INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'09
24 - 27 AUGUST 2009, STANFORD UNIVERSITY, STANFORD, CA, USA

GIVE DESIGN A BREAK? THE ROLE OF INCUBATION PERIODS DURING IDEA GENERATION

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ABSTRACT
When tackling design problems, designers sometimes become too attached to particular ideas, either developed by them or induced by external exemplars. Inadequate adoption of features and principles from other existing solutions has been described as design fixation. This behaviour has been observed in experimental settings where designers showed signs of being fixated on particular pictorial representations of such solutions. The study presented here investigated the influence pictorial and also written representations of a particular solution had upon two groups of industrial design students addressing the same design problem. The results demonstrate the presence of fixation with the participants exposed to both priming materials. The study also looked into the potential influence of an incubation break during these groups' ideation sessions. The introduction of a short break halfway through the sketching session did not have the expected incubation effect of reducing design fixation. Potential causes for the occurrence of design fixation are discussed and examined.

Keywords: design fixation, incubation break, pictorial and written representations

1 INTRODUCTION
While trying to solve design problems, designers are likely to spend a considerable amount of time collecting information from a range of different sources. This is especially the case when considering that during idea generation designers find inspiration in a variety of sources, especially in visual representations [1]. Design practitioners also come across other types of information during the design process, such as existing physical designs and its contexts, external encoded sources like books and drawings, and their own internal collection of experiences [2]. During this process, however, designers (particularly experienced ones) often become strongly attached to certain dominant concepts, which they continually try to improve instead of diverging into the search of alternative solutions [3, 4 and 5]. We define such premature, and sometimes inappropriate, attachment to design features or concepts designers are working as 'fixation' in design.

1.1 Background on fixation
The concept of fixation is originated in Gestalt theory, where a series of studies were conducted to explore the occurrence of such behaviour [6, 7 and 8]. Fixation was categorised into different types, generally referring to a series of 'inappropriate' assumptions people exhibited when trying to solve a particular problem. One such type of fixation, for instance, was termed as "functional fixedness". This behaviour consists of a situation whereby people can only conceive of a single and typical use or function for a particular object, when it would actually be advantageous to use it in a different function [6 and 7]. In this type of fixation, people are constrained by their prior knowledge regarding the use of particular devices and cannot think of novel ways to utilise such objects. Another type of fixation, termed "mechanised thought" or "mental set", describes a behaviour whereby participants in an experiment were asked to tackle a number of problems which could be solved using the same algorithm. When reaching a problem, which could not be solved with the algorithm used earlier (with the preceding problems) but instead through an easier approach (*i.e.*, another algorithm), these participants were fixated on using the original, often applied algorithm; ultimately, failing to notice an alternative and more advantageous solution to the problem [8].

1.2 Research on design fixation

Fixation, which has since been studied in different fields, was later revisited in the area of engineering and design. Design research on fixation has demonstrated that designers' ability to come up with new ideas could be limited when presented with pictorial representations of existing solutions [9]. Such research encompassed a set of experiments involving senior mechanical engineering students, as well as professional engineers. In these experiments, the participants were presented with a picture of an existing solution prior to addressing a particular problem. It was found that the different pictures presented, which were directly related to the problem at hand, had a major influence upon the designers' ideas. Consequently, a significant number of the ideas developed by the designers incorporated a number of characteristics from the given example, which on occasions resulted in a reuse (and hence repetition) of poorly design attributes/ principles. The main outcome of such research was the conclusion that designers who were exposed to pictorial representations became 'fixated' and were thus prevented from considering other (new) ways of solving the problem in question.

Further studies on this topic, using some of the same priming material examples and experimental conditions implemented by the abovementioned study [9], investigated the role of disciplinary background in relation to the presence of fixation [10]. These studies confirmed the presence of design fixation on students from a mechanical engineering background, but found no evidence of 'traditional' fixation effects on industrial design students [10]. The main conclusions were that fixation could be related to certain educational programmes, as industrial designers are being trained to generate as many novel ideas as possible.

1.3 Beyond pictorial stimuli in fixation

Both the aforementioned studies, which explored the occurrence of fixation during idea generation, incorporated primarily the use of pictorial representations as the main fixation stimuli. The study here presented is the second in a series of experiments, where the topic of design fixation is explored further by comparing the effects of designers' exposure to *pictorial* representations *versus written* representations of the same existing design solution. In the preceding study, it was found that a group of design students (n=8) primed with a *picture* of an existing design solution was significantly more fixated than a control group (n=8), which received no priming material, and also than another group (n=8) presented with a *written* description of the same pictorial stimuli [11]. In that same study it was argued that pictures had stronger exemplar influence than written words on those participants' solution ideas.

1.4 Incubation periods during idea generation

Driven by previous research and theories on the effects of incubation periods during the creative process [12] and incubation periods during problem solving exercises [13], the study presented here introduces a new variation to the previous experimental set up (Section 1.3). In the new setting, there are also two treatment groups (on exposed to a pictorial and another to a written representation of an existing solution), who rather than undergoing a continuous ideation session were interrupted for a short incubation break halfway through. The main purpose of the new treatment condition was to investigate the possible impact of an incubation period during generative tasks. Both the former treatment groups – now named *pictorial group* and *written group*, used the same design brief and priming material as the ones utilised by the new treatment groups - named *pictorial incubation group* and *written incubation group*. The following sections describe the details of this second study (yet occasionally making reference to the former experiment), the results and discussion regarding the role of the incubation break during the generation of ideas.

2 EXPERIMENTAL SET-UP OF THE STUDY

The present study includes the analysis of the results of 24 participants, 4th year master students from an industrial design engineering course. The study is part of a broader experiment where 80 students (all with the same educational background) were asked to generate solutions for the same design problem. Participants were allocated to several groups undergoing different treatment conditions, where each participant was asked to individually generate ideas through sketches for the following design assignment: "To design a device that allows people to pickup a book from a shelf (*e.g.*, in a library) that is out of their reach, for instance, above their head." As participants were expected to develop as many concepts as possible within the duration of the session (60 minutes), efforts were

made to devise a design brief that was deliberately non-complex. Participants were requested to explain their solution ideas by adding written notes to their sketches or when considered necessary to complement their designs in terms of usage, materials, mechanisms and so forth. The design exercise specified that the solutions had to "be easy to use; possible to manufacture with existing technologies; and minimise book damage". Lastly, at the end of their sketching sessions, participants were asked to fill in a short questionnaire consisting of a few questions about the assignment.
This experimental study comprised three distinct set-up conditions, which resulted in three different groups with eight participants each:

- control group (n=8);
- pictorial incubation group (n=8);
- written incubation group (n=8).

The control group was presented with the brief only. The pictorial incubation group was provided with the design brief and a pictorial representation (priming material) of a possible existing solution (Figure 1, left). The written incubation group was given the brief and a written description (priming material) of the same pictorial representation (Figure 1, right).

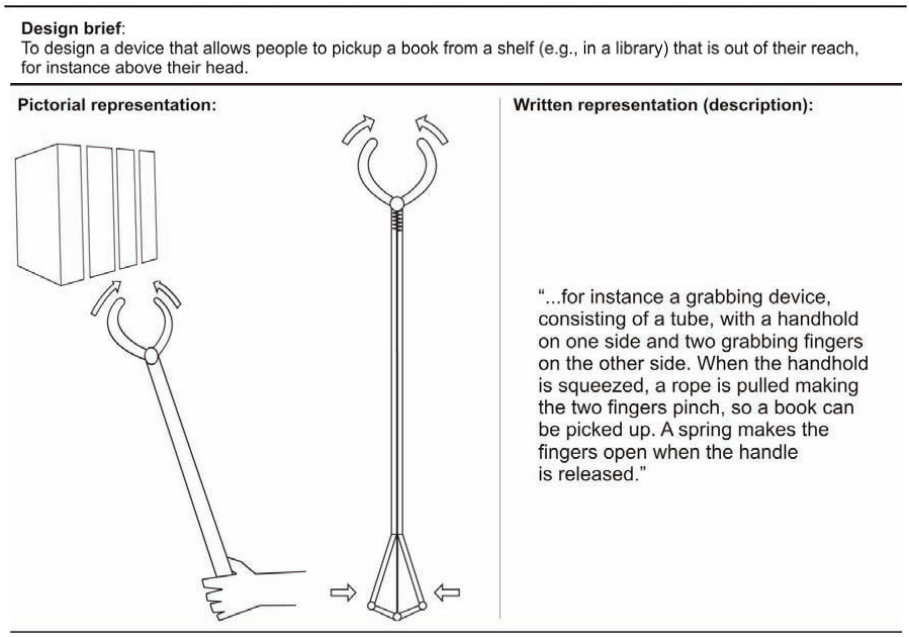

Figure 1. Pictorial and written priming material. The left hand side of the figure shows the pictorial representation of an existing solution of a device to grab objects presented to the pictorial incubation group. The right hand side of the figure shows the written description presented to the written incubation group.

Both pictorial incubation and written incubation groups had a ten minute break halfway through their sketching session, where they played a game unrelated to the design task, afterwards resuming their sketching activity for another 30 minutes. For later analysis, the two half sessions, pre- and post-incubation, were differentiated by having the participants drawing with a black marker in the first half and with a blue marker in the second. The game introduced to both pictorial and written incubation groups was meant to serve as tentative incubation period, where the participants are expected to put the problem on hold for a short break. This activity involved all participants' collaboration and consisted of each individual holding five balloons and a small and thin wooden stick. The objective of the game was to puncture one another's balloons until there was only one remaining participant (*i.e.*, the winner) holding at least one inflated balloon.

Consequently, the research hypotheses for the present study were formulated as follows:

- Hypothesis 1:

The introduction of an incubation break halfway through a one-hour problem solving exercise will decrease any induced fixation on a group exposed to a *pictorial example* of an existing design solution.

- Hypothesis 2:

The introduction of an incubation break halfway through a one-hour problem solving exercise will decrease any induced fixation on a group exposed to a *written example* of an existing design solution.

3 DATA ANALYSIS

The analysis of the results includes the measurement of: the number of ideas generated and the occurrence of particular fixation aspects. In order to identify the presence of design fixation in the outcome of the treatment groups (pictorial incubation and written incubation) a system of categorisation was devised based on the physical and functional characteristics of the example solution presented to the participants (Figure 1). The categorisation enabled assessing the design ideas from the treatment groups in terms of similarity to the priming material. The participants' outcomes showed signs of design fixation if they incorporated a design idea:

a) where the environment (*e.g.*, the library) was not changed;
b) with a hand tool;
c) with extension of the arm(s);
d) using mechanic clamps/ fingers (to grip book);
e) using a tube/ pole (as an arm extension);
f) using a squeeze handle (to operate clamping mechanism).

Based on this system of categorisation, one single solution idea could comprise from zero up to six fixation aspects. Fixation category 'a' (environment not changed) is not directly related to a specific product feature of both pictorial and written priming examples. However, not changing the environment reflects a possible type of fixation induced by the priming examples – *i.e.*, devising a handheld device that is brought into the context of use (library) as opposed to, for instance, an automated shelving system for book retrieval where the books come within arms' reach (which constitutes a change in the environment). Fixation categories 'c' (extension of the arm) and 'e' (tube/ pole), which are generally correlated, are kept as separate aspects. In fact, several of the participants' sketches incorporated concepts where an extension of the arm was achieved through some sort of long tube/ pole. However, in some other occasions arm extension was accomplished by developing different designs (*e.g.*, an elastic cord).

4 RESULTS

This section presents the number of solution ideas developed by each group (control, pictorial incubation and written incubation), as well as the occurrence of design fixation effects for all three conditions. Firstly, the results report on the comparison between the three groups as a whole, without differentiating between pre- and post-incubation half sessions (Section 4.1). Secondly, there is a closer comparison between the pre- and post-incubation results of both, the pictorial incubation and written incubation groups (Section 4.2).

4.1 Comparison between groups: whole session

As it can been seen in Figure 2, the 'sum of fixation aspects' for the control group cannot be interpreted as fixation *per se*, because this group was not exposed to priming material. Hence, in the case of the control group the data simply relates to the features/ principles that coincide with the priming example and may be regarded as a baseline for determining the level of 'fixation' for the remaining groups.

An overview of the number of solution ideas and occurrence of design fixation effects is shown in Figure 2, which also presents the results for the treatment groups' pre- and post-incubation half sessions.

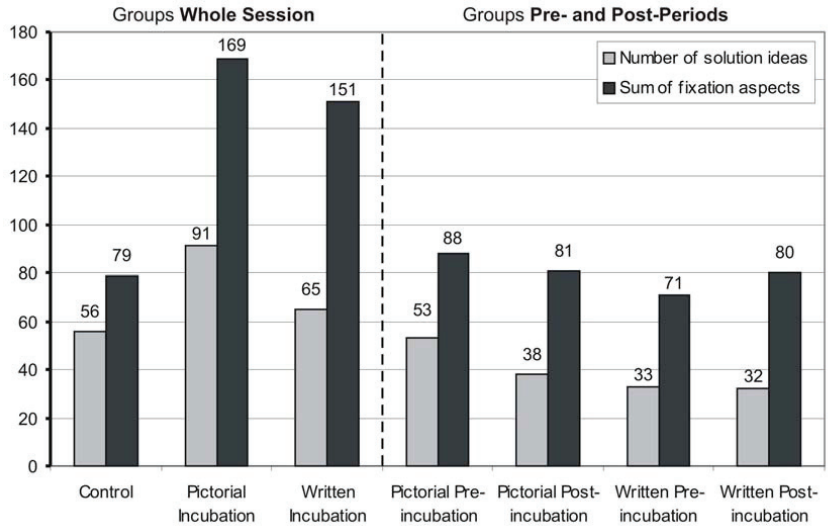

Figure 2. Total 'Number of solution ideas' and 'Sum of fixation aspects' per group (one single solution idea can present from zero up to six fixation aspects). The left hand side of the graph shows the results for the whole 60-minute session for each group; and the right hand side of the graph presents the same results for the pictorial incubation and written incubation groups divided into two 30-minute half sessions (pre- and post-incubation).

Since the data are not normally distributed, the analysis of the results was performed using a Mann-Whitney test. In terms of differences between the *number* of ideas generated by each group (Figure 2 and Table 1), the results show that the pictorial incubation group generated significantly more ideas than the control group ($p < 0.05$, Table 2 – 'Total no. of solution ideas').

Table 1. Total number of solution ideas generated per group (row 1); average numbers of solution ideas (row 2) and average numbers of different categories of fixation aspects per participant for each group (rows 3 to 8).

	Control (n=8)	Pictorial Incubation (n=8)	Written Incubation (n=8)
1) Total no. of solution ideas per group	56	91	65
2) Av. no. of solution ideas per participant	7.0	11.4	8.1
3) Av. no. solution ideas where environment is not changed	3.3	5.1	4.4
4) Av. no. solution ideas with hand tool	1.9	5.1	4.6
5) Av. no. solution ideas with extension of the arm(s)	2.0	5.4	4.4
6) Av. no. solution ideas using mechanic clamps	1.0	0.9	4.6
7) Av. no. solution ideas using a tube/ pole	1.8	4.6	3.9
8) Av. no. solution ideas using squeeze handle	0.3	0.1	0.3

However, the difference between the number of ideas generated by the written incubation and the control groups was not significant (Table 2). Equally, there were no significant differences between the number of ideas generated by the pictorial incubation and written incubation groups. Therefore, whereas the introduction of the priming material and/ or the incubation break could have had an effect on the (high) number of ideas developed by the pictorial incubation participants, this does not seem to be the case with the written incubation group. In terms of differences between the *number* of ideas generated by each group (Figure 2 and Table 1), the results show that the pictorial incubation group generated significantly more ideas than the control group ($p < 0.05$, Table 2 – 'Total no. of solution ideas').

*Table 2. Differences in frequency of occurrence of fixation aspects between the different groups - control, pictorial incubation and written incubation (p < 0.05 *).*

	Control *vs.* Pictorial Incubation	Control *vs.* Written Incubation	Pictorial Incubation *vs.* Written Incubation
Total no. of solution ideas	.03*	.59	.09
Sum of fixation aspects	.06	.06	.83
No. solution ideas where environment is not changed	.36	.79	.67
No. solution ideas with hand tool	.06	.04*	.83
No. solution ideas with extension of the arm(s)	.04*	.04*	.71
No. solution ideas using mechanic clamps	.56	.22	.13
No. solution ideas using a tube/ pole	.04*	.04*	.55
No. solution ideas using squeeze handle	1.00	.26	.26

However, the difference between the number of ideas generated by the written incubation and the control groups was not significant (Table 2). Equally, there were no significant differences between the number of ideas generated by the pictorial incubation and written incubation groups. Therefore, whereas the introduction of the priming material and/ or the incubation break could have had an effect on the (high) number of ideas developed by the pictorial incubation participants, this does not seem to be the case with the written incubation group.

In regard to the 'Sum of fixation aspects' (*i.e.*, when all fixation categories are combined), the results shown below in Table 2 indicate that the participants in the pictorial incubation and written incubation groups exhibited a tendency towards developing more fixated solutions, when compared to the control group (p=0.06). When comparing the pictorial incubation to the written incubation condition, the former presents a higher value (though not significant) for the 'sum of fixation aspects' (Figure 2), but it is the latter that exhibits signs of fixation on more individual categories of fixation (Table 2). For two out of six categories, indicating the occurrence of design fixation, the participants from the pictorial incubation group had significantly more fixated ideas implemented than the control group (p < 0.05). Participants in the pictorial incubation condition generated more solution ideas comprising *extension of the arm* and more solutions using a *tube/ pole*. They also showed a tendency (p = 0.06) to become fixated on a third additional aspect – *i.e.*, ideas comprising *hand tools*.

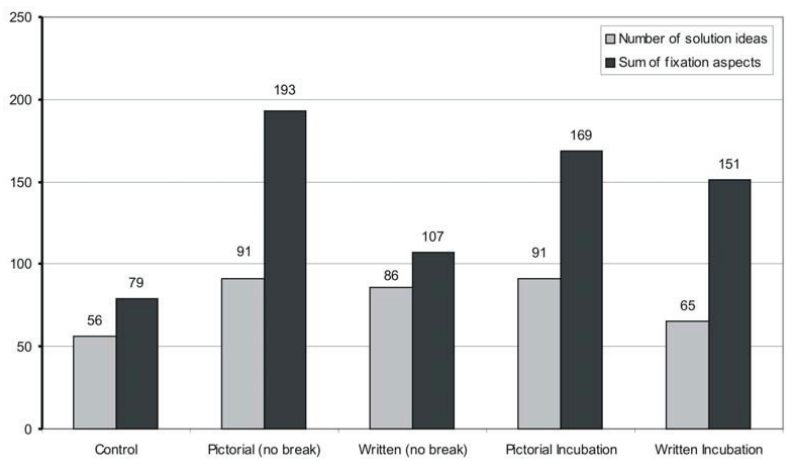

Figure 3. Total 'Number of solution ideas' and 'Sum fixation aspects' per group – comparison between former pictorial and written conditions (no incubation break) and new pictorial incubation and written incubation groups.

Similarly, the written incubation condition presented significantly more fixated ideas on the same three categorical aspects when compared to the control group ($p < 0.05$): more designs with *hand tools*, more solutions with *extension of the arm(s)*, and additional ones containing *tubes/ poles*.
Lastly, when comparing the pictorial incubation against the written incubation group the results show no significance on possible levels of fixation between the two. Ultimately, this indicates that the participants on each treatment group were on average similarly fixated on a number of aspects, when comparing both groups against the control group.
The presence of design fixation in the group with pictorial material treatment (*i.e.*, pictorial incubation group) are in line with the authors' previous study with another group of industrial designers also exposed to the same pictorial example (but without incubation break, Figure 3) [11]. The findings are also congruent with other studies, involving mechanical engineering students, where the participants' solutions showed clear signs of fixation by integrating a number of features comprised by the pictorial priming examples presented to them [9].
The results from the written incubation group in the present study, though, are in contrast with the authors' preceding experimental study [11], where a group of designers exposed to the same written example utilised here (yet not interrupted by an incubation break) showed no significant signs of fixation (Figure 3).

4.2 Comparison between pre- and post-break sessions for pictorial incubation and written incubation conditions

At the beginning of this research phase, it was hypothesised that introducing a short break (incubation period) halfway through the one-hour sketching session performed by the pictorial incubation group, would diminish the presence of fixation on the participants' solution ideas. This would have been congruent with previous research (on the use of Remote Associate Tests, but not design problems) which suggested that induced fixation could be decreased after the introduction of an incubation period [13]. However, within the pictorial incubation group itself, the break does not seem to have had a significant effect between the pre-incubation (first half hour) and the post-incubation (second half hour) sessions. Hence, the first hypothesis presented earlier (Section 2) must be rejected.
The occurrence of fixation on solution ideas with *extension of the arm* and *use of a tube/ pole* (and to some extent, the reuse of ideas integrating *hand tools*) was generally constant before and after the break and amongst the eight participants in the pictorial incubation group (Tables 2 and 3). The only exception where the break seemed to have had an effect (between half sessions) was in regard to the solution ideas where the *environment was not changed*, which decreased significantly after the break ($p < 0.05$, Table 4).
The participants in the pictorial post-incubation session started to develop alternative ways to reach for a book by changing characteristics of the environment (*i.e.*, library); which was different from the priming example solution, whereby a small handheld device is brought into the context of use (Figure 1). Nevertheless, while this is significant in between pre- and post-incubation half sessions, as a whole the pictorial incubation group does not show significant signs of being fixated on this category when compared to the control group ($p=0.36$, Table 2). Lastly, and opposite to the constant level of fixation throughout the session, the pictorial incubation group presents a significant decrease in the number of ideas generated during the post-incubation session ($p < 0.05$, Table 3 and 4).
Similar to the treatment conditions for the pictorial incubation group, it has been also hypothesised earlier in this paper that a short break halfway through the written incubation group's session would diminish fixation effects induced by the priming material (Section 2). However, the written incubation group was continually fixated, before and after the break, on reintegrating *hand tools*, *extension of the arm(s)* and *tubes/ poles* in their solution ideas (Tables 2 and 3).
In effect, and refuting the second hypothesis formulated earlier (Section 2), the written incubation condition became significantly fixated on a new category after the break – *i.e.*, solution ideas (re)using *mechanic clamps* ($p < 0.05$, Table 4); however, this was not significant when compared to the control group (Table 2).
Ultimately, and unlike the pictorial incubation condition, the written incubation group kept an even average number of ideas from pre- to post-incubation sessions (Table 3 and 4).

Table 3. Total number of solution ideas generated between pre- and post incubation sessions (row 1); average numbers of solution ideas (row 2) and average numbers of different categories of fixation aspects per participant for each half session (rows 3 to 8).

	Pictorial incubation (n=8)		Written incubation (n=8)	
	Pre-break	Post-break	Pre-break	Post-break
1) Total no. of solution ideas per group	53	38	33	32
2) Av. no. of solution ideas per participant	6,6	4,8	4,1	4
3) Av. no. solution ideas where environment is not changed	3,3	1,9	2,4	2,0
4) Av. no. solution ideas with hand tool	2,5	2,6	2,1	2,5
5) Av. no. solution ideas with extension of the arm(s)	2,6	2,8	2,1	2,3
6) Av. no. solution ideas using mechanic clamps	0,4	0,5	0,4	1,3
7) Av. no. solution ideas using a tube/ pole	2,3	2,4	1,9	2,0
8) Av. no. solution ideas using squeeze handle	0,0	0,3	0,3	0,4

*Table 4. Differences in frequency of occurrence of fixation aspects between pictorial incubation and written incubation conditions during pre- and post-break ($p < 0.05$ *).*

	Pictorial incubation (n=8)	Written incubation (n=8)
	Pre-break *vs.* Post-break	Pre-break *vs.* Post-break
Total no. of solution ideas	.03*	.87
Sum of fixation aspects	.44	.67
No. solution ideas where environment is not changed	.04*	.92
No. solution ideas with hand tool	.78	.53
No. solution ideas with extension of the arm(s)	.83	.94
No. solution ideas using mechanic clamps	.66	.05*
No. solution ideas using a tube/ pole	.85	.76
No. solution ideas using squeeze handle	.16	.56

5 DISCUSSION

In a previous phase of the research study presented in this article, the authors investigated the influence of pictorial and written representations during a one-hour design exercise [11]. As mentioned before, it was found that the group exposed to a pictorial example turned out to be more fixated than the control group and the written-example group. In the experiment presented here, it was further investigated if the introduction of a short break (incubation period), during the same one-hour exercise, would have a different effect upon the second half-hour session of the two groups of designers exposed to the pictorial and written examples previously used (Figure 1).

5.1 Pictorial incubation group: the influence of priming material and incubation break

Introducing a break halfway through the pictorial incubation group's exercise did not decrease the effects of induced fixation between pre- and post-break sessions (Section 4.2). Possible reasons could have been due to the presence of the priming material as well as the participants' sketches (available on their desks) throughout the whole session. In spite of the distracting intention of the break, coming back to the drawing table and looking at the priming material, for instance, could have influenced the generation of new ideas; which carried on comprising particular fixation aspects. It is also possible that the participants revisited their own previous sketches, which in some cases can be seen in the presence of blue ink marker (which was only given to them after the break) in some of the participants' pre-incubation drawings (which were done during the first half hour session using black marker only). By revising earlier ideas they ended up repeating variations of initial concepts, rather

than coming up with entirely different ones. This tendency to become attached to early ideas has been discussed in previous research [3, 4 and 14].

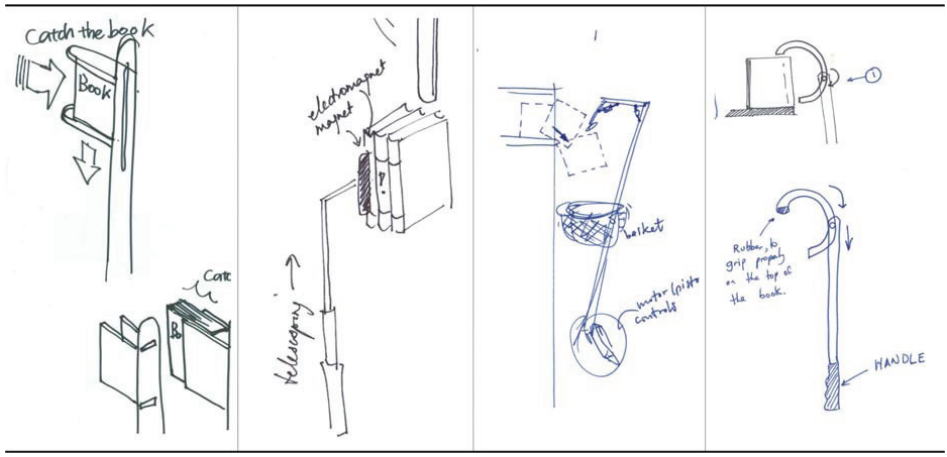

Figure 4. Examples of solution ideas generated by the pictorial incubation group with evident similarities to the pictorial representation (priming material, Figure 1).

The game itself did not seem to have 'distracted' the participants as expected, by helping them to put aside the priming example and develop different new ideas. It could be the case that the break was simply too short (10 minutes). Alternatively, the game could have been too physically demanding/ dynamic, preventing the participants from experiencing an incubation effect, whereby the incubation period is expected to yield the opportunity to think of possible 'improvements' when they resume to the given problem [13].

When looking into detail at the occurrence of fixation, particularly the repeated integration of a *tube* or *pole* in the solution ideas developed by the pictorial incubation group (Table 2), it is possible that the repetition of certain characteristics in the priming material example may be related to this behaviour. This particular feature (tube) appears twice in the pictorial material – *i.e.*, in use and in cross-section drawing (Figure 1). The tube represents a straightforward mechanical/ artificial *extension of one's arm*, which could have been difficult to avoid while trying to come up with new ideas.

Interestingly, one could also argue that the mechanical clamps, which were not a fixation issue in the pictorial incubation group ($p=0.56$, Table 2) were also represented twice, and yet their reproduction in the participants' drawings is not a fixation issue. However, the type of mechanical clamps depicted (Figure 1) is, arguably, a poor design solution. In fact, if these types of clamps/ fingers were to be used to pickup a book, especially the ones that are tightly placed against one another on library shelves, it would probably present a series of shortcomings; as they are too thick to be inserted in-between books, aggravated by being limited to pickup the books horizontally. This problem was identified by a number of participants, which came up with more effective ways of picking up the books. Hence, this feature of the pictorial example could have been dismissed by the participants as a potential inadequate solution, and as a result not significantly present in the participants' ideas.

Lastly, the results indicate that the priming material given to the pictorial incubation group seemed to have led the participants to generate more ideas, especially in the first half session (Figure 2 and Table 3 and 4). Thus, we can assume that the material could have worked as a straightforward and easier starting point facilitating the quick generation of a higher number of solution ideas, though generally more fixated ideas.

In the second half session, however, there was a significant decrease in the number of solution ideas generated by the participants. From the participants' feedback (collected through a post-session questionnaire), it seems that the break had, to some extent, an additional different influence. In effect, some participants reported that:

"After the balloons [break/ game activity] I run out of ideas (…) I lost my concentration, it took me 10 min of thinking of the library before I came up with a couple of ideas"; "Felt a bit stuck at one point

(…)"; "It was difficult to go back to 'thinking' mode. It was a fun break, but I continued with the last concept I was working on, so I didn't immediately start [a] new thinking. I ran out of ideas pretty soon though, after the activity".
It is also possible that the number of ideas had been eventually declined even without the break interruption, especially when considering the high number of solutions devised in the pre-break session.

5.2 Written incubation group: the influence of priming material and incubation break

Unlike a number of participants in the former written group (no incubation break), which reported not reading the priming example, the participants in the written incubation group seemed to have read it more carefully – some of them reporting to have re-read it after the break, eventually showing signs of fixation on three out of six fixation categories (Table 2). In fact, five out of eight participants, in the written incubation group, reported that they used the product description (priming material) as starting point for further ideas, stating that:
"…it was a good way to start, because 'device to pickup books' is really broad and without any constrictions it is difficult to begin"; *"…the example makes me try to think [of something] else, but it still inspires me"*.
Interestingly, the presence of a significant high number of solution ideas integrating a *hand tool* and a *tube/ pole* in the written incubation sketches ($p < 0.05$, Table 2) could also be related to another aspect - the cognitive bias termed *primacy effect* [15]. This behaviour refers to the tendency that people remember more easily words read/ heard first (for instance, at the beginning of a list or text), rather than words later in the serious. For example, the word *grabbing device*, which can (arguably) be easily related to a handheld object – *i.e.*, *hand tool*, is mentioned at the very beginning of the written material (Figure 1).
Equally, the word *tube* is the first word naming a physical feature of the object depicted in the priming written example (Figure 1). This could have been the reason why seven out of eight participants sketched a higher number of ideas incorporating a *tube/ pole* at the beginning of both pre- and post-incubation sessions (Figure 4).
The same significant presence of fixation can be observed for the presence of solution ideas integrating *extensions of the arms* ($p < 0.05$, Table 2) in these same phases. Whereas arm extension was not always achieved through the use of a *tube/ pole*, it was in the case of the written incubation group coinciding with the presence of such feature. Ultimately, and according to the system of categorisation used to determine the occurrence of fixation (Section 3), this group ended up devising a high number of ideas comprising *extensions of the arm*.

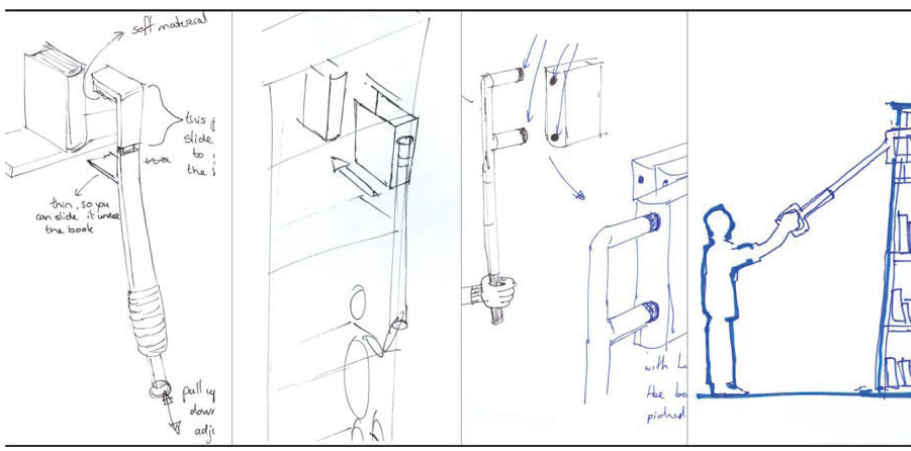

Figure 5. Examples of solution ideas generated by the written incubation group with evident similarities to the pictorial representation (priming material, Figure 1).

Finally, the reduced number of ideas generated by the written incubation group (when compared to pictorial incubation group) could have been related to the fact that reading the priming material inevitably took longer than glancing at the picture. Despite the apparent simplicity of this written description, participants could have taken longer to visualise/ interpret what the short text was actually trying to depict. Lastly, and as above mentioned, with the break in between, a number of participants in the written incubation group reported they had to re-read the product description, once again leaving less time to develop more solution ideas.

6 CONCLUSIONS

The study presented here has demonstrated the occurrence of design fixation in two different groups of industrial design students, one exposed to pictorial and another to written representations of an existing solution, during a problem-solving activity. Both groups generated solution ideas which integrated several features comprised by the pictorial and written priming examples. The introduction of a short break halfway through the sketching session did not have the expected *incubation effect* of attenuating or even decreasing the occurrence of fixation of either group, during the session following the break. On the contrary, it can be even argued that the break allowed for the constant reoccurrence of fixation on the solution ideas developed by both groups. This was especially the case as the break made the participants to revisit both the priming materials, as well as their preceding ideas, ultimately leading to a continual design fixation.

When transferring this type of behaviour to design practice, it is conceivable that incubation breaks (*i.e.*, typical interruptions within and between design phases) that might occur during the design process will not necessarily deter designers from constantly re-appropriating preceding (and possibly inadequate) solution exemplars they have access to. In cases where fixation limits the development of creative and innovative ideas, it is important to contemplate that incubation breaks may not be the most suitable way to tackle this type of behaviour. Alternatively, other research projects have empirically proved that it is possible to *de-fixate* participants by using a set of instructions that explicitly instruct them to avoid reusing particular (poorly) design elements incorporated by priming exemplars [16].

Due to the number of participants and type of exercise (design brief) involved in this study, it is important to be conservative in regard to possible generalisation. The overall findings are an indication that, at least within the set up and conditions of this experiment, certain kinds of external encoded sources of information can influence designers' creative process during idea generation. The findings also show that the type and length of the break utilised here did not necessarily translate into what has been described as an *incubation period*, where one may set the problem aside and come back with a 'breakthrough' solution to the problem.

Future work will involve variations on: the type of break (different activity/ game), and the duration of such periods. In addition, the continuation of this research requires the involvement of a higher number of participants to compensate for the impact of inter-individual differences in each group.

Further research will also explore the impact of different types of material sources as potential causes of fixation during idea generation phases. The purpose of these studies on design fixation is to question the excessive reliance on particular types of iconic material, and by contrast the disregard towards other potential sources of information and knowledge.

Additionally, further research should also investigate the possible impact of design briefs *per se* upon the design process. For instance, the design brief used in this experiment stated that participants had to: *"design a 'device' that allows people to pickup a book from a shelf (…)"*. Had the brief stated instead that the aim was to: *"design a 'way' to allow people to pickup a book from a shelf (…)"*, participants might have not been fixated on reproducing handheld *devices* that similar to the priming exemplars. Ultimately, the manner in which assignments are framed and presented to design practitioners might have consequences on the success of the design outcome.

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