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OVERCOMING DESIGN FIXATION THROUGH EDUCATION AND CREATIVITY METHODS

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1 INTRODUCTION

In 1937 Edison recorded sound, in 1969 NASA sent the first man to the moon, but it wasn't until the early 1970s that Bernard Sadow thought to put wheels onto a suitcase! We had long felt the effects or cognitive fixation before its discovery came to the lime light with the publication of Duncker's (1945) famous candle-box problem, and we have continued to struggle to avoid them ever since.

Cognitive fixation is essentially a mental block in the production of novel ideas when problem solving, where someone is unable to think beyond what they have been exposed to in the past in relation to the problem at hand. Psychologists began using the term 'Functional Fixedness' to describe this phenomenon, with the topic focused on peoples' inability to think of other ways to use (or other functions of) a device or product.

Functional fixedness was further explored, not in problem-solving but in design, where the problems are more open-ended. This was brought into the spotlight in a paper by Jansson and Smith (1991) who showed that designers can become fixated on previous designs and example solutions. This raised a number of important questions.

For Design Research: What are the exact causes of design fixation? Why do some things inspire and others fixate? What can be done to overcome fixation?

For Design Practitioners: How can we share knowledge and avoid fixation? How can we strive for expertise in a domain and still avoid fixation? How should we present design tasks and use design representations such that they limit fixation?

For Design Education: How can we expose students to previous a solution without fixating to the solution? How can we construct examples and explain tasks without fixating student? What can we teach our students to help them both avoid and overcome fixation?

In this paper we primarily investigate the last question in the list, where we hypothesise that educating students of the phenomenon and effects of design fixation will help them to avoid and overcome fixation. A second hypothesis is that arming students with the 'bad ideas method' will further help students to overcome fixation. Further hypotheses are developed throughout the paper.

2 LITERATURE REVIEW

The literature review aims to gain and develop a classification scheme from fixation types in section 2.1. In section 2.2 the literature reviewed focuses on results of previous studies and theory that enable the formulation of the hypotheses.

2.1 Fixation types

In recently published work, Youmans and Arciszewski (2012) undertake an extensive literature review on design fixation, leading to the following proposed categorisation of fixation types:

1. *Unconscious Adherence:* When a designer proposes an idea believed to be new but in actual fact the designer had been exposed to the idea at some point in the past. Pre-design exposure to certain ideas and cognitive "cues" are often given the term "priming".
2. *Conscious Blocking:* When a designer is aware that he/she is unable to break free from a certain concept or thinking pattern.
3. *Intentional Resistance:* When a designer is unwilling to let go of a previous design through a preference for the previous design and a lack of motivation for change.

The above scheme provided a useful way to separate out the concepts related to design fixation. However, it is quite difficult to categorise fixation caused by example solutions where the effect of fixation is unconscious and at the same time the designer is aware that parts of the example solution

are being replicated. The authors thus feel the need to build upon this categorisation scheme by introducing a matrix and a fourth fixation type – ‘Unconscious Blocking’ (see Table 1) which features heavily in this fixation study.

Table 1. Categorisation of design fixation

	Designer exposed to fixation Prior to Task	Designer exposed to fixation During the Task
Conscious	Intentional Resistance	Conscious Blocking
Unconscious	Unconscious Adherence	Unconscious Blocking

2.2 Fixation effects and remedies

This study looks at unconscious blocking through example exposure. In previous research it has been shown that example exposure “improves Novelty and Variety while it marginally worsens Quantity and Quality” as written by Hernandez et al (2010) who go on to state that “Examples can cause conformity, have no effect, or they can make one go into new directions”. This last statement raises an interesting question that example solution may have different characteristics affecting designers in different ways in terms of fixation.

One theory that may be able to shed light on these characteristics and provide an explanation of how they impact the designer is C-K theory. C-K theory provides a useful framework to think about concept generation and development, allowing us to understand how one concept is similar or differs from another and thus can help to identify elements of fixation. Here it is suggested that design can be described by the exploration of two spaces, the knowledge space (K) and the concept space (C). To simplify for the purposes of this paper, we will look only at the C-space where concepts are explored and developed through set theory. If we take an example from Hatchuel et al. (2011) for the concept space exploration of a shopping cart (Figure 1), we can see that the design is further specified through what is termed as partitions. In Figure 1, some example concepts are given as the result of several partitions. The diagram describes three “restrictive” partitions (propositions that further specify a concept in a routine or already known way) and one “expansive” partition (propositions that further specify the product but by adding an original element to the concept). It is suggested that restrictive partitions are evidence of fixation and whenever they occur, expansive partitions should be sought in order to thoroughly explore the design space.

In a further publication by Agogu e et al. (2011), concepts created from expansive and restrictive partitions are tested for their effects on cognitive fixation. The hypothesis was that examples of expansive partitions work better to stimulate designers’ creativity and have less fixation effects than examples made from restrictive partitions. The most important findings in this study (with statistical significance) showed that an example concept from an expansive partition stimulated more original ideas than the control group (given no example concept) and that the groups given an example concept from a restrictive partition led to fewer and less creative ideas than the control group. It is, however, hard to understand from the paper whether a restrictive partition built onto a concept from an expansive partition is classed as an original output.

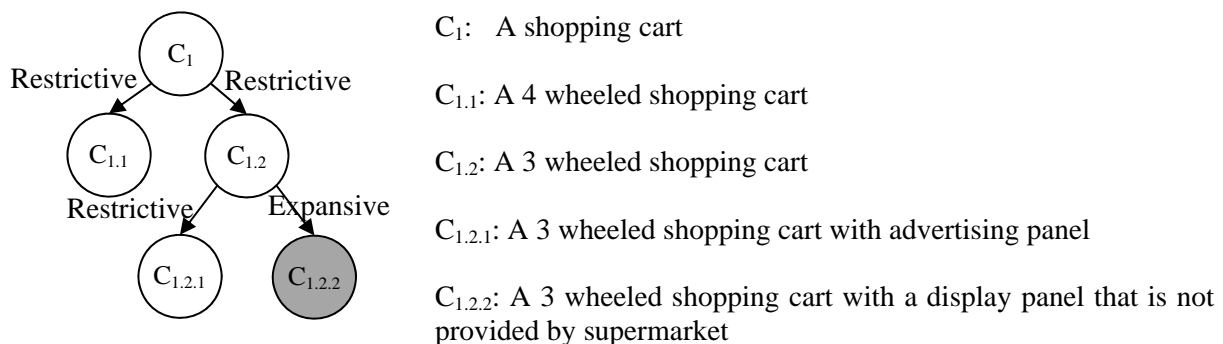


Figure 1. An example of restrictive and expansive partitions as described by C-K Theory adapted from (Hatchuel et al., 2011)

Agogu  et al.'s study has large implications for the debate between fixation vs inspiration, as dealt with through a special issue on this topic edited by Cardoso and Badke-Schaub (2011). In a synopsis of the special issue, Youmans and Arciszewski (2012) conclude that the seven papers reveal quite different results regarding design fixation and report that a concept example in some cases caused fixation (Dong and Sarkar 2011) and in others they lead to inspiration (Goldschmidt 2011). In other previous research, Smith and Linsey (2011) further affirmed the positive effects of incubation showing how short breaks can have positive affect in overcoming fixation. In yet other research, the example concepts and solutions are treated as design stimuli (Howard et al 2010, 2011) where it was shown that using previous ideas from similar design tasks helped to stimulate both more and more-appropriate ideas during brainstorming sessions in industry (with statistical significance). However, this study also showed that there was no difference in effect between stimuli that was sourced from within the same industry/company (the packaging industry) and stimuli from outside the company and other domains. Most importantly, this research introduced all stimuli after 30minutes of brainstorming, suggesting a temporal element to the effect of fixation that seems to have a greater effect when examples are given at the beginning of a design session. The research went further in differentiating between four different ways by which ideas are created (see Figure 2) by using the FBS framework as proposed by Gero (2004). Here, we can see the fourth class of analogy (the Sb analogy) where the stimuli has a similar structure (or form) which is then maintained in the solution but the behaviour of the stimuli in transfer to (or mimicked in) the solution. In the third class of analogy (Bs analogy) the behaviour in the stimuli is likened to the behaviour required in the solution and the structure is then transferred or replicated. Both of the above-mentioned analogies could be deemed as creative mechanisms and at the same time they are examples of fixation, thus highlighting the fact that a creative solution can also contain elements of fixation. For this reason, the authors would like to emphasise that this research is to study fixation rather than creativity.

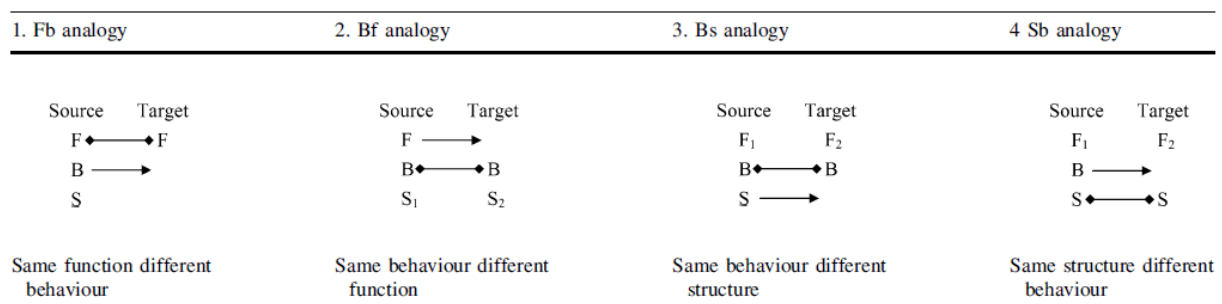


Figure 2. The four mechanisms of analogical transfer, from (Howard et al 2010)

The authors therefore believe that approaches defining fixation as the amount of creative divergence from an example are therefore flawed as many creative solutions may analogically adopt elements of the example in a useful manner. However, in the seminal works of Jansson and Smith (1991) on design fixation they avoid this problem through an innovative research method, where each of the examples contains major design faults. They state that if these design faults are found within the solutions then we can suggest that this is a good measure of fixation, as non-useful elements are transferred to the solution. The same research method will, therefore, be adopted in this paper.

3 METHOD

This section details the experimental procedure and set-up, the design tasks, the approach for fixation identification and finally the two interventions or prescribed approaches.

3.1 The procedure

The study consisted of 12 teams each undertaking three different design tasks. Each team was comprised of four masters-level students with engineering backgrounds. In addition there were three further groups who participated but were omitted from the results due to their inconsistency with the research methodology, one of which was being filmed (Figure 3). See Figure 4 for example sketches.



Figure 3. A team in a design session



Figure 4. Example concepts

The students were put into teams during the morning introduction and were given the agenda for the day and the rules for each session. The term fixation and all clues to it were removed until after the first control session.

Table 2. Agenda and rules of the study

Agenda	Rules for the experiment
<p>08:30 – Introduction 08:40 – Session 1 09:00 – Break 09:15 – Lecture on design fixation 09:40 – Session 2 10:00 – Break 10:15 – Training in Bad Ideas Method 10:40 – Session 3 11:00 – Break 11:15 – Show students the fixation elements for each example 11:30 – Student to count and record the number of design solutions for each task and then the number of fixation elements they can identify.</p>	<p>Each exercise will last exactly 20 minutes. Turn the problem sheet over so that all members can see it. Give the first one-two minutes to read/understand the task. Brainstorm solutions to the task, remembering to:</p> <ul style="list-style-type: none"> • Voice your ideas out loud • Defer judgment • Sketch all of your ideas! • As many ideas as you can!! <p>With two minutes left, you will be asked to rate your top idea by placing a red dot next to the favoured idea. Do not discuss the tasks with other groups!!!</p>

After the final session the students were shown the fixation element that we expected them to have in their concepts, these are listed under the three example solution in Figure 5. The teams were then asked to count and report (online survey) the number of ideas for each session and the number of fixation elements in each session.

The researchers were aware that the teams, although relatively homogeneous, and the tasks, although relatively similar, would lead to different results so it was important to mix the order of the tasks and teams as shown in Table 3. This allowed us to compare the effects of the interventions in sessions 2 and 3 over multiple tasks and teams. However, the order of the interventions could not be changed and was the same for all teams leaving team-fatigue uncontrolled.

Table 3. Teams, tasks and session schedule

	Introduction to the task procedure		
	Teams 1,2,3 & 4	Teams 5,6,7 & 8	Teams 9,10,11 & 12
Session 1: No intervention	Coffee Cup Task	Cycle Rack Task	Measuring Device Task
Session 2: Knowledge of Fixation	Measuring Device Task	Coffee Cup Task	Cycle Rack Task
Session 3: Knowledge of Fixation and Bad Ideas Method	Cycle Rack Task	Measuring Device Task	Coffee Cup Task

3.2 Design tasks and identifying fixation

The design tasks and method for identifying design fixation were taken directly from Jansson and Smith's (1991) seminal study on design fixation. As discussed in the literature review, the faults in the example solutions (fixation elements) were seen as good indicators of design fixation. Three separate design tasks were selected for the study. The example solutions are given for each task in Figure 5 and the tasks are described below.

Key to understanding the analysis of this study is the fixation ratio which we define as follows:

$$\text{Fixation Ratio} = \frac{\text{Number of fixation elements}}{\text{Number of ideas}}$$

In Figure 5 we can see the example solutions for each of the design tasks. The first example is of a measuring device for the blind. In this task it is specified that the product must enable continuously variable measurements and the fixation element in example solution is that it only allows for incremental variants. The second design task is to design a spill proof cup in which the example contains the fixation element that allows the cup to spill or leak fluid when the cup is flat but the mouth piece is rotated to half way between the top and bottom of the mug. The third task is to design a simple to mount bicycle rack with which an example was given with a fixation element that makes the bicycles very difficult to mount in the centre of the rack. Regarding the differences between the tasks, based on C-K theory (see literature review) we can formulate the following hypothesis:

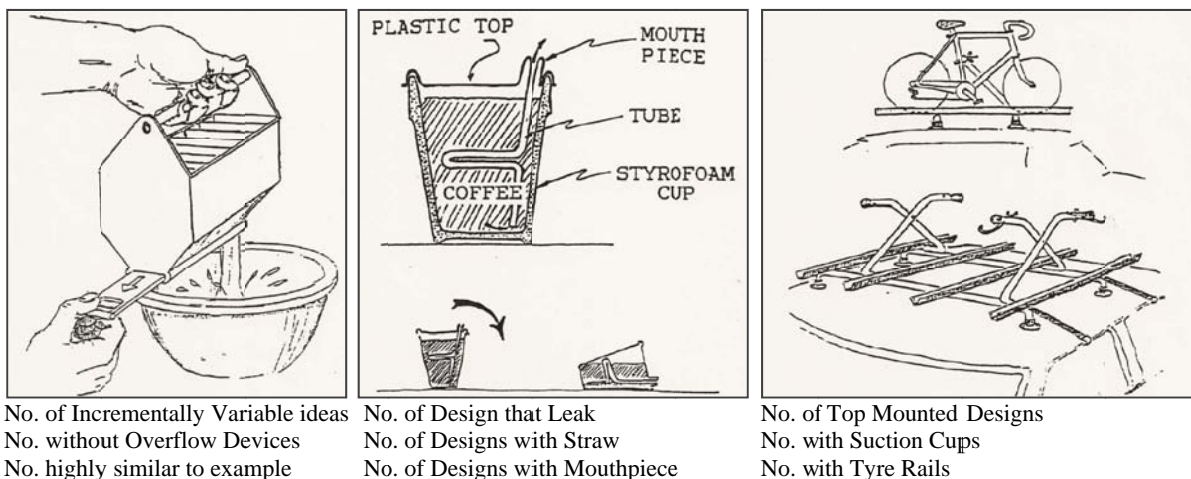


Figure 5. The solution examples given for each design task

Hypothesis 1: The bicycle rack will lead to more fixation elements being reproduced than the other two tasks, as the example solution is created from fewer expansive partitions.

3.3 Prescribed approaches

As previously stated in Table 3, during session 1 there was no intervention and the students were allowed to work on their design tasks without any prior education of the concept of fixation and thus, this session acted as the control group. Before the second session all students were given a brief education into the concept of design fixation. The lecture started with examples from everyday life before building up a theoretical and neuroscientific perspective of the phenomenon. The lecture ended with three problems for the students to try to solve before the answers were given. This intervention should remove the teams from a state of unconscious blocking as described in Table 1. We hypothesise the following in terms of the effectiveness of this lecture:

Hypothesis 2: Once the students have understood the phenomenon of design fixation they will be able to better avoid it and we should see a reduction in the fixation ratio during this session.

Before the final session the students were taught a fixation removal method which they should apply during the third session. Whilst there are numerous ways in which researchers have suggested fixation may be overcome, we have selected one that we believe to be theoretically good due to its emphasis on analogical reasoning, namely the ‘Bad Ideas Method’ (Dix et al., 2006). The method is described in Figure 6 where it is represented in the same form it was given to the students.

We hypothesise the following in terms of the effectiveness of this method:

Hypothesis 3: The use of the Bad Ideas method will further decrease fixation and we should therefore see the fixation ratio in session 3 to be lower than the other sessions.

In addition to the above hypotheses we pose two further hypotheses:

Hypothesis 4: There will be a decrease in number of ideas through using the Bad Ideas method as applying the method will take time.

Hypothesis 5: As a team’s idea quantity increases, the fixation ratio should remain unaltered within a session (based on the marginally popular scientific opinion that more ideas do not lead to better ideas, though many argue the opposite).

Getting bad Ideas

Dix et al., 2006

- Normally, when trying to solve a problem, one tries to think of good ideas. Instead we now have to think of bad ideas! This is not as crazy as it sounds ☺
- Individually
 - brainstorm as many bad or really silly ideas as possible
- In your group
 - Share your bad ideas with your group
- Individually
 - again, generate more bad ideas. Get inspired and/or build on the bad ideas in you group
- In your group
 - Pick out the three best bad ideas and write them down

Analyzing your bad Ideas

- The Bad
 - what is bad about the idea?
 - why is this a bad thing?
 - can you think of anything that share this feature, but in a good way?
 - if so, what is the difference?
- The Good
 - what is good about the idea?
 - why is this a good thing?
 - can you think of anything that share this feature, but in a bad way?
 - if so, what is the difference?

- The clever
 - Now, for each idea, consider it carefully. How can you modify or remove all the bad elements, so that only good features remain? Your task is to convert your bad idea in to a really good idea!!!

Figure 6. Description of Bad Ideas Method

4 RESULTS

This section contains the results and discussion from the research. Firstly, we report the fixation ratio for each of the design tasks (Figures 7a-c) followed by an aggregation of these results (Figure 8). At the end of the section we report the number of ideas created by each team in comparison with their fixation ratios (Figure 9) and the total number of ideas created in each session (Figures 10). The data can be found in the appendix at the back of the paper.

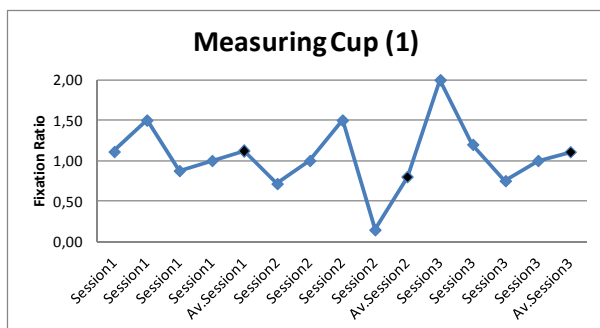


Figure 7a. Fixation ratio for measuring cup task

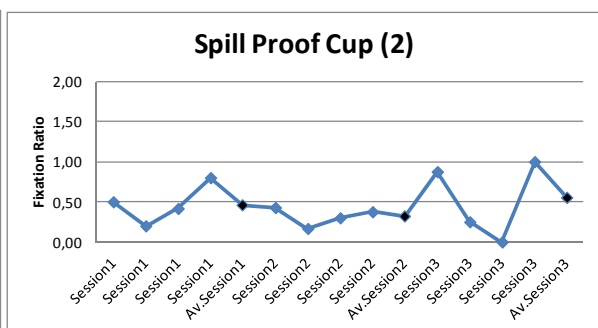
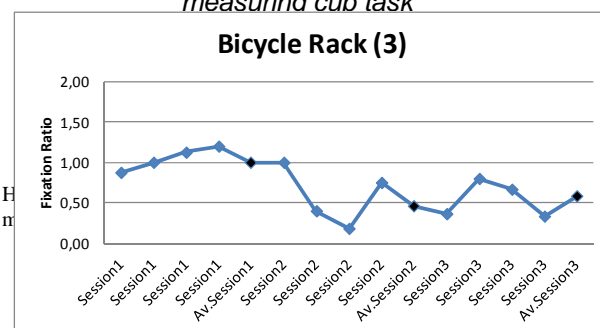


Figure 7b. Fixation ratio for spill proof cup task



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013): Overcoming design fixation through education and creativity in Korea, August 19-23, 2013. (Camera-ready version; 1. July 2013).

Note the data points marked “Av.Session” on the x-axis are the averages of the previous four data points from the same session.

Figures 7a-c are mainly for the purposes of conveying the results for the scrutiny of the readers. The results could provide an interesting study comparing design tasks and example solutions in terms of levels of fixation. One notable result is the large degree of fixation observed in the bicycle task in the first (control) session. This confirms *hypothesis 1* which stated that the example solution in the bicycle rack task was created from a restrictive partition where the other two examples were from more expansive partitions thus supporting prediction made by C-K theory.

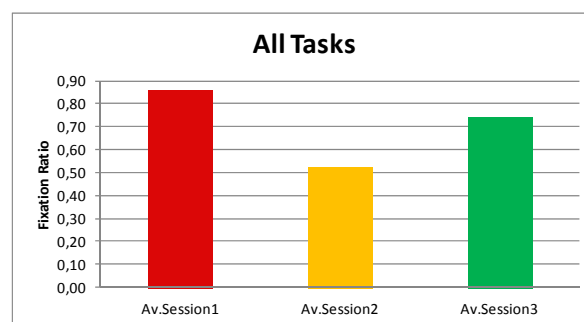


Figure 8. Average fixation ratio for each session

Figure 8 aggregates the fixation ratio for each session so that we can compare the three sessions, the control (session 1) and the two interventions (sessions 2 and 3).

For the first session there were a total of 86 designs across the 12 teams (7.2 per group) containing 76 fixation elements in total (fixation ratio of 0.88). After the lecture on how the brain makes associations and how this can lead to fixation these numbers changed and the teams were able to produce a total of 89 designs (7.4 per group) in which 48 contained flaws (fixation ratio of 0.53). When running a two-tailed paired student t-test it was shown with statistical significance ($p=0.025$) that over the total number of designs there was a significant decrease in the number of flaws following the lecture, thus confirming *hypothesis 2*.

In the third session where the Bad Ideas method was used we saw the total of 80 designs (6.7 per group) 56 contained flaws (74%). This result was not in support of *hypothesis 3*, suggesting that the Bad Ideas method had not worked in reducing the fixation ratio which was higher than without using the method. There may be many reasons for this, one being that the students were beginning to feel fatigued, another may be that this was due to the method being slow to apply accounting for a reduction in the number of ideas produced (see Figure 9).

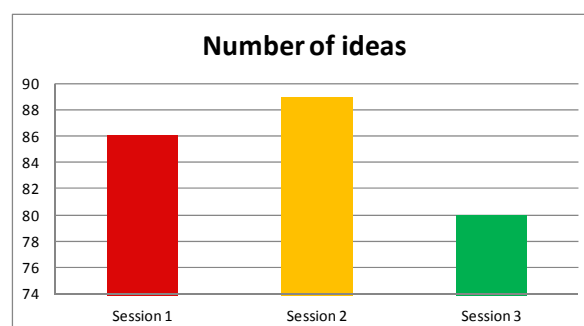


Figure 9. Number of ideas produced in each session

When using the Bad Ideas method in session 3, teams seemed to have a significant decrease in idea production in line with *hypothesis 4*. This negative impact on idea production makes the Bad Ideas method an undesirable concept generation tool. Even though the method is reasonably light weight, the authors believe the reason for the result is caused by the method taking too much time to apply, perhaps explaining why there is a lack of uptake of creativity tools in industry other than brainstorming.

Hypothesis 5 was the final hypothesis tested. For the analysis, we ordered the teams in terms of the number of ideas produced across all 3 sessions and separated them by intervals of 5. Each of the groups' overall fixation ratios were also recorded and plotted in Figure 10. Here we can see a clear decrease in the fixation ratios as the number of ideas per group is increased. In simple terms, the more ideas you come up with the less fixation you are experiencing.

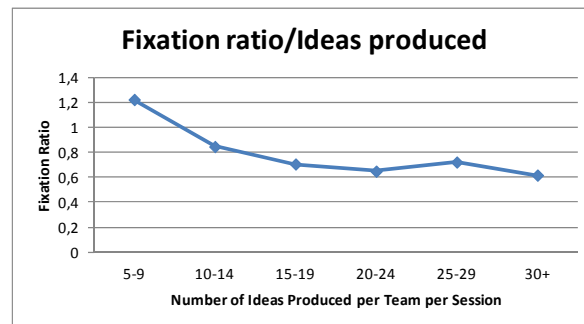


Figure 10. Fixation ratio/ideas produced for each team

This result is very interesting and insightful for the quantity of ideas breeds quality (or novelty) debate. The result suggests that quantity does probably breed novelty through less fixation. However, for these results the cause and effect cannot be determined as the groups may have produced more ideas because they were less fixated, or they were forcing themselves to come up with more ideas which in turn helped them to overcome fixation. This builds onto the further research programme of the authors who claim that teaching how the brain works can enable the designers to overcome undesirable cognitive mechanisms and also to improve others that are more desirable.

5 CONCLUSIONS

The main conclusion drawn from this paper is that educating students in the phenomenon and effects of fixation enables them to effectively devise their own strategies to avoid or overcome fixation. This conclusion was from the result showing the fixation educated students produced designs with fewer fixation elements ($p=0.025$).

The Bad Ideas method was evaluated as poor in overcoming fixation, where teams using this method produced designs with fewer fixation elements without using the tools. The likely cause of this result is that the method hinders the teams in terms of their rate of idea production. We would advise that the method is not suitable for students or industry for purposes of generating a high amount of ideas during conceptual design (based on our results). However, using the method at the later stages of creative sessions is likely to give a more positive result (see Howard et al., 2008, 2010).

Understanding the difference between restrictive partitions and expansive partition may be the key to unlocking the difference between creative stimuli and fixation elements. The results in this paper further support this hypothesis posed by Agogu  et al. (2011). However, much more work needs to be done to investigate the effect ratios and levels of restrictive partition on fixation.

The final conclusion is that fixation ratios and idea quantity do correlate but the reason was not determined in this paper. The authors would suggest that neuro-imaging studies may help us to determine cause and effect between fixation ratios and idea quantity. This leads to the extended programme of research learning more about the cognitive mechanisms in the brain that support design, being able to perform real-time analysis and feedback to designers about their brain-states and to increase learning and coping strategies for designers.

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APPENDIX

Table 4. Number of ideas and fixation indeces per task

Team #	Order of tasks	Measuring Cup (1)				Spill Proof Cup (2)				Bicycle Rack (3)						
		Number of Designs	Number of Incrementally Variable Designs	Number without overflow devices	Number highly similar to example	Fixation Index	Number of Designs	Number of Design that Leak	Number of Designs with Straw	Number of Designs with Mouthpiece	Fixation Index	Number of Designs	Number of Top Mounted Designs	Number with Suction Cups	Number with Tyre Rails	Fixation Index
1	1,2,3	9	4	6	0	1,11	7	3	0	0	0,43	11	3	0	1	0,36
2	1,2,3	6	5	2	2	1,50	6	1	0	0	0,17	15	9	0	3	0,80
3	1,2,3	8	1	6	0	0,88	10	3	0	0	0,30	6	3	0	1	0,67
4	1,2,3	4	3	1	0	1,00	8	3	0	0	0,38	6	1	0	1	0,33
Total:		27	30			1,11	31	10			0,32	38	22			0,58
5	2,3,1	3	3	2	1	2,00	2	0	0	1	0,50	4	2	0	2	1,00
6	2,3,1	5	1	4	1	1,20	5	0	0	1	0,20	5	0	0	2	0,40
7	2,3,1	8	3	3	0	0,75	12	2	0	3	0,42	11	2	0	0	0,18
8	2,3,1	4	2	2	0	1,00	5	3	0	1	0,80	4	1	0	2	0,75
Total:		20	22			1,10	24	11			0,46	24	11			0,46
9	3,1,2	14	8	0	2	0,71	8	7	0	0	0,88	16	10	0	4	0,88
10	3,1,2	7	2	5	0	1,00	8	2	0	0	0,25	6	2	2	2	1,00
11	3,1,2	6	3	5	1	1,50	3	0	0	0	0,00	8	3	0	6	1,13
12	3,1,2	7	1	0	0	0,14	3	0	0	3	1,00	5	4	0	2	1,20
Total:		34	27			0,79	22	12			0,55	35	35			1,00