Jansson and Smith (1991) showed designers an example solution to a problem as part of the design brief and found that this reduced the designers' propensity to move effectively between the conceptual space (of abstract ideas) and the configuration space (of potential solutions). Jansson and Smith described design fixation as the blind adherence to a limited set of ideas in the design process. According to them, fixation occurred in their experiments when features from the example solution were incorporated into the participants' own designs. These features were sometimes problematic (e.g. contradicting the brief) and this was taken as evidence that the repetition was blind and counterproductive.

Since Jansson and Smith's first study, the idea of design fixation has attracted many researchers from a variety of backgrounds. Whilst this diversity of backgrounds has brought a valuable range of perspectives to the field, it has also led to different understandings of what fixation is and it is possible that different types of fixation are being discussed (Youmans & Arciszewski, 2014). Consequently, the interpretation of design fixation has sometimes been narrowed from its initial meaning and sometimes broadened. Narrower interpretations of fixation may focus on a designer's overreliance on the features given in examples (Youmans & Arciszewski, 2014) or a tendency to structure new creations that conform to a familiar model (Finke, 1996). In contrast, broader interpretations may just consider any cognitive interference that guides the design work (Perttula & Sipilä, 2007) or any process that can interfere during creative acts (Agogué, Poirel, Pineau, Houdé, & Cassotti, 2014). Perhaps even more broadly, it is also possible to understand design fixation as a specific instance of low creativity levels (Zahner, Nickerson, Tversky, Corter, & Ma, 2010). As a result of this conceptual range, research into design fixation has approached its subject from different perspectives or has even been approaching different subjects. However, what is quite consistent is that fixation is framed as an unfavourable phenomenon, with most of the studies presenting ways to avoid, mitigate or overcome it.

As with the interpretation of design fixation, there is also some variation with the method applied in the experiments, although a common procedure might be observed. The studies typically require that a number of participants (often students) work individually to generate multiple solutions to a given problem in a controlled environment (often in a class setting). Due to the limited time available in most of the experiments (often an hour or less), the problem statements that are provided to participants are quite simple and so are and the design outputs that are required from them. The participants are divided into experimental groups, typically with only some of those groups being exposed to external stimuli, either before starting to generate solutions or when they are already engaged in generating solutions. The impacts of this stimulation are tested through metrics that are either relatively objective (such as the number of final concepts, the number of different types of concepts and the repetition of key features from the stimuli) or more subjective (such as the novelty, feasibility and ease of use of the final concepts). Lastly, the results are analysed and rated, comparing the design work of the different treatment groups and control groups.

Whilst typically following the experimental paradigm outlined above, the different inspiration and fixation experiments to date have explicitly manipulated a range of different variables. The next section seeks to understand these variables by discussing the main findings of the studies that address them.

2 *Variables manipulated in the studies*

Studies of inspiration and fixation are mainly concerned with the idea generation phase of the design process. They typically manipulate variables relating to the stimuli that are presented to the participants (such as the novelty and quantity of the stimuli), but they also manipulate variables relating to the design process (such as the characteristics of the participants, the size of the group and the time available). Recently, Sio et al. (2015) reviewed a set of studies looking for commonality in the results, mapping and statistically analysing some of the manipulated variables (namely 'timing of presentation', 'common-ness of the example', and 'number of examples'). Here we investigate a broader set of 14 variables found in the literature reviewing each of them qualitatively. We collect studies together according to the variables they manipulate, noting where there is agreement between them and highlighting where there are disagreements.

Whilst we discuss a broad range of studies in this section, only a subset of papers 25 are examined closely. This selection focuses only on studies that have used external stimuli as inspiration sources and provides an overview of the empirical research into external inspiration and design fixation. The methodological details of these studies are presented in summary tables, with each row corresponding to a publication. Where a publication refers to more than one experiment, all experiments within scope are considered for that publication. This basic table structure is repeated throughout the following sections of this paper.

2.1 External stimuli

A large number of studies investigate how different properties of external stimuli affect the design process and the outcomes that result. These properties may relate to the modality of representation used for the stimuli and the fidelity of that representation, the quantity of stimuli and their proximity to the design problem, the diversity and novelty of the stimuli, and the timing of their presentation. These variables are discussed in each of the subsections that follow, with each subsection summarised in a column of Table 1.

2.1.1 Modality of representation

External stimuli can be represented in many ways, such as real objects, pictures, words, and videos. Research has shown that textual stimuli can help participants increase their originality (Goldschmidt & Sever, 2011). It was also found that using general linguistic representations when learning about similar products plays a positive impact on designer's ability to use them (Linsey, Wood, & Markman, 2008). However, research suggests that designers tend to prefer working visually (Hanington, 2003) and that they are more inspired by visual stimuli (Goldschmidt & Smolkov, 2006) but they are equally more susceptible to negative effects from them (Chrysikou & Weisberg, 2005). Similarly, Sarkar and Chakrabarti (2008) provide evidence to support the claim that non-verbal representations (image and video) increases both the quantity and quality of designers' solutions. Additionally, when comparing the use of 2D images and 3D objects, Toh and Miller (2014) found that images still yield better results, as physical objects reduced the novelty and variety of the final concepts. In general, it is suggested that multimodal stimuli are particularly important for ideation. For instance, Sarkar and Chakrabarti (2008) claim

Table 1 External stimuli variables manipulated in inspiration and fixation studies. 'X' indicates where a given variable was assigned a particular value. '?' indicates where it was not possible to identify the value assigned to a variable. 'IG' stands for idea generation

First author, year	*Modality of representation*				*Fidelity*		*Quantity*		*Proximity*		*Diversity*		*Novelty*		*Timing*		
	Text	*Picture*	*Diagram*	*Physical objects*	*Abstract*	*Concrete*	*One*	*More*	*Within*	*Between*	*Self-similar*	*Diverse*	*Common*	*Novel*	*Before brief*	*Along brief*	*During IG*
Cardoso, 2011		X			X	X	X		X		X		X			X	
Cheng, 2014		X			X	X		X	X			X	X			X	
Chrysikou, 2005	X	X			X		X		X		X		X			X	
Dahl, 2002		X			X		X	X	X		X		X		X		
Fu, 2013	X		X		X			X	X	X		X	X	X			X
Goldschmidt, 2006		X		X	X			X	X	X	X	X	?	?	?	?	?
Gonçalves, 2012	X				X	X	X		X	X	X		X	X	X	X	X
Jansson, 1991	X	X			X		X		X		X		X			X	
Liikkanen, 2008	X				X		X			X	X		X			X	
Linsey, 2010	X	X			X		X		X		X		X			X	
Lujun, 2011	X	X			X		X		X		X		X			X	X
Moreno, 2014	X	X			X			X		X	?	?	?	?			X
Nijstad, 2002	X				X			X	X	X		X	X				X
Perttula, 2006a	X	X			X			X	X			X	X			X	
Perttula, 2007	X	X			X			X	X			X	X	X		X	
Purcell, 1996	X	X			X			X	X		X		X	X		X	
Sarkar, 2008	X	X	X		X	X		X		X	X		X				X
Siangliulue, 2015	X					X		X	X			X		X			X
Smith, 1993		X			X			X	X		X			X	X	X	
Toh, 2014		X		X		X	X		X		X		X			X	
Tseng, 2008	X				X			X	X	X	X	X	X			X	X
Viswanathan, 2014				X		X	X		X		X		X			X	
Yilmaz, 2010	X	X			X			X	X		X		X			X	X
Youmans, 2011a	X	X				X	X		X		X		X			X	
Youmans, 2011b				X		X	X		X		X		X			X	

that although pictorial representations are probably better for providing specific information, diagrams are known to be more effective for describing general information and making search and recognition easier. Thus, it is expected that a combination of modalities will result in more complete inspiration. Experimentation has shown, however, that even a single word, when introduced to participants prior to idea generation, can affect the subsequent design work (Liikkanen & Perttula, 2008). According to the literature, different modes of representation will affect idea generation in different ways, and it might be that the most appropriate modality to use depends on the task at hand.

2.1.2 Fidelity of the representation

The solutions offered to participants can be represented at different levels of detail. For example, the stimuli might clearly resemble an actual product or only provide some clues of what that could be. Some research analysed the influence of the fidelity or level of abstraction of both textual descriptions and pictorial representations on problem solving. For example, Gonçalves, Cardoso, and Badke-Schaub (2012) found that when industrial designers were exposed to a verbal description that only provided clues to a potential solution, their ideas were more numerous, and more diverse and original than the ideas of those who saw either a description of a solution itself or a description of a completely unrelated phenomenon. In a similar study, Cardoso and Badke-Schaub (2011) compared the design work of participants exposed to line drawings as visual stimuli (abstract or low-fidelity) to that of participants exposed to real pictures of the mechanism and its parts (concrete or high-fidelity). Whilst no significant differences were found with respect to the repetition of key attributes, exposure to high-fidelity iconic representations seemed to yield less novel ideas. Similarly, Cheng, Mugge, and Schoormans (2014) concluded that industrial designers who were shown only partial photographs of products developed more original solutions than those who saw the full photographs. Participants also reported that they paid more attention to details in the partial pictures condition. Overall, the studies indicate that changing the fidelity of the representation of stimuli (and possibly using low-fidelity or more abstract stimuli) may help in counteracting fixation, although some fixation is still likely to occur.

2.1.3 Quantity

Inspiration in design can result from either a single stimulus or from many. In one study, Perttula and Liikkanen (2006a) observed the influences of presenting multiple stimuli to participants. Whilst some participants were presented with no stimuli prior to idea generation, others were presented with four designs based on different principles. Perttula and Liikkanen found that, when compared to analogous studies into design inspiration and fixation, participants in their experiment seldom included solutions from the categories represented in the examples, which indicates the absence of fixation. Thus, using several different kinds of stimuli can be a means to avoid fixation and increase the number of final concepts. However, when comparing the work of the treatment and control groups, no significant differences were found, so the influence of the number of stimuli is not clear. Similar results were found in another study, in which the number of examples presented to the participants had no influence on the solutions that they arrived at (Perttula & Sipilä, 2007). In a similar fashion, Dahl and Moreau (2002) found that increasing the number of examples (provided before idea generation) did not increase the number of seemingly distant analogies that were drawn during the design process. The same held for the originality and perceived value of solutions. As a result, exposure to any concrete example – irrespective of their quantity – might inhibit the creativity of participants and affect the potential of the concepts they create. In fact, it might be the case that providing several example solutions can actually further inhibit creativity instead of enhancing it (Sio et al., 2015), and one possible explanation is that there are more concrete properties of the examples to attract the attention of the participants (Dahl & Moreau, 2002). However, this seems to be true only when examples that promote the use of near analogies are provided, thus it is expected that using examples from very different domains helps to avoid fixation in design and may increase creativity. Still, from the literature it is not clear how many stimuli to present to designers when trying to limit fixation effects.

2.1.4 Proximity to the problem

Stimuli can be regarded as relatively 'near' or 'far' from the problem domain (Fu et al., 2013) Although research on stimuli proximity does not present clear boundaries for what could be considered near and far, there is good support for the idea that stimuli that are neither too near nor too far from the problem domain are more likely to produce creative insights and novel solutions (Chan et al., 2011; Dahl & Moreau, 2002; Fu et al., 2013; Gentner & Markman, 1997; Gonçalves et al., 2012; Linsey et al., 2010). It was also found that providing participants with (unfamiliar) biological examples increased idea novelty when compared to no examples used, while (familiar) human-engineered examples will decrease the variety of ideas (Wilson, Rosen, Nelson, & Yen, 2010). However, related problem solving studies in psychology revealed that when there are no directive hints, analogous thought is not likely to be enhanced (Anolli, Antonietti, Crisafulli, & Cantoia, 2001; Gick & Holyoak, 1980, 1983), indicating that spontaneous analogical transfer is not simple. Still, if there is enough 'surface similarity' or 'proximity' between previous analogues and the current problem, designers are more likely to transfer information between the two cases (Holyoak & Koh, 1987; Keane, 1987). In that sense, it is likely that there is some optimal distance between the problem and the stimuli, but research has only offered general suggestions for what this distance is.

2.1.5 Diversity

When considering multiple stimuli and their domains, mechanisms, or structures, the stimuli may vary from being self-similar (sharing many characteristics among themselves) to diverse (being different from each other in some way). Nijstad et al. (2002) found that a diverse range of stimuli can activate different aspects of a participant's knowledge. In their experiment, this diversity generated a greater variety of solutions even if the exploration of any given solution was quite superficial. In contrast, stimuli that were similar to each other only activated a single or narrower aspect of knowledge. Self-similar stimuli can therefore cause designers to explore fewer categories of solutions, but to explore those categories more deeply. The best scenario seems to happen when diverse stimuli are presented in a structured way, which enables different categories to be covered as well as sufficient exploration of each category. Additionally, it was found that being exposed to diverse stimuli might reduce the response latency (i.e. time between two ideas) when participants change categories, at the same time that it does not affect the response latency when they are 'repeating' solutions within the same category. As a result, participants can increase their productivity when category changes occur as fast as the repetition of similar ideas within a category (Nijstad et al., 2002). Results from Goldschmidt and Smolkov (2006) also indicated that rich and diverse stimuli help designers be more original in design problems for which aesthetics and emotional appeal are very important. Overall, it seems that the stimuli diversity can affect idea generation in different ways, and the right diversification will depend on what each brief requires from the designers.

2.1.6 Novelty

Whether the stimuli are novel or not may be cause for different levels of inspiration or fixation in designers, and therefore fixation research has been testing how participants respond to common and uncommon examples. Purcell and Gero (1996) analysed the influence of stimuli novelty. In the experiments they conducted, which in general found little evidence of fixation, adopting a novel example as stimulus did not show any significant impact with respect to fixation in participants. However, they add that fixation could be associated with the principles or mechanisms involved in the example design rather than just its external features. In contrast, Perttula and Sipilä (2007) found a correlation between the novelty of the stimuli presented and a positive design outcome. They noted that common stimuli decreased the number of new solutions and increased the repetition of aspects from the examples provided. This happened even though participants were told to use the stimuli just as triggers and that they should aim at generating the largest variety of ideas. Dugosh and Paulus (2005) also found that when compared to novel examples, common examples tend to cause more fixation. Considering these studies, the inspiration material should probably include both novel and common examples but it is difficult to tell exactly what influence the novelty or commonality of stimuli has on idea generation.

2.1.7 Timing of stimulation

Stimuli can be presented to designers at different moments during the design process, such as before they engage in the task, along with the design brief, when already engaged in idea generation, or perhaps when idea generation is ending. Sio et al. (2015) suggest that the moment when stimuli are provided to designers might also play an important role in idea generation, and that the earlier the examples are provided, the larger the positive impact on design solutions will be. However, Tseng, Moss, Cagan, and Kotovsky (2008) add that the nature of the impact is affected by the proximity of the example to the problem. For instance, distantly related stimuli impact more positively the design process when it has already started while near ones have more effect before any design activity takes place. Perttula and Liikkanen (2006b) also found that designers explore more categories when stimuli are presented in the middle of the process than when they are presented at the beginning. This idea is supported by the idea that new information is more effective to designers when they eventually come to an impasse in problem solving (Moss, Kotovsky, & Cagan, 2007). However, Siangliulue, Chan, Gajos, and Dow (2015) add that reaching an impasse is not enough; people should be aware that they are stuck in order to benefit from external stimuli. They report that examples automatically shown to participants who had temporarily run out of ideas might lead to more ideas, but not necessarily better ones. Stimuli presented to participants on demand, however, were found to lead to more novel ideas. Thus, apart from considering properties of the stimuli, an equally important aspect to take into account when providing designers with stimuli is the timing for inspiration and what difference that could make to designers' cognitive processes.

2.2 Design process

In addition to manipulating properties of the stimuli, other aspects that influence the participants' work in the experiments have also been investigated. These other variables are related to the design process in some way, including the characteristics of the participants (i.e. level of experience, disciplinary background), the way in which the task is presented (e.g. level of problem abstraction and instructions to prevent stimuli reproduction), and the context within which the design work is performed (e.g. duration and group size). These variables are discussed in each of the subsections that follow, with each subsection summarised in a column of Table 2.

2.2.1 Experience of the participants

In design, experiments into inspiration and fixation are most often conducted with university design students (with varying levels of experience) or

Table 2 Design process variables that have been manipulated in inspiration and fixation studies

First author, year	*Experience*				*Disciplinary background*		*Problem abstraction*		*Instructions for reproduction*		*Time available (up to)*				*Testing*		*Group size*	
	Novice student	*Senior student*	*Novice designer*	*Expert designer*	*Mixed*	*Unique*	*Concrete*	*Abstract*	*None*	*Cons-training*	*30 m*	*60 m*	*2 h*	*Gap*	*None*	*Proto-type*	*One*	*Team*
Cardoso, 2011		X				X	X		X			X			X		X	
Cheng, 2014		X				X	X		X			X			X		X	
Chrysikou, 2005	?	?			X		X		X	X	X				X		X	
Dahl, 2002	X	X				X	X		X			X			X		X	
Fu, 2013	X	X			X		X		X		X				X		X	
Goldschmidt, 2006		X			X		X		X		X				X		X	
Gonçalves, 2012	X					X		X	X			X			X		X	
Jansson, 1991		X		X		X	X			X		X			X		X	
Liikkanen, 2008		X				X	X		X		X				X		X	
Linsey, 2010			?	?	X		X		X			X			X		X	
Lujun, 2011	X					X	X		X		X				X		X	
Moreno, 2014				X	X			X	X		X			X	X		X	
Nijstad, 2002	?	?			?	?		X	X		X				X		X	
Perttula, 2006a		X				X	X			X	X				X		X	
Perttula, 2007		X				X	X			X	X				X		X	
Purcell, 1996	X	X		X	X		X		X			X			X		X	
Sarkar, 2008			X		X		X		X		?	?			X		X	
Siangliulue, 2015			?	?	X		X		X		X				X		X	
Smith, 1993	?	?			?	?		X		X	X				X		X	
Toh, 2014	X					X	X		X		X				X		X	
Tseng, 2008		X				X	X		X		X				X		X	
Viswanathan, 2014	X					X	X		X				X	X		X		X
Yilmaz, 2010	X					X	X			X		X			X		X	
Youmans, 2011a	?	?			X		X		X		X				X		X	
Youmans, 2011b	?	?			X		X		X			X				X	X	X

professional designers (again with varying levels of experience). Wiley (1998) suggests that although experts might solve problems more efficiently than novices due to their structured knowledge, this knowledge can also limit their solution search to a known space in which the best solution may not reside. Accordingly, Kim and Ryu (2014) compared the design process of expert and novice designers and concluded that expert designers are more effective at framing design problems as well as being more committed to their own previously developed design concepts, which means that they may exhibit more fixation than novice designers. A similar relation was noted in a student context: it was found that graduating engineers are often less innovative than freshmen students (Lai, Roan, Greenberg, & Yang, 2008). These results, however, vary considerably in the presence of external stimuli. For instance, Linsey et al. (2010) report a study in which experienced academic designers produced a larger number of novel solutions after exposure to an example design when compared to novices in similar studies. According to Dahl and Moreau (2002), experience might provide some immunity to fixation derived from exposure to examples and help designers create potential problem spaces and explore them. However, it is noteworthy that experience can also limit an individual to conform too much to previous practical knowledge. As a result, it is not clear what level of experience allows designers to be most creative, but it is known that both experts and novices can make effective use of external stimuli and visual analogies to improve their performance (Casakin & Goldschmidt, 1999).

2.2.2 *Disciplinary background of the participants*

As with the experience of individuals (i.e. accumulated practical knowledge), their disciplinary background (i.e. field of practice or study) also relates to inspiration and fixation. Agogué et al., (2014) found that an individual's background might influence how deep or wide the exploration of solution spaces is. For instance, when compared to engineers, industrial designers were be more capable of generating solutions outside common and easily-accessible solution spaces, which suggests that industrial designers can be more resistant to conform to design fixation. Engineers, on the other hand, provided more complex and detailed solutions with respect to the working mechanism underlying the idea. In other words, although industrial designers create a greater number and variety of solutions, engineers might be more concerned with how these solutions will actually solve the problem. These results reinforce the early studies into design fixation performed by Purcell and Gero (1996) in which they found that when compared to mechanical engineers, industrial designers produced more designs, more types of design and more unique designs, whether they were exposed to external stimuli or not. This may reflect something about design education that makes industrial designers continuously search for difference, perhaps even becoming fixated on being creative (Purcell & Gero, 1996). As such, the education or training of individuals (which defines their background) seems to impact directly on solutions they create; therefore, some profiles may be more susceptible to fixation effects than others.

2.2.3 Problem abstraction

In inspiration and fixation experiments, problem statements or briefs vary in their length, level of detail and how explicit they are, and participants may interpret and respond to them differently on this basis. When generating alternative solutions, problem abstraction is required to draw analogies between dissimilar domains and to identify similarities between apparently different structures. It is important to notice, however, that abstraction should not modify content, but make the problem independent of domain or context instead (Zahner et al., 2010). When investigating these aspects, Zahner et al. (2010) found that abstract problems promote the divergence of ideas, whilst more concrete problems increase convergence. However, if a problem is framed in terms that are too abstract, then alternatives are less likely to fit the problem requirements, and if it is too concrete the solutions become similar and converge within a domain. In other words, abstract definitions for problems can enhance the number of ideas, the number of domains represented by the ideas and the overall originality of solutions. Concrete definitions, on the other hand, are more likely to yield solutions that better fit the problem constraints. Similarly, Liikkanen and Perttula (2008) revealed that defining a context in the problem statement (or brief) has also been proven to influence the final designs, especially with respect to the diversity of ideas. The context defines the problem space and is therefore necessary for retrieving memory related to the problem. Conversely, the absence of information about the context can activate a contextual defaulting strategy, therefore leading to self-similar solutions. Overall, it seems important to specify context and constraints when defining a problem and designing for it, but at the same time some abstraction of the problem is beneficial; the most appropriate balance, however, is not clear.

2.2.4 Instructions for reproduction

Instructions provided to participants can be more or less restrictive with respect to how participants may use and reproduce the inspiration sources. Chrysikou and Weisberg (2005) found that informing participants of the presence of negative features in example solutions was not enough to avoid fixation; participants had to be asked to avoid using the negative features in order to eliminate the fixation effect. They also reported an additional outcome of using instructions to prevent feature duplication, which is an apparent increase in the difficulty of the task. When using examples of design heuristics to help design students generate new concepts, Yilmaz, Seifert, and Gonzalez (2010) also reported instructing the students not to repeat the examples in their own designs. The researchers found no fixation and reported that the stimuli used were beneficial to the students' work. However, it is not clear whether the positive results can be attributed to the constraining instruction or not. In contrast, the results from Jansson and Smith (1991) revealed the occurrence of design fixation even when students were instructed to avoid using features from the example provided. Perttula and Sipilä (2007) arrived at similar conclusions, even though they clearly instructed participants not to reproduce the examples as such. Moreover, Smith et al. (1993) found that explicitly telling participants to diverge as much as possible from the examples (and not only prohibiting participants from reproducing the examples) did not decrease the participants' conformity to example solutions. One possible explanation for this, as LeFevre and Dixon (1986) suggest, is that participants are naturally more likely to follow the examples given than they are to follow the instructions. In summary, although it has been show to affect inspiration, research has been equivocal on the benefits of constraining instructions when providing stimuli to designers.

2.2.5 Time available

When the experiments are conducted, the participants are only given a certain amount of time to explore the solution space and to represent their ideas. When analysing the difference between short and long periods of idea generation, Tsenn, Atilola, McAdams, and Linsey (2014) found that their participants generated more diverse solutions when allowed to work for longer time periods, and that the additional time increased the level of creativity of the solutions. However, even though participants continued generating solutions, the rate of idea generation decreased. This study also suggests two related findings. Firstly, whilst novelty and quality of the participants' concepts do not seem to vary through the duration of the experiment, a longer procedure yields more varied solutions (covering a wider range of solution categories) and more non-repeated solutions. Secondly, time away from the problem (or what Smith (1995) and Wallas (1926) would describe as incubation) was shown to mitigate design fixation because more varied and novel solutions were observed after participants had a long period away from the task; the quality of the solutions remained similar however. Youmans (2011a) also found that interrupting participants (e.g. a sudden change of task) could impact positively on the way they design under fixation, especially if the disturbance happens in the very early stages of conceptual design. In contrast, Siangliulue et al. (2015) revealed that participants who were regularly interrupted to pay attention to examples were less productive, resulting in the generation of fewer ideas. Summing up, in order to deal with fixation induced by external inspiration sources, it seems having enough time to generate ideas and spend some time away from the task may help.

2.2.6 Testing the ideas

In most of the inspiration and fixation experiments, participants do not get to test their ideas, but are only required to sketch and describe them. However, in less restrictive design contexts, prototyping and model building are common ways to test ideas and develop them further. Viswanathan and Linsey (2011) observed that working with physical models such as prototypes can reduce cognitive workload, visualizing solutions for complex problems, and identifying flaws in concepts; therefore leading to more feasible ideas. Similarly, Youmans (2011b) observed that building models and testing the solution against its requirements (i.e. validating an early-stage design) increased the chances of producing solutions that are both more original and more useful. In addition, Youmans (2011b) states that prototyping helps reducing fixation and leads to superior designs, therefore improving innovative design thinking, while it could also be a quick and inexpensive design method. In the same direction, Kershaw, Hölttä-Otto, and Lee (2011) indicate that constant prototyping through the design process might mitigate fixation, especially if individuals would otherwise receive no feedback on the concepts they develop. Jang and Schunn (2012) also report positive results of prototyping: they argue that using prototypes early during idea generation led participants to create more innovative designs, although using prototypes late was not correlated with the success of the experimental groups. Consistent with this last point, Vidal, Mulet, and Gómez-Senent (2004) found no correlation between idea generation and physical models. In fact, there is even some evidence suggesting that being exposed to prototypes can inhibit the creation of between-domain or distant analogies, therefore constraining the creative process (Christensen & Schunn, 2007). Negative effects of prototyping are also reported by Viswanathan and Linsey (2011), when they describe how participants can fixate on their own initial solutions due to a phenomenon called the sunk cost effect (Arkes & Blumer, 1985), i.e. investing effort and time in developing a physical model leads designers to become more attached to it. As has been noted, it is not clear how working with prototypes can be beneficial − or harmful − for the creative process.

2.2.7 Group size

Although some studies emphasise the benefits of group work and supports the idea that groups will outperform individuals working alone (Brodbeck & Greitemeyer, 2000; Shaw, 1932; Tindale & Larson, 1992), other studies suggest that, in fact, it can inhibit creative thinking and yield worse results than if individuals had worked alone (Mullen, Johnson, & Salas, 1991; Nijstad & Stroebe, 2006; Taylor, Berry, & Block, 1958), or even that no difference can be measured (Youmans, 2011b). Indeed, some evidence indicates that the group is only as good as its best individual, with the ability of that individual predicting the overall success of the group (Tindale & Larson, 1992). When working in groups, mutual stimulation may lead to what is called the 'assembly bonus' effect, whilst interference caused by other members may lead to a 'mutual production blocking effect' (Nijstad et al., 2002). Therefore, being introduced to others' ideas can have both positive and negative impacts when designers work in groups. Additionally, ideas that are offered by others can become new search cues for the individuals. This can interrupt the idea generation process of an individual, but it can also reduce the time needed to produce new search cues and speed up the search for related knowledge in memory, therefore being beneficial (Nijstad et al., 2002; Perttula & Sipilä, 2007). It is believed that group work can also help sharing the cognitive workload of the task among team members (Youmans, 2011b). Thus, if we understand design as a knowledge-based activity, it is the case that when compared to homogeneous teams, heterogeneous teams generate a greater variety of ideas and are more efficient in producing those ideas, as suggested by Liikkanen and Perttula (2008). On the whole, however, it is difficult to say whether the best results come from individuals working alone or from group work, or on what should the size of these groups be.

3 Differences between the studies

As seen in Section 2, the studies conducted to date have manipulated many different variables and a great deal has been learnt about the possible effects of external inspiration. The studies are generally conducted in a way that permits comparison between them, even if there is not always agreement between then studies' results. However, a closer examination reveals that the studies differ in a number of significant ways. This leaves much room for interpretation when comparing the studies and makes it more difficult to design future studies that are consistent with those that have already been conducted. These issues are outlined here, by considering variation in how the studies are conducted, variation in the assessment methods and metrics used, and variation in the phenomena of interest and how they can be explained.

3.1 Variation in how the studies are conducted and reported

As with any kind of experimental research, inspiration and fixation studies are potentially influenced by confounding variables that are overlooked, not controlled for or just not reported on. We focus here on those variables that might be particularly relevant to the design process and thus to the outcomes of such studies. In particular, we focus on variables that have not been systematically manipulated, that have varied between the experiments depending on how they were conducted, or that have not been controlled on some studies. Ignoring some of these variables, such as the complexity of the task, might not harm the internal validity of an experiment, but can prevent the comparison of results between experiments. For instance, two studies with same independent variable (e.g. the disciplinary background of participants) are likely to generate different results when the task complexity varies between experiments. Other variables that require attention and further investigation include aspects related to the participants' background (e.g. previous experience in solving the task, exposure to the example solution, knowledge of similar solutions), or related to experimental factors (e.g. the level of complexity of the problem statement, whether participants must generate as many ideas as possible or just one final idea; and whether they must communicate their ideas only at the concept level or in more detail).

Another point of difference between the studies that is central to the general method of how fixation is investigated is how the example solutions are provided to the participants. Some studies explicitly report providing written instructions to participants saying that the example should be considered a solution for that problem (Linsey et al., 2010), the example was provided to help them get started (Dahl & Moreau, 2002), that the examples are there to raise thoughts (Liikkanen & Perttula, 2008) or that the examples should be used to awaken thoughts, but not just be reproduced (Perttula & Sipilä, 2007). Other studies only report that the stimulus was provided to participants, without describing how it was explained to them (e.g. Cardoso & Badke-Schaub, 2011; Fu et al., 2013; Moreno et al., 2014; Tseng et al., 2008; Viswanathan, Atilola, Esposito, & Linsey, 2014). This matter is potentially critical, as irrespective of whether any instructions are written about how to use the stimuli or not, participants may wonder why they are being exposed to that extra material and change their idea generation process accordingly. For instance, participants may see the example as an extension of the instructions or even decide to incorporate that information to possibly please experimenters (Page, 1981). However, the impact of varying how these external stimuli are introduced to designers has not yet been studied systematically.

Table 3 summarises some of the design process variables that vary between the studies without being manipulated or reported. Ideally, all these variables should be taken into account in designing an experiment and reporting on it, better allowing others to compare results between different experiments or replicate previous findings.

3.2 *Variation in assessment methods and metrics*

Whilst the earliest design fixation experiments measured fixation effects by observing how participants reproduced features from an example (Jansson & Smith, 1991; Purcell & Gero, 1996), later research has reported on the occurrence of fixation based on the novelty and variety of participants' ideas (Viswanathan & Linsey, 2011) or on the participants' resistance to change (Kershaw et al., 2011). Even where researchers analyse the repetition of features from the example solutions they have provided to participants, this could involve repeating the overall structure of the solution, or some of its

Table 3 Design process variables that have not been systematically manipulated, controlled or reported in inspiration and fixation studies

First author, year	*Previous task experience*		*Existence of solutions*		*Complexity of the task*		*Complexity of the problem statement*		*Final number of ideas*		*Modality of the communication*			*Complexity of the communication*	
	Yes	*No*	*Known*	*Unknown*	*Complex*	*Simple*	*Complex*	*Simple*	*One or a few*	*Many*	*Text*	*Sketch*	*Prototyping*	*Concept*	*Detailed*
Cardoso, 2011	?	?	X			X		X		X	X	X		X	
Cheng, 2014	?	?	X			X		X	X		?	X		X	
Chrysikou, 2005	?	?	X			X		X		X	X	X		X	
Dahl, 2002		X		X		X	X		X			X		X	
Fu, 2013	?	?		X	X		X			X	X	X		X	
Goldschmidt, 2006	?	?	X			X		X		X		X		X	
Gonçalves, 2012	?	?		X		X		X		X	X	X		X	
Jansson, 1991		X	X			X		X		X	X	X		X	
Liikkanen, 2008	?	?		X		X		X		X	X	X		X	
Linsey, 2010		X		X		X	X			X	?	?	?	X	
Lujun, 2011	?	?	X			X		X		X	X	X		X	
Moreno, 2014		X		X		X		X		X	X	X		X	
Nijstad, 2002	?	?	?	?	?	?		X		X	X			X	
Perttula, 2006a	?	?		X		X		X		X		X		X	
Perttula, 2007	?	?		X		X		X		X	X	X		X	
Purcell, 1996	?	?	X			X		X		X	?	X		X	
Sarkar, 2008	?	?	X			X		X		X	X	X		X	
Siangliulue, 2015	?	?		X		X		X		X	X			X	
Smith, 1993	?	?		X		X		X		X	X	X		X	
Toh, 2014	?	?	X			X		X		X		X		X	
Tseng, 2008	?	?	X			X	X			X	X	X		X	
Viswanathan, 2014	?	?		X		X		X	X				X		X
Yilmaz, 2010	?	?	X			X		X		X	X	X		X	
Youmans, 2011a	?	?	X			X		X	X		X	X		X	
Youmans, 2011b	?	?		X		X		X	X			X	X		X

components, functions, mechanisms or something else. However, whichever of these is being measured, it relates to the outputs of the design process and not the process itself. Most inspiration and fixation studies take this approach, but there is also variation here, with some studies focussing on impacts on the process and some on the participant.

In addition to the variation in what is being measured, there is variation in how the studies refer to what is measured. For instance, most of the studies that analyse fixation quantitatively take into account the final number of concepts that participants generate. This 'number of solutions', however, is also reported as 'fluency', 'productivity' or 'quantity'; and what is being counted is variously described as 'solutions', 'ideas', 'concepts' and 'designs'. Another common measure is the number of ideas that differ from each other based on some system of classification and this is usually defined either as the 'flexibility', 'variety' or 'breadth' that the participants achieved. Similar observations can be made for the diversity of terms used for the qualitatively assessed measures, such as the quality, also reported as 'usefulness' and 'functionality', and the viability of the candidates' solutions, also reported as 'feasibility' or 'practicality'. Finally, many studies measure the 'originality' of the participants' solutions, sometimes quantitatively (i.e. the uniqueness of the ideas generated relative to the rest of the experimental cohort, also defined as 'novelty' or 'rarity') and sometimes qualitatively (i.e. based on the evaluators' judgement), even if the assessment is then quantified.

All of the measures discussed above, even those that might seem at first to be objective (such as number of ideas), require interpretation and assessment. These tasks are performed by evaluators whose characteristics can influence the assessments that are made. As such, most studies report the number of evaluators involved, and sometimes they provide a basic profile of the evaluators, such as by describing them as PhD students or design practitioners. However, these studies seldom report on the process by which the evaluators were selected, blinded, briefed or otherwise assisted − important factors that might critically vary between the studies. The studies also typically provide very little information about the evaluators' background, such as their area of expertise or their level of experience. In fact, some papers do not offer any information at all about who performed the evaluation or how, again potentially compromising the interpretation of existing studies and the planning of new ones. Table 4 summarises this information and more generally represents the variation that exists in how the inspiration and fixation studies are analysed.

3.3 Variation in the explanation of the effect

As discussed in the introduction to this paper, there are many different definitions of fixation, and as demonstrated above, there are many different ways to

Table 4 Experimental variables, assessment methods and metrics used in inspiration and fixation studies

First author, year	*Input focus (independent variable)*			*Output focus (dependent variable)*			*Output evaluation focus*		*Evaluation metrics*	*Methods and tools*	*Evaluators*	
	Process	*Parti-cipant*	*Example*	*Process*	*Parti-cipant*	*Solution*	*Quality*	*Quantity*			*#*	*Profile*
Cardoso, 2011			X			X	X	X	Repetition of attributes, Fluency, Flexibility, Originality, Ease of use, Manufacturing, Damage to product	Solution analysis	2	Expert judges
Cheng, 2014			X		X	X	X	X	Number of initial ideas, Originality, Achieving the criteria	Questionnaire, Solution analysis, Self-reporting scales	2	Professional judges
Chrysikou, 2005	X		X	X		X			Number of solutions, Repeated solution, Repeated parts, Repeated domains, Repeated flaws	Solution analysis, Verbal protocol, Video recording	2	Author, Independent rater
Dahl, 2002	X		X			X	X	X	Number of different categories, Repetition of features, Analogical distance, Originality, Perceived customer value	Questionnaire, Solution analysis,	25	2 Research assistants, 3 Senior product design professionals, 20 Potential customers
Fu, 2013						X	X	X	Quantity of ideas, Breadth of search, Novelty, Manufacturing (costs, feasibility, people and time)	Questionnaire, Solution analysis	2	PhD students
Goldschmidt, 2006	X		X			X	X		Originality, Practicality, (Creativity), General quality	Questionnaire, Solution analysis, Verbal protocol, Video recording	3	Senior graduate students in design or architecture with professional experience

Table 4 (*continued*)

First author, year	*Input focus (independent variable)*			*Output focus (dependent variable)*			*Output evaluation focus*		*Evaluation metrics*	*Methods and tools*	*Evaluators*	
	Process	*Parti-cipant*	*Example*	*Process*	*Parti-cipant*	*Solution*	*Quality*	*Quantity*			*#*	*Profile*
Gonçalves, 2012			X			X	X	X	Fluency, Flexibility, Originality	Solution analysis	2	Independent expert judges
Jansson, 1991		X	X			X		X	Number of solutions, Repetition of features, Flexibility, Originality	Questionnaire, Solution analysis	?	?
Liikkanen, 2008			X			X	X		Categorical frequency	Solution analysis	?	?
Linsey, 2010	X				X	X		X	Number of solutions, Repetition of features, Number of solution types, Number of analogies drawn	Questionnaire, Solution analysis, Self-reporting scales	2	Authors
Lujun, 2011			X			X	X	X	Number of designs, Proportion of designs with features from example	Solution analysis	?	?
Moreno, 2014	X		X	X				X	Number of ideas, Number of repeated ideas	Solution analysis, Survey,	2	Domain knowledge expert raters
Nijstad, 2002	X		X	X		X	X	X	Productivity, Diversity, Within-category fluency, Ratio of clustering, Recall, Response latency	Solution analysis, Time tracking	2	Independent raters
Perttula, 2006a			X	X		X	X	X	Fluency, Flexibility, Number of unique categories, Categorical frequency, Explicit linkage, Cognitive stimulation	Solution analysis, Verbal protocol, Video recording	?	?

(*continued on next page*)

Table 4 (*continued*)

First author, year	*Input focus (independent variable)*			*Output focus (dependent variable)*			*Output evaluation focus*		*Evaluation metrics*	*Methods and tools*	*Evaluators*	
	Process	*Participant*	*Example*	*Process*	*Participant*	*Solution*	*Quality*	*Quantity*			*#*	*Profile*
Perttula, 2007			X			X		X	Number of new concepts, Genealogical linkage	Solution analysis	?	?
Purcell, 1996		X	X			X		X	Number of solutions, Repetition of features, Number of solution types, Number of unique designs	Questionnaire, Solution analysis	?	?
Sarkar, 2008	X		X			X	X	X	Number of solutions, Number and type of search spaces, Flexibility	Solution analysis	?	?
Siangliulue, 2015	X		X	X		X	X	X	Number of nonredundant ideas, Novelty, Value	Questionnaire, Solution analysis, Timestamps	?	2 Authors, Amazon Mechanical Turks
Smith, 1993	X		X			X		X	Number of designs, Proportion of designs with features from example	Solution analysis	1	Author
Toh, 2014	X		X			X	X	X	Novelty (function and form), Quality, Number of methods, Functional focus	Solution analysis, Design rating survey	2	Independent raters
Tseng, 2008	X		X			X		X	Number of designs, Number of functional repeats, Number of different categories, Novelty	Solution analysis, Timestamps	2	Authors
Viswanathan, 2014	X		X			X		X	Replication of features	Solution analysis	3	Primary rater, Independent raters

Table 4 (*continued*)

First author, year	*Input focus (independent variable)* Process	*Input focus (independent variable)* Parti-cipant	*Input focus (independent variable)* Example	*Output focus (dependent variable)* Process	*Output focus (dependent variable)* Parti-cipant	*Output focus (dependent variable)* Solution	*Output evaluation focus* Quality	*Output evaluation focus* Quantity	*Evaluation metrics*	*Methods and tools*	*Evaluators* #	*Evaluators* Profile
Yilmaz, 2010	X		X		X	X	X	X	Number of designs, Creativity, Practicability	Solution analysis, Self-reporting scales	3	Undergraduate students
Youmans, 2011a	X				X	X		X	Repetition of features, Working memory capacity	Solution analysis, Working memory capacity measurement	2	Blind judges
Youmans, 2011b	X		X	X		X			Repetition of features, Functionality, Originality	Solution analysis, Time tracking, Video recording	2	Undergraduate researchers

measure what occurs in the experiments. There is even sometimes a difference between a study's stated definition for what fixation is and how it is subsequently measured (perhaps because these experiments measure a more observable aspect as a proxy for fixation). This variation points to a general issue with the literature on inspiration and fixation: it does not very precisely or consistently define what situations 'in the world' are of interest and thus how the design of the experiments relates to those situations. For example, the provision of example solutions in the experiments might be intended to represent real design contexts where examples are provided with the brief, or where they are already known to be viable, already known to be not viable, are searched for in a database for inspiration or are developed by the designers in their initial response to the brief (Crilly, 2015). Some of these situations imply that the potentially fixating example is new information, whilst others that it resides in long-term memory; some imply that it is explicitly related to the problem and some that it originates from a seemingly random source; some imply that it results from the intellectual work of the designer and some that it is someone else's idea. Unfortunately, these different situations are rarely elaborated on or distinguished between in the literature, even though the experimental designs and the experimental findings might be interpreted very differently depending on the situation that is being considered.

Although the experimental studies relate to design contexts in different ways, they all somehow induce fixation effects by providing only one or a few example solutions to participants, which may not resemble real world situations. As such, it is conceivable that fixation could be avoided by providing designers with access to multiple and more diverse examples (Perttula & Liikkanen, 2006a) or even with no examples at all (Dahl & Moreau, 2002). In addition, fixation in design, as initially defined, would seem very unlikely to happen during the development of novel products, since they lack pre-existing solutions and that would make the use of example designs barely possible (Tseng et al., 2008). Alternatively, if we explain fixation as any influence of exemplars during generative tasks (Christensen & Schunn, 2007), it is likely that some sort of fixation will always occur during the design process because designers usually explore exemplars from their own experience when facing new problems. Again, indicating the design context and the real world situation being simulated is important for clarifying why, when and through what mechanisms fixation might occur and thus how it might be studied.

In addition to there being various situations that the inspiration and fixation studies might relate to (more or less easily), there are also different possibilities for how the measured effects might be explained. For instance, *the path of least resistance* (Ward, 1994) describes the tendency to select the easiest way of solving tasks. Thus, individuals are likely to access known entities to generate new ideas, and an effortless way to do so is to generate new concepts based on existing ones (Cheng et al., 2014). The *sampling probability effect* (Perttula & Liikkanen, 2006a) suggests that most of the solutions generated initially are common and easily accessible ideas and would appear with or without the exposure to examples. As such, supposedly fixated participants add fewer solutions to their idea-pool because the example solutions they are provided with 'pre-exhaust' the solution space they could have explored. *Satisfaction of search* (Fleck, Samei, & Mitroff, 2010) explains how people become less likely to find further targets in a search, when they have already found one. Similarly, when engaged in problem solving, designers may reduce efforts after they have found an initial solution that meets the problem requirements. Finally, as introduced previously (see Section 2.2.5), another mechanism proposed as a cause for design fixation is the *sunk cost effect* (Viswanathan & Linsey, 2011). However, this effect is more easily explained as participants being reluctant to change an idea (rather than being fixated on a supplied example), and thus might also be connected to issues of *psychological ownership*, where people become attached to their ideas and seek to defend them (Baer & Brown, 2012; Pierce, Kostova, & Dirks, 2003).

Finally, many studies use the repetition of negative features from an example solution or features from a flawed example as an indication that fixation has occurred. It is assumed that designers should be able to spot these flaws and thus avoid copying the examples. However, once the examples are introduced as potential solutions (often as an existing fully functional product), participants may ignore details of the example, not expecting flaws and copying the designs as they are in order to avoid unnecessary rework (Youmans & Arciszewski, 2014). Thus, design fixation may result from the participants recognising that the requirements have already been met by an existing solution that they then adopt, rather than being a creative issue of not being able to arrive at a different idea. Conversely, it is even possible that by presenting flawed solutions as examples (e.g. Chrysikou & Weisberg, 2005; Jansson & Smith, 1991; Linsey et al., 2010; Perttula & Liikkanen, 2006a; Viswanathan et al., 2014; Youmans, 2011b), researchers may shift the participants' attention towards those flaws. This would effectively change the design problem that they are addressing if they concentrate on solving these flaws rather than addressing the specified problem.

In considering these explanations, it seems that fixation exists in a number of forms, by different names, and due to many possible reasons. So maybe, as Purcell and Gero (1996) suggested, we should not be fixated on the conception of what fixation is, but we should also be aware that many different effects are being investigated.

4 Discussion and recommendations

Over the last few decades, many studies have been conducted into inspiration and fixation in design, generally using a similar experimental approach. The phenomena that are being studied potentially lie at the heart of creative design activities and a better understanding of them will allow the field to improve design practice and education, better develop design support tools and structure further research efforts. The work to date has investigated the impacts of many variables related to the nature of external stimuli (see Section 2.1) as well as those related to the design process itself (Section 2.2). However, close attention to the studies reveals that there is variation in how the studies are conducted (Section 3.1), assessed (Section 3.2) and also how they can be explained (Section 3.3). More generally, there is also variation in how the studies are reported and this can make it difficult to understand the ways in which any given study is similar or different to the others. There are aspects of the design process not currently being attended to in the literature (Section 3.1), and even though that may represent an opportunity for further research, it is also a matter of concern. As such, whether taken individually or collectively, the studies into inspiration and fixation leave room for interpretation and debate.

Having reviewed the methodological features of the studies in detail, it is possible to make some recommendations for actions that might help research in this area move forward. Some of these recommendations relate to increasing the formalisation of the basic method that is typically applied. For example, classification schemes could be defined for some key characteristics of participants and the design problems set so that these could be reported consistently. Standards could be established for aspects of timing and environment, the presentation of stimuli and the outputs the participants are required to generate (see Table 3). Standards could also be defined for the quantitative and qualitative measures adopted to assess the resulting designs (see Table 4). However, standardising might still be difficult as researchers continue to explore the methodological possibilities within the field. In fact, the studies have been explicitly examining different variables, whilst the methods have been varying implicitly or accidentally. Instead, researchers could now conduct focussed methodological research to better understand how the different methods influence the results that are obtained.

Beyond formalising the methods that are typically applied in studies of inspiration and fixation, future work might also adopt a greater variety of approaches. On the one hand this might involve using a broader range of experimental methods, including eye tracking (Smith, Youmans, Bellows, & Peterson, 2013), brain scanning (Alexiou, Zamenopoulos, Johnson, & Gilbert, 2009), verbal protocols (Chrysikou & Weisberg, 2005) and other techniques that could complement the output-based analysis of the current studies (for a discussion, see Howard, 2013). On the other hand, future research might also seek to adopt non-experimental methods such as interviews, observations, diary techniques and other approaches to gain a better understanding of the real design situations that the experiments attempt to simulate (Crilly, 2015; also see Busby & Lloyd, 1999a; 1999b; Eckert, Stacey, & Earl, 2005; Robertson & Radcliffe, 2009). This more qualitative work could be used to understand the limitations of the current experimental design and develop new approaches to overcome those limitations.

In addition to engaging with methodological developments, future work might also address different research questions to those that have been focussed on to date. For example, studies could address the issue of whether the constrained behaviour measured in the experiments is really negative and undesirable, as most of the literature suggests it is. For instance, Sio et al. (2015) suggest that although fixation may restrict the variety of solutions that designers generate, it may also enhanced the quality and novelty of those solutions. Viswanathan et al. (2014) also propose that some sort of fixation could be beneficial in later stages of the design process, when the costs of making changes increase. In addition, if expert designers are supposedly more prone to fixation than novices (Kim & Ryu, 2014), that can possibly tell us that experts stick to their previous ideas because they know that these ideas lead to great designs, instead of investing time on uncertain and perhaps fruitless solutions. We can also ask if it is possible to be highly creative and highly fixated simultaneously. According to some metrics found in the literature, the answer would be yes. That is, depending on the extent to which we limit the observation, some people could be highly creative inside one category of solutions while being highly fixated by not exploring other categories. Research could thus explore what different types of inspiration and fixation exist, and learn how to differentiate them and their underpinning mechanisms.

In summary, research into inspiration and fixation has the potential to provide important insights into design creativity, but it would benefit from a more systematic approach if it is to realise that potential. This would involve defining general sets of research questions that the field should address (relating to what forms of fixation occur in design practice, how can they be studied, and how to apply the findings); recognising the diversity of possible research methods that might be employed (whether experimental or observational); and establishing a more uniform approach to the experimental work that is conducted (once different methods have been explored). Reviewing and scrutinizing the current literature was an important step to help design research in deciding how to study fixation next, and to clarify what is known and unknown about interference in creativity for both design education and practice.

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