Increasing creativity in design by functional abstraction

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Human-Computer Interaction

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ABSTRACT

With advancements in big data, designers now have access to design tools and ideation platforms that make it easy for them to review hundreds of examples of related designs. But how can designers best use these examples to come up with creative and innovative solutions to design and engineering problems? Building off creative cognition literature, we present an approach to increase creativity in design by making people think more abstractly about the functions of the product in their design problem through morphological concept generation. We tested this mechanism with an experiment in which the treatment and control condition had the same design task with the same examples for the same amount of time. The results supported our claim and showed that the treatment condition that followed our approach had more novel designs. These results can be used for product design practices and would drive future research in the role of abstraction for creativity in design and can also be used to explain the conditions in which creativity is enhanced rather than diminished when designers are given a database of exemplars.

Author Keywords

Creativity; ideation; examples; design

ACM Classification Keywords

INTRODUCTION AND BACKGROUND :

Examples play a major role in creative design practice, but the details of how they work is still a puzzle [1]. Designers are getting access to new design tools and ideation platforms that allow them to access hundreds of examples at once. In generative design tools, once the constraints and goals of a design are specified, the system retrieves hundreds of designs or design fragments that are potentially related. For helping designers best use the database of examples and to be able to develop tools and software for aiding designers think creatively, we need to understand whether and under what conditions do these examples stimulate creativity in design.

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Opinion is divided, and conflicting literature is found on whether and under what conditions do examples fixate or inspire. There are studies that show that there is a design fixation effect by viewing examples [2]. And there is literature that argues that showing examples leads to more creative designs [3]. The existence of both positive and negative effects make it harder to judge if and how the exposure to examples increase productivity for designers [4]. This inconclusiveness and divide in opinion exists in architecture too. In some architectural schools, the review of previous designs, especially excellent ones, is thought to inhibit imagination, squelching creativity. Viewing previous work primes the mind to duplicate the past, making it harder to think freshly, appropriating the problem completely. In other schools, it is assumed that to break free of the past one must know the past. Invention requires due diligence. Not reviewing past work is as irresponsible as not doing research for an essay. Besides, no one comes to a problem without some prior exposure to designs.

To solve this enigma, we hypothesize that it's not the number of examples or the examples that are a source of fixation or inspiration, but rather the method in which/how the examples are viewed that leads to an increase or decrease in creativity in the design solutions.

In this paper, we use literature on morphological charts [5] and product dissection [6] to create a method to perform functional abstraction on the examples. We use this method to help people think more abstractly about their design problem. For example, functional abstraction is thinking about a chair as (i) a structure that supplies an upward force at sitting height over a seating surface (n x m), and (ii) a back as an addition that provides a forward force over an area (j x k). This would lead to more creative designs than thinking of a chair as (iii) a structure with legs, a seat and a back. (This is a parts based approach / structural approach). In other words, functional descriptions are more facilitative than structural descriptions. We conduct an experiment to test if the method of using morphological concept generation and product dissection leads to functional abstraction and more novel results than examining examples without any direction.

Related Work

One can find through the design, creative cognition and engineering literature that there are different factors that affect creativity. Ut Na Sio et al. (2011) [4] performed a meta-analysis of 43 design studies and showed how the quality of examples given to people plays a role in how creative their

design solutions would be. It showed how better quality examples lead to better quality solutions. Kulkarni et al. [7] and Siangliulue et al. [8] found how the timing at which the examples are displayed affect creative output. (Chi et al., 1981) examined how the quantity of examples given also plays a role. It also showed how experts and novices behave and approach multiple examples differently. Experts process information at a higher level of abstraction (Chi et al., 1981) and hence, are able to abstract from more examples more efficiently. Starkey E.M. et al. [6] showed how creative self-efficacy i.e. believing in one's creative ability also has an impact on creative outputs. It shows that the people who believe that they are capable of coming up with creative and novel ideas are the most likely to engage, persist and seek out potentially risky acts of creativity [6].

However, how deeply the examples are thought about is a relatively under researched area. Starkey at al [6] performed an experiment that touches on how thought is deepened by dissection practices. However, they were comparing the effect of disassembling a product into its parts virtually and disassembling a product into its parts physically.

We want to use literature on morphological concept generation and product dissection to aid us in making our subjects think abstractly about the functions of the parts of the product in examples.

Morphological Concept Generation

Engineering design is a demanding process, requiring both ingenuity and a methodical approach to collecting, interpreting, and using information [9]. A morphological chart is a method to generate ideas in an analytical and systematic manner [10] used in engineering design in order to make the design process more productive. Morphological concept generation is the method in which the design space is decomposed into required functions and means by which those functions are achieved. We are terming this principle abstraction. Taking multiple examples, finding the principles common to each and the means in each example, is abstracting over all the examples. This should allow us to understand what the basic components are, and what different means are available, and thus develop a new design from a much broader position then if we were not abstracting over examples.

EXPERIMENT

Participants

We recruited 29 participants who were undergraduates at UC San Diego with experience in drawing and design. 8 participants did not follow the instructions correctly and were excluded from the sample size before we started our analysis. (N = 21)

Task and Procedure

In this in-between subject experiment, each participant had to go through four stages of experiment : Pre-Test, Training, Study Period, Design Task (Fig 1).

In the Pre-Test stage, all the participants were given the Guilford Test (to generate as many alternate uses of a common household object) to get a measure of their native creativity.

Conditions	Pre-test	Training	Study period	Make the Design
Abstraction: use m-chart	Guilford Creativity Test	Learn how to make morphological chart for toasters	Make morphological chart for 5 soap dispensers	Design a new soap dispenser
Control: just look at examples		Look at toaster examples and estimate price of each	Look at the same 5 soap dispensers any way they like	
	4 mins	**10 mins**	**10 mins**	**10 mins**

Figure 1. Experimental Design displaying 4 stages of the experiment

This Pre-Test was performed to ensure that if there is an effect, it is not because the treatment group has more creative subjects than the control group.

Before the subject proceeded to the next phase of the experiment(Training Phase), each participant was randomly assigned to one of the two conditions

1. Abstraction using Morphological Charts condition (Abstraction condition)
2. Control condition

   Participants in these 2 conditions had different training. In the Training Phase for the abstraction condition, participants were taught to think abstractly using a morphological chart using videos, texts, and activities like drag and drop screen to test their skill on functionally abstracting a toaster (as shown in Fig 2)

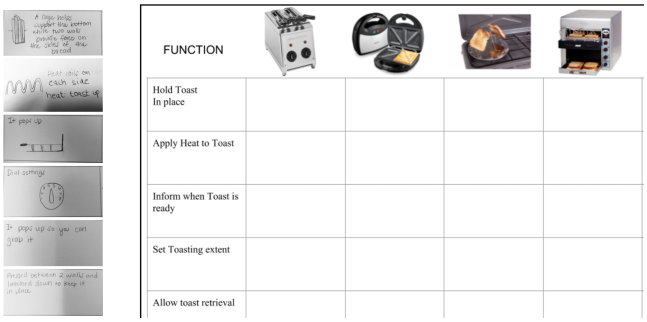

Figure 2. Partial screenshot of the Training Phase interface for the Abstraction condition

The control condition in the training phase did not see the morphological chart. Instead, they looked at the same examples of toasters and were asked questions about them such as the toaster's likely price, and their worth to them (as shown in image below). The time for training for both the conditions was the same.

In the study period, both groups were shown 5 examples of interesting soap dispensers for 10 minutes. In this time, the abstraction condition group had to make a morphological chart using these examples and the control group was asked to examine the examples without any specific instructions.

After the study period, both groups moved onto the design task. Both groups were given 10 minutes to design an innovative soap dispenser that is novel in the sense that it is not a copy of

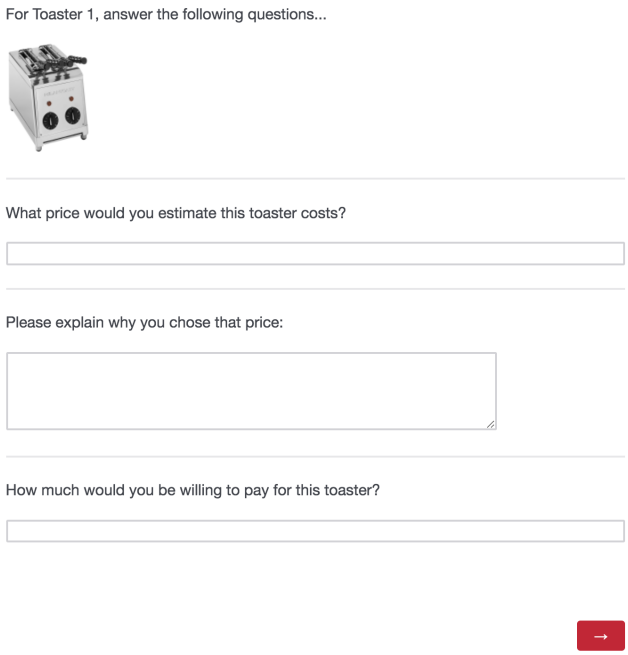

Figure 3. Screenshot of the Training Phase interface for the Control condition

a known one. They both kept the images of examples and in the case of the abstraction group they kept their morphological chart.

The prompt for the design task was an extension of the prompt given for performing dissection of the product [11] and the drawing aliens task [3]. The exact prompt we used for our experiment is given below

"At a big Tech Conference, the Chief Innovation Officer (CIO) of Apple realized how bad the design of soap dispensers are! Imagine you are employed by a tech company in Silicon Valley that is in need of new ideas for soap dispensers. Your task is to design a new soap dispenser for the company. Within the allotted 10 minutes draw a new and different soap dispensers of your own creative design. Duplication of soap dispensers that currently exist or have already existed is not permitted. After completing the drawing of a soap dispenser ON THE PAPER PROVIDED: (1) label each part and (2) briefly describe and explain the soap dispenser. The design you develop should be able to be used by the consumer with minimal instruction. Eventually, it will be up to the board of directors to determine if your project will be carried out into production."

The idea of using a soap dispenser as our challenge problem owes to a comment by Johnny Ives that what the world needs is a better soap dispenser. It nicely fits our requirement of being a challenging design topic but less familiar than chairs or lamps.

Evaluation Method

For evaluating the novelty, we used 3 evaluators. The evaluators were students with experience in either designing or grading design projects and were asked to rate the 21 designs created independently. They were blind to the which designs were made by the abstraction condition and which designs were made by the control condition. The evaluators were told to read all the ideas, decide whether they were functional or not, and then rate them on a 7- point likert scale for novelty. For deciding whether the product idea fulfills the role of a soap dispenser, we asked the evaluators check on either the 'yes or the no' checkbox depending on whether design fulfilled the role the basic role of a soap dispenser. If they marked yes, we asked the evaluators to rate to "consider how novel, original or surprising the idea is (1- Not Novel ; 7- Very Novel ") based on the evaluation method to measure novelty used in Siangliulue et al.[8] Below are some designs that had high novelty scores.(Fig 4 & 5)

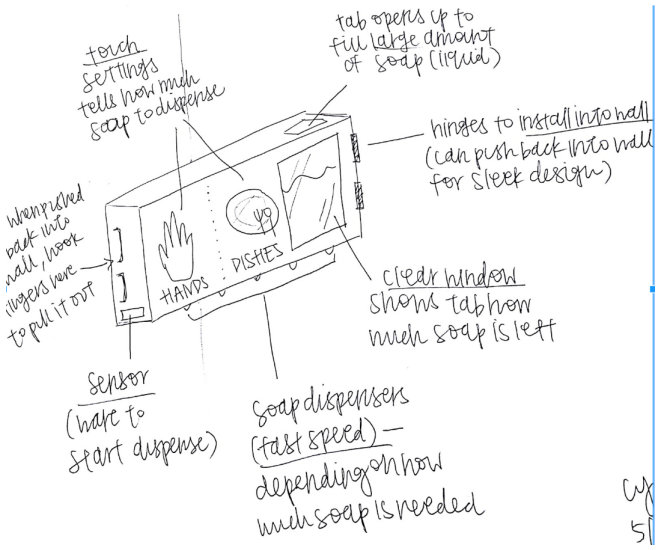

Figure 4. Design with high novelty score

For evaluating the Guilford Test, we used the standard Guilford metrics based on originality, fluency, flexibility and elaboration to obtain a score of their native creative ability.

RESULTS

On the analysis of variance that we performed, we observed a main effect of abstraction through morphological charts on novelty of ideas, $F(1,18) = 8.15$, with $p = 0.01$.

On average participants in the abstraction condition scored 4.33 out of 7 on the novelty scale as assessed by our raters, compared with an average of 3.15 out of 7 for participants in the control condition (Fig 6). This supports our hypothesis that subjects don't just describe example structures in their morphological chart. By going through the process, subjects abstract functions. It also indicates that functional abstraction of the design problem leads to more novel design solutions.

We also found that the designs of the abstraction condition were not just a mix and match from the structures that were presented in the examples. In some cases, the subjects in the abstraction condition had new structures as well.

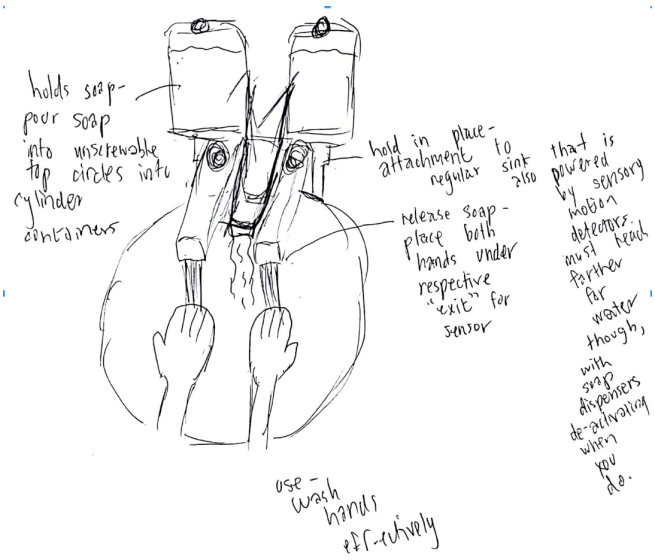

Figure 5. Design with high novelty score

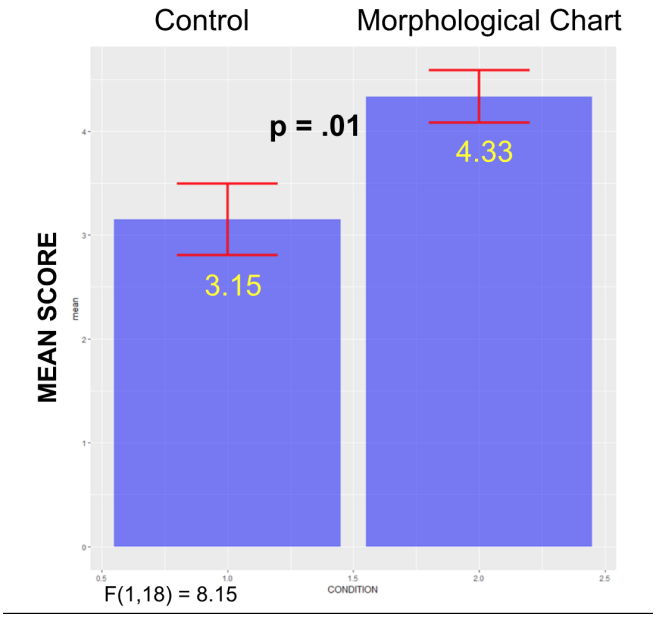

Figure 6. Participants in the Abstraction condition generated significantly more novel designs than the participants in the Control condition. Error bars show standard error.

Inter- Rater Reliability

We performed the Fliess' Kappa test for measuring the inter-rater reliability. The p value was = .445, which indicated that the raters are not similarly reliable to each other. However, all 3 raters show the same patterns in the overall effect (Fig 7). So though the raters did not agree on how novel the designs were, the raters results correlated in that the abstract group had more novel designs than the control group.

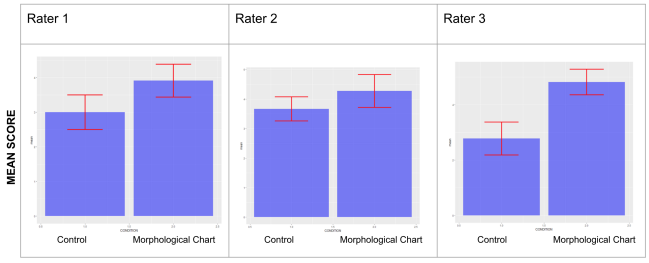

Figure 7. Novelty scores for all 3 raters were higher for the Morphological Chart condition than the Control condition. Error bars show standard error.

Native Creativity

We averaged each participant's score on the Guilford Test and performed a t-test on the set of means within each group, control and abstract group. It was found that the average score for the abstract condition was 3.2125 and the average score for the control group was 3.3625. There was no significant difference between the scores of their native creativity. This ensures that the control was at least as creative as the abstraction group.

DISCUSSION

Both the control group and abstraction group were given the examples and the design task for the same amount of time. The results display that the abstraction group came up with significantly more novel designs for soap dispensers by following our approach for improving creativity through functional abstraction. This method should work for any product for designers, as there was no special step needed for abstracting the functions of a soap dispenser as compared to any other product. Apart from being inspired from Johnny Ives comment that the world is need of a better soap dispenser, we chose the soap dispenser as we were testing our hypothesis on common people, and not on designers. Common people are not experts in designing technology that addresses people's needs, but they are experts of their own lives and have at least some knowledge about the problems of a simplistic object they use daily. This method of increasing creativity in the design process has direct application to web design, interaction design and industrial design.

An explanation for the success of this method is that thinking at a deeper level about the functions reduces the effects of priming of the world around us. Since novelty is defined as something that is not common and away from the stereotype, thinking about the functions and the purpose of a product would reduce the priming effect of the designs of the objects that people might see daily.

The success of this method brings clarity to the conflict in creative ideation literature about examples having fixating and inspiring effects. The studies that show that examining examples leads to reduced creativity could be because of how the subjects are examining and interacting with examples. Maybe, one needs to perform some form of functional abstraction on the examples given to understand the problem and solution space better, and only then can one come up with a creative

solution. If this is the case, it would explain the inconsistency and puzzle that exists in creativity.

Another qualitative finding was that when subjects think about the functions of the given examples, and fill the morphological charts with the means by which the given examples fulfills those functions, they gain an understanding of the purpose of the product, and come up with their own means of fulfilling those functions in their design solution. In other words, the designs of the abstraction condition were not just a mix and match from the structures that were presented in the examples. We had cases, when the subjects in the abstraction condition had created new structures for fulling the function which is not based on any of examples given.

This work could even be applied to improving education in classrooms with examples and change the way people interact with examples for maximum understanding and novelty.

With this understanding of how examples work in ideation, we will be able to create digital and physical environments that stimulate creativity, and not just meet the needs of designers in this data age but also lay the foundation to address changing user needs and technology.

CONCLUSION

There are many puzzles about design and examples. This paper makes three majors contributions in design. First, it sheds light on improving creativity in design by following the method we used. In this paper, we used the technique of morphological concept generation and product dissection to aid subjects think more abstractly about their design problem. We wanted to test if thinking more abstractly about the functions of the product in the design problem leads to more novel results than usual. To test our hypothesis, we conducted an experiment between subjects in which we taught them how to think abstractly about the functions of a product using morphological charts. Our results show that people come up with more novel designs when they think abstractly about the functions of a product than usual.

Second, it indicates that giving people a tool (morphological chart in this case) to scaffold their thinking leads to more novel designs.

Third, the paper also brings clarity to the conflicting literature about whether examples enhance or stifle creativity. This paper indicates that showing subjects examples help them design better if they learn how to use them correctly.

We hope this line of work helps in creating tools and software for designers that stimulate creativity

Future work

There are several directions for our future work. First, we would want to repeat the experiment with a larger sample size. In that modified experiment, we would give the Guilford Test again as a post test to see if the morphological concept generation practice improves creativity by teaching abstraction.

Second, we would want to see if people who make good morphological charts make better designs. We feel this would be true as the better the morphological chart is, the better the designs would be. This is because if someone makes a bad morphological chart, it indicates that he/she is bad at abstraction. With enough subjects we'd like to find the effect of a good morphological chart on performance, and then control for creativity according to Guilford.

Third, we would like to see if the least creative people according to the Guilford Test, benefit the most from the morphological chart. i.e. compare how much better (mean improvement) the subjects with Guilford weak, Guilford moderate and Guilford strong scores do when they use a morphological chart as compared to not using morphological chart.

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*23c)*http://curtbonk.com/bobweb/Handout/d1.uses.htm