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The Role of Personality and Team-Based Product Dissection on Fixation Effects

Christine A. Toh
University of Nebraska at Omaha, ctoh@unomaha.edu

Scarlett R. Miller
The Pennsylvania State University

Gül E. Okudan Kremer
The Pennsylvania State University

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CHRISTINE TOH

SCARLETT MILLER

AND

GÜL E. OKUDAN KREMER
The Pennsylvania State University
State College, PA

ABSTRACT

Design fixation has been found to be complex in its definition and expression, but it plays an important role in design idea generation. Identifying the factors that influence fixation is crucial in understanding how to enhance the design process and reduce the negative effects of fixation. One way to potentially mitigate fixation is through product dissection activities since this activity has been shown to increase creativity and design space exploration in engineering design. However, product dissection has not been studied in the context of design fixation, so it is unclear if, or how, this type of activity influences fixation. Additionally, although prior work studied product dissection in a team environment, it did not examine how individual factors such as personality attributes influence one's involvement or exposure to the activity. Therefore, this study explores the role of product dissection and personality traits on design fixation in an engineering design classroom setting. Our results show that product dissection can reduce fixation effects when students are actively engaged in the activity. However, individual personality attributes can influence one's engagement in a team-based dissection activity and thus, can serve to reduce the positive impact of product dissection. These findings demonstrate a relationship between personality and active engagement in product dissection activities, and also indicate product dissection as a way to mitigate fixation effects in engineering design education. The results from this study can be used to enhance our understanding of the design process, and help reduce fixation effects in the engineering classroom.

Key Words: design fixation, product dissection, personality

INTRODUCTION

Vilfredo Pareto said that "An idea is nothing more or less than a new combination of old elements" [1]. This is found to be true in engineering design where designers transform, combine, or adapt elements of existing designs in order to generate new ideas [2]. In fact, educators often use examples as tools to teach design in engineering education. Although examples are now considered the cornerstone of the engineering design process [2; 3] they can also negatively impact idea development by fixating designers on the information contained within the example set. This limiting adherence to existing examples is termed design fixation [4] and has been shown to affect different levels of expertise [5] and different design disciplines [6]. Therefore, it is important to identify design methods that mitigate fixation effects in order to improve strategies for teaching design in engineering education and to improve our overall understanding of the design process.

One way that fixation effects can potentially be reduced is through product dissection, as dissection has been shown to increase creativity and design exploration in engineering design [7]. However, since product dissection has not been studied in the context of design fixation, it is unclear if, or how, this type of activity influences fixation. In addition, although prior work studied product dissection in a team environment [8], it did not study how individual factors such as personality influence one's involvement in a dissection activity. Therefore, the purpose of this paper is two-fold. First, we seek to understand how individual factors such as personality attributes affect the individual's exposure to team-based dissection activities. Second, we aim to explore the impact of product dissection activities on design fixation in a team environment. The results from this study are used to derive recommendations to mitigate fixation effects through dissection activities and identify new research directions that explore methods for reducing fixation through new engineering pedagogical practices.

DESIGN FIXATION

Anecdotal and historical accounts have shown that even the most creative ideas are developed through minor extensions of familiar concepts [9]. Although this mapping of old to new can facilitate progress, it can also limit an individual's ability to 'think outside of the box' or move beyond familiar concepts to develop something truly unique. Jansson and Smith [4] were the first to study fixation effects in design. They hypothesized that designers who were shown pictorial examples prior to idea generation would experience a mental block that would limit their ability to solve the problem in other ways. Their research validated this theory when they found that designers who were shown examples prior to idea generation utilized more features from the example set compared to those who were not shown examples. This was found to be true for both novice (students) and expert (practitioners) designers even when example features were deemed inappropriate. They defined this lack of flexibility during idea generation as design fixation, or a "blind and sometimes counter-productive adherence to a limited set of ideas in the design process" (p. 4). Follow-up studies also reported similar findings on the fixation effects of example usage during the design process [10; 11; 5; 12].

While these studies highlight the presence of fixation in design, other research has explored the complex nature of fixation. For example, Purcell and Gero [6] found that although designers can become focused on examples during the design process, fixation might be dependent on variables such as the designer's domain knowledge. Tseng et al. [13] also explored the factors that impact design fixation and found that the timing and analogical similarity of the examples that participants were exposed to impacted fixation effects. Other studies, such as those done by Purcell and Gero [14] found that the designer's familiarity with the example presented plays a role in the fixation effects experienced. This result is thought provoking because it suggests that the type of example presented before idea generation may impact the fixation of the generated designs. Linsey et al. [5] also studied the complexity of fixation and their results showed that engineering design faculty who research fixation effects can become fixated during the design process, without even realizing that fixation is happening. The complexity of fixation has also been shown to affect engineering education, as research on fixation has been shown to reduce a students' performance when examples with inappropriate solutions are presented [12]. These studies highlight the complexity of fixation and its negative impact on idea generation. They also motivate studies that identify methods to reduce fixation effects in order to properly modify pedagogical practices.

Although design fixation has been shown to be limiting in the design process, researchers have shown that it is possible to overcome fixation by providing participants with de-biasing instructions [12] or by providing useful analogies [5]. The results from these studies highlight the possibility of mitigating fixation effects, but both of the studies required additional information (instructions and analogical operators) to be provided to the participants during the design activity reducing the practicality of this type of approach in design. In addition, because fixation happens in an unconscious manner [15], it is not always easy to perform an intervention at the design stage. Nevertheless, these works direct researchers to focus on methods for mitigating design fixation effects, starting with understanding the factors that contribute to fixation in existing design activities. Therefore, the goal of this study is to understand how product dissection activities, tools frequently used during the re-design process in engineering education, affect fixation. Product dissection is particularly apt for mitigating fixation effects as it can be implemented without specificity to the problem, and it has previously been shown as a beneficial activity in engineering education [16-18].

PRODUCT DISSECTION

Product dissection has been utilized in various engineering design settings, and it is often used during the design process as a way to systematically uncover opportunities for re-design [7]. Dissection involves taking apart or analyzing all components and subcomponents of a product [18], and thereby adding to the understanding of its structure and properties while uncovering opportunities for product improvement [16]. Ultimately, the goal of dissection is to improve the maintainability and reliability of a product, implement new technologies, and increase the functionality of the product [19] through the examination, study, capture, and modification of existing products.

The benefits of product dissection activities are realized in both industry and academia. At the industry level, companies perform product dissection to provide competitive benchmarks and gain knowledge and insight of a particular product [8]. In the classroom setting, product dissection provides students with insight into industry practices [16] and 'hands-on' experience [20]. In fact, studies have shown that product dissection can help students relate classroom material to real-life engineering problems [21], help engage first year engineering students in learning [22], improve the effectiveness of instruction [23], improve students' practical knowledge [24], increase student learning and enjoyment [25], and allow students to learn about team dynamics and the importance of inter-personal communication [21]. Research has also shown that students who perform product dissection in a team environment are more creative, develop more ideas, and explore both the form and function of a design compared to those who do not [7]. This deeper exploration of the design space as a result of dissection activities suggests that product dissection could have an impact on design fixation and thus, impact the way dissection is utilized in an educational setting. However, no research to date has explored how dissection affects fixation or how individual factors such as personality traits can mediate involvement in dissection activities. This study was developed to respond to these research gaps.

PERSONALITY, TEAM PERFORMANCE, AND CREATIVITY

While the previous section outlined the potential positive effects of team-based product dissection activities, a team member's level of involvement in the dissection may impact the extent of these positive effects. Factors that impact team participation have been widely studied in the literature and include variables such as motivation [26], status difference [27], and self-knowledge [28]. In addition, individual personality attributes have been shown to have a strong influence on team member participation [29; 30]. Due to the fact that personality traits largely influence the way in which individuals behave and interact with each other [31], it is important that this factor be studied for its impact on team involvement. This is crucial because design is being recognized and taught as a team process in engineering [32], in part because products developed by teams have been shown to be of higher quality than those produced solely by an individual [33], and in part because teams foster a wider range of knowledge and expertise which aids in the development of ideas [34]. In addition, teamwork has been shown to increase classroom performance [35] and encourage more creative analysis and design [36] in engineering education. Therefore, it is important that we study personality attributes as they relate to the exposure to the dissection activity in team environments and design fixation.

One way in which personality traits can be assessed is through The Big Five Factors of Personality (Five Factor Model) framework developed by Costa and McCrea [37]. This framework has been used extensively in literature, and is recognized as a reliable instrument. The Five Factor Model states that personality has five dimensions: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness. These personality traits have been found to differ across genders [38-40] (e.g., females scoring higher on neuroticism and agreeableness than males). Importantly, these attributes have been shown to play a significant role in small team performance [30], a setting that is common in engineering design. For instance, those that score high on agreeableness tend to engage in teamwork, are more cooperative, and have a higher quality of personal interaction, while those who score high in neuroticism tend to be less cooperative in a team environment [41]. On the other hand, the extraversion personality trait has also been positively linked to successful team performance [42], while conscientiousness has been shown to be negatively correlated with social loafing [43]. Therefore, we hypothesize that personality attributes will affect team member involvement and interactions, and hence, the individual exposure to the product dissection activity.

In addition to linking personality attributes to team performance, several scholars have summarized the role of personality in creative achievement. For instance, McCrae [44] found that openness to experience had a strong effect on creative achievement, while Steel et al. [45] linked innovation to both openness to experience and conscientiousness. Hoff et al. [46] suggested that creative individuals are low on agreeableness and "do not adapt to others, but go their own way" (p. 254), while Stafford et al. [47] linked creative achievement to high levels of extraversion. Other researchers have also found highly neurotic individuals to be less likely to have boosts in creativity due to anxiety [48]. Although work in this research area has revealed a relationship between personality attributes and creative achievements, the results are mixed and the participants used in these studies were mostly undergraduate psychology students, not engineers. This makes their results questionable for application in the engineering domain. Therefore, the current study seeks to understand how personality traits affect involvement in team product dissection activities, and hence, how this factor affects design fixation.

RESEARCH OBJECTIVES

The purpose of this study is to examine the interactions between individual personality traits, exposure to a team-based dissection activity, and design fixation. Our two primary research hypotheses are as follows: (1) personality traits affect the participant involvement in the dissection activity; (2) exposure to the dissection activity and personality traits affect design fixation. For the second hypothesis, the personality traits and the exposure to the dissection activity variables are anticipated to be correlated to one another and thus, will be analyzed concurrently for their effects on design fixation. Additionally, we seek to determine how the dissected product affects the involvement in the dissection activity as well as the amount of fixation apparent in the generated ideas, as prior research has linked fixation to participants' familiarity with provided examples. To test these hypotheses, an exploratory study was conducted in a first-year engineering design classroom involving the dissection and re-design of an electric toothbrush. It should be noted that this study was exploratory in nature and thus, did not seek to control the extent to which exposure to the product dissection activity affects design fixation, but rather sought to find a relationship between these two quantities in a natural classroom setting. Hence, a control group was not utilized for this study because we wanted to see how the personality attributes naturally affected team member participation in the activity. The results obtained from this study will be used to contribute to the understanding of how team-based dissection activities influence design fixation in order to derive implications for engineering education and identify new research paths that extend the knowledge of de-fixating methods.

EXPLORATORY STUDY TO EXAMINE DESIGN FIXATION

Participants

The participants in this experiment were undergraduate students in a first-year engineering design course at a large northeastern university. There were 76 students (61 males, 15 females) that participated in this study from three different sections of the course. Each section consisted of 3- and 4-member design teams (20 teams in total, with 4 teams consisting of 3 members). Teams were assigned by the instructor based on prior expertise and knowledge of engineering design so as to balance the performance of the teams. This was accomplished through questionnaires that were given at the start of the semester that asked about student proficiencies in the following areas: 2D and 3D modeling, sketching and engineering design experience.

Personality measures for each participant were captured prior to the start of the study using the short Five Factor Model (FFM) online questionnaire (Short Form for the IPIP-NEO (International Personality Item Pool Representation of the NEO PI-R™) [49]).

Procedure

The design teams were tasked with redesigning an electric toothbrush for increased portability. Two of the three sections (44 students) re-designed the Oral-B Advance Power 400 electric toothbrush while the other section (32 students) redesigned the Oral-B Cross Action Power electric toothbrush, both seen in Figure 1. Two toothbrushes were chosen because we were interested in understanding if the product provided to the students affected their involvement in the dissection activity or their degree of fixation.

Each team was given 90 minutes during one class period to dissect the electric toothbrush that they were assigned to re-design. During this activity, participants were asked to develop a bill of materials (BOM) for each subcomponent and identify the team member that led each individual part dissection. Examples of the partially dissected toothbrushes with the number of parts for each category are shown in Table 1.

Figure 1. Electric toothbrushes used for the design project. Left: Oral-B Cross Action Power, right: Oral-B Advance Power 400.

	Number of Parts	
		
	Oral-B Advance Power 400	*Oral-B Cross-Action Power*
Brush Head	8 (29.7%)	7 (28.0%)
Body	9 (33.3%)	6 (24.0%)
Energy Mechanism	7 (25.9%)	7 (28.0%)
Power Generation	3 (11.1%)	5 (20.0%)
Total Number of Parts	27	25

Table 1. Partially dissected toothbrushes with the number and percentage of parts by category for the 2 toothbrushes.

A week later, the participants attended a brainstorming session where each team member was given 30 minutes to generate as many ideas as they could for the re-designed toothbrush without consulting with the other participants. The participants were not informed of the brainstorming session prior to attending class the following week, and thus, were not primed to generate ideas before the brainstorming session. During the brainstorming session, participants were asked to sketch as many concepts as possible; writing notes on each sketch such that an outsider would be able to understand the concepts upon isolated inspection. Each participant was provided with paper that had boxes on it to clearly distinguish each idea. Participants were asked to focus their ideas on four general categories: brush head, body design, energy mechanism, and power supply/accessories, refer to the example in Figure 2. Each team had to select two team members to develop ideas in each of the four categories. For example, team member 1 may have developed ideas for the brush head and power supply; team member 2 addressed the brush head and energy mechanism; team member 3 focused on the energy mechanism and body design; and team member 4 dealt with the body design and power supply. In total, there were 40 participants that

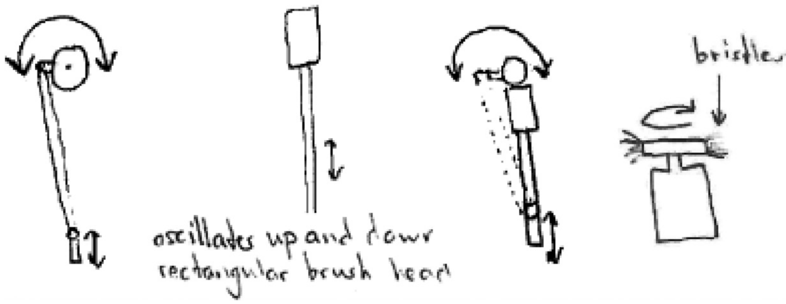
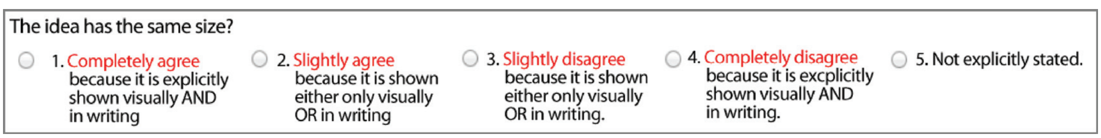


Figure 2. Sequential concepts generated for the energy mechanism design by participant 45.

generated ideas for each category. On average, participants generated 4.5 ideas for the toothbrush head, 3 ideas for the toothbrush body, 3.9 ideas for the energy mechanism, and 4.4 ideas for the power generation category.

Metrics

To quantify the degree of design fixation for the participants' solutions, a fixation metric was developed based on the method used by Linsey et al. [5]. In their study, Linsey et al. [5] measured fixation as the number of times a feature from an example was present in a participant's solution. In order to calculate this metric, they identified a set of features from the example solution provided to participants and had two judges independently rate whether the feature was present or not in the participant's solution. Similar to this method, 52 features of the toothbrush provided to participants in the current study were identified and were later categorized into one of four subcategories for analysis: brush head, body, energy mechanism and power generation design, see Table 1. Two independent raters were then used to determine the degree of similarity between the features in the generated solution and the features in the provided toothbrush. This differed from Linsey et al.'s [5] study because rather than merely judging if the feature was present in the participant's solution,


The idea has the same size?

1. Completely agree because it is explicitly shown visually AND in writing
2. Slightly agree because it is shown either only visually OR in writing
3. Slightly disagree because it is shown either only visually OR in writing.
4. Completely disagree because it is excplicitly shown visually AND in writing.
5. Not explicitly stated.

Figure 3. Example of an energy mechanism rating question with numbered rating scale.

the raters were tasked with rating how similar the feature was to the original toothbrush's design. The development of a rating scale was necessary to aid raters in this judgment process due to the increased resolution in the rating system and also because of the varied ways in which participants presented their design concepts during the study.

During the study, participants were asked to produce both a sketch and a written description of their idea. However, on inspection of the ideas, the authors found that the participants often created simple drawings and described additional features in the written design description for complex ideas. For example, participant 25 sketched a simple toothbrush head design but added features such as the motion of the toothbrush only in the written description, see Figure 4. Therefore, in order to help raters judge how similar the feature in the idea was to the original design, a 5-point rating system was developed through discussions and training sessions with the raters, see Figure 3. Rating values of 1 or 2 were deemed as the solution having a similar feature to the original design (fixated), with a rating of 1 indicating that the idea addressed the feature through both sketches and writing, and 2 indicating that the idea addressed the feature through either sketches or writing alone. A similar system was employed for rating values of 3 and 4 that were deemed as not similar to the original design (not fixated). A rating of 5 was used when the participant did not address the feature in their design. A design-benchmarking handbook was developed to assist the raters and provide a reference during the rating process. Since the goal of this study did not focus on how the participants presented their ideas (pictorial or written), ratings of 1 and 2 and ratings of 3 and 4 were combined for analysis in the study. Examples of designs rated according to this scale are shown in Table 2.

The inter-rater reliability for this rating system was 85.2% with a Cohen's Kappa of 0.76. Disputes were settled in conference between the raters as was done previously by Chrysikou et al. [12].

These ratings were then used to calculate the following fixation metric:

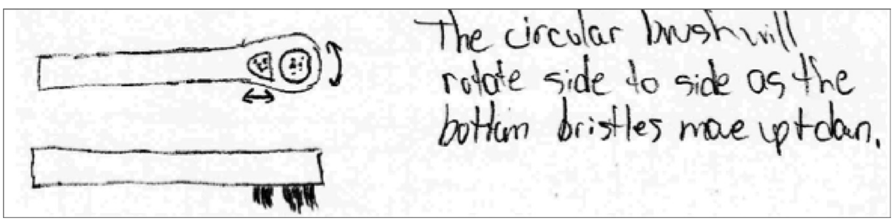


Figure 4. Participant 25's brush head design that uses writing to supplement the sketch in order to communicate the design idea.

Fixation Percent:

The number of similar features that appeared in the generated concept (rating of 1 or 2) was taken as a percentage out of the total number of features that the design addressed to give a fixation percent value, as seen in Table 2. Each participant's fixation percent was then taken as the average fixation percent of the participant's generated designs.

In order to examine the effects of the dissection activity on the amount of fixation present in the designs, an exposure metric was defined:

Rating Questions	Similar/ Different from original design	
 *Original Design*		
The idea has the same shape	Similar	Different
The idea has the same method of providing grip	Different	Different
The idea uses the same materials	Different	Not explicitly stated
The idea has the same number of components	Similar	Similar
The idea has the same level of portability	Similar	Different
The idea has the same power button location	Not explicitly stated	Different
The idea has the same battery access location	Not explicitly stated	Not explicitly stated
# of similar features	**3**	**1**
# questions NOT rated as 'Not Explicitly Stated'	**5**	**5**
Percent fixation	**60%**	**20%**

Table 2. Example body design ideas rated using the questions discussed above. Ratings of 1 or 2 were referred to as 'agree' whereas 3 or 4 were referred to as 'disagree'.

	Brush Head	Body Design	Energy Mech.	Power Gen.
Total # of parts	7	6	7	5
# of parts dissected	1	1	5	3
Parts exposure percent	14.2%	16.7%	71.4%	60%

Table 3. The number of parts that participant 45 was exposed to during the product dissection activity. The parts exposure percent metric was calculated out of the total number of parts in each category.

Parts Exposure Percent:

The number of parts that each participant dissected out of the total number of parts in the original design within each category. Table 3 shows the computation of parts exposure percent for each category for participant 45.

Statistical Analysis

Our first hypothesis was that personality traits affect the involvement in the dissection activity. In order to investigate this relationship, multivariate regression analyses were performed with the dependent variables being the percent parts exposure for the 4 separate categories, and the independent variables being each individual personality trait. For the purposes of this analysis, the exposure percent and fixation percent variables were considered for each category of the toothbrush. There were 40 participants who generated ideas for each category, bringing the total sample size for the analysis to 160. In order to address the problem of multiple comparisons and maintain a family-wise error rate, a correction of $\frac{\alpha}{n}$ was applied to the significance level, where $\alpha = 0.05$, and n is the number of hypotheses in the multivariate regression ($n = 4$) [50]. This correction ensures that the significance level for the whole family of tests is, at most, α. Therefore, the significance level for each of the individual multivariate tests was 0.01.

In order to address our second hypothesis, stating that exposure to the dissection activity and personality traits affect design fixation, we ran a multiple regression analysis with the dependent variable being fixation percent and the independent variables being the parts exposure percent for the 4 separate categories, and the 5 personality traits. In addition, in order to investigate the difference between dissection of the Oral-B Advance Power 400 toothbrush and the Oral-B Cross Action Power toothbrush, an independent t-test was performed to compare fixation percent for these two products. SPSS v 20.0 was used to perform all of the statistical tests. The level of significance was 0.05.

RESULTS

The purpose of this study was to investigate the interactions between exposure to a product dissection activity, individual personality traits, and design fixation, and to examine the impact of the product used for dissection on design fixation. Therefore, these interactions were analyzed in three phases. The first phase was to explore the interaction between personality traits and exposure to the dissection activity. The second phase explored the combined effect of personality traits *and* exposure to the dissection activity on the resulting design fixation. Finally, a third analysis was performed in order to understand how the product chosen for dissection affects design fixation.

The Relationship between Personality and Exposure to Dissection

To examine the relationship between personality traits and the exposure to the dissection activity, multivariate regression analyses were performed using the four categories of percent parts exposure as the dependent variables, and each individual personality trait as the independent variable. The personality trait distribution of the participants can be seen in Figure 5. A corrected significance level of 0.01 was used in order to maintain a family-wise error rate.

The results revealed significant relationships between the personality traits and the parts exposure percent, see Table 4. The results indicated that the personality traits were significantly related to the exposure to the dissection activity. In particular, the extraversion and conscientiousness personality traits were highly correlated with the energy mechanism and power generation percent parts exposure categories, and to the body design, energy mechanism, and power generation percent parts exposure categories, respectively. Similar effects were found for all toothbrush dissection categories. This suggests that personality traits play a significant role in determining each individual's exposure

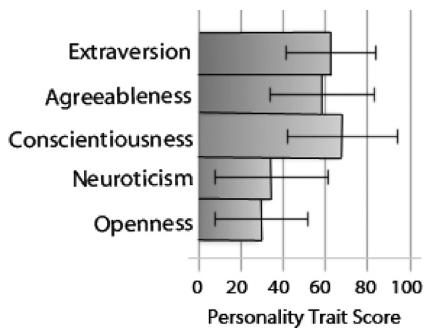


Figure 5. The means and standard deviations of the personality traits of the participants.

		Brush Head	Body Design	Energy Mechanism	Power Generation
Extraversion	R^2	0.36	0.36	**0.80**	**0.82**
	F(4,136)	1.36	1.33	**9.51**	**10.51**
	p-value	< 0.10	< 0.29	**< 0.002**	**< 0.002**
	Coefficients, B	0.001	0.001	**0.002**	**0.001**
Agreeableness	R^2	0.36	0.27	0.26	**0.65**
	F(4,136)	1.64	1.05	1.01	**5.26**
	p-value	< 0.02	< 0.41	< 0.47	**< 0.001**
	Coefficients, B	0.001	0.000	0.000	**0.002**
Conscientiousness	R^2	0.29	**0.88**	**0.98**	**0.67**
	F(4,136)	1.13	**20.06**	**98.98**	**5.87**
	p-value	< 0.297	**< 0.001**	**< 0.001**	**< 0.001**
	Coefficients, B	0.002	**0.000**	**0.001**	**0.002**
Neuroticism	R^2	**0.43**	0.22	**0.53**	**0.51**
	F(4,136)	**2.06**	0.77	**3.18**	**2.91**
	p-value	**< 0.001**	< 0.833	**<0.001**	**< 0.001**
	Coefficients, B	**−0.001**	−0.001	**−0.001**	**−0.001**
Openness	R^2	0.23	**0.42**	0.34	**0.44**
	F(4,136)	0.98	**2.34**	1.71	**2.61**
	p-value	< 0.516	**< 0.001**	< 0.016	**< 0.001**
	Coefficients, B	0.000	**0.000**	-0.001	**0.000**

Table 4. Summary of the multivariate regression analysis. The bolded results indicate significant findings.

to dissection of various types of products in a group setting. It also shows that the different levels of complexity of the dissection categories affect team member involvement. Therefore, these two related variables should be explored further for their combined effect on design fixation.

The Effect of Personality and Exposure to Dissection on Fixation

The previous section revealed a relationship between exposure to the dissection activity and personality attributes. Further tests were required to investigate whether exposure to the dissection activity and individual personality traits affected design fixation. The regression results revealed that there was a significant relationship between fixation percent and parts exposure percent coefficient for the body design category ($b = -0.358$, $p < 0.02$), as seen in Table 5. The analysis for the other three categories (brush head, energy mechanism, and power generation) and personality traits indicated

	Model	Coefficients, B	Sig.
Percent parts exposure	Constant	0.461	0.06
	Parts exposure percent (brush head)	0.089	0.89
	Parts exposure percent (body design)	−0.358	**0.02**
	Parts exposure percent (energy mechanism)	0.025	0.44
	Parts exposure percent (power generation)	0.017	0.50
Personality Traits	Extraversion	0.000	0.84
	Agreeableness	0.000	0.94
	Conscientiousness	0.000	0.97
	Neuroticism	0.000	0.65
	Openness	0.001	0.62

Table 5. Summary of the multiple regression analysis with coefficients and significance values. The bolded result indicates a significant finding.

no significant relationships with fixation percent. These results suggest that the more individuals participate in the dissection activity for the body design category, the less fixated they appear to be in their generated designs.

The Impact of Dissecting Different Products on Fixation

In order to investigate if the product being dissected influences the fixation effects found, an independent t-test was performed to compare the percent fixation of the two toothbrushes dissected. The results revealed a significant relationship between type of toothbrush and percent fixation ($F = 0.76$, $p < 0.01$). Therefore, profile plots were used to explore this relationship in more detail, see Figure 6. These results indicate that participants who dissected the Oral-B Advance Power 400 toothbrush generated designs that were slightly more fixated ($M = 0.48$, $SD = 0.16$) than those who dissected the Oral-B Cross Action Power toothbrush ($M = 0.39$, $SD = 0.19$).

DISCUSSION

The purpose of this study was to explore the link between product dissection, personality traits, and design fixation in engineering design education. It was hypothesized that the fixation experienced by engineering students could potentially be mitigated through product dissection activities since

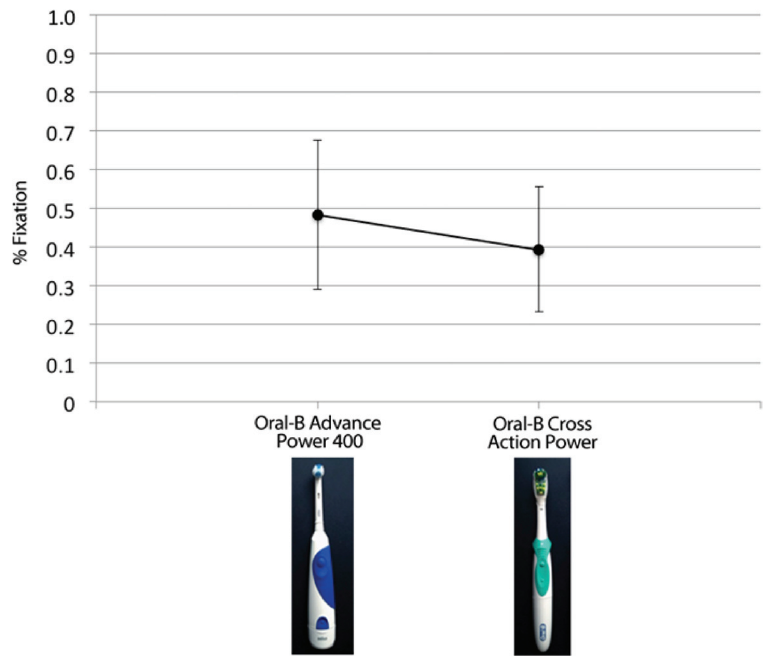


Figure 6: Profile plot of percent fixation vs. toothbrush type.

this activity has been shown to increase creativity and design exploration in engineering design [7]. However, product dissection activities have not been explored for its effect on design fixation. Additionally, because product dissection is often performed in a team environment, individual factors such as personality traits may influence each team member's involvement in the dissection activity, ultimately affecting the potential positive effects of this activity on design fixation. Therefore, the current study was conducted to understand how individual personality traits and exposure to a dissection activity affect design fixation.

The results from the study indicate that personality traits are related to the amount of exposure to a dissection activity in an engineering classroom. In particular, participants that scored high on the extraversion, conscientiousness, agreeableness, and openness personality traits and low on the neuroticism personality trait were found to participate more in the dissection activity. However, not all toothbrush categories had significant relationships with all personality traits, indicating a complex and multi-faceted effect of personality traits on the amount of involvement in a product dissection activity. In other words, individuals may be involved at varying levels of both personality traits and the type of part being dissected in product dissection-based activities. This result points toward the fact that individuals, if left to self-select their involvement in dissection activities, will not participate equally in a team setting. Thus, it may be necessary to conduct more structured dissection activities that ensure equal involvement by all individuals to reap the positive effects of this activity in engineering education. For example, having each student perform the dissection, or having each student fill out a bill of materials could contribute to a more equally distributed work load in an educational setting. However, the fact that significant results were found between all personality traits and the overall involvement in product dissection suggests that personality can indeed be more generally linked to involvement in team-based product dissection. For example, prior research that found that extraverted individuals contributed more to successful team performance [42] agrees with the finding that extraverted individuals participated more in complex dissection categories (e.g., energy mechanism and power generation). Similarly, individuals that scored high on conscientiousness and low and neuroticism tended to be more involved in 3 out of 4 dissection categories, as predicted by prior research [43; 41]. However, the results not only linked these personality attributes to the exposure to the dissection activity, but also explored the potential role of personality traits on the amount of fixation experienced by designers.

The results also reveal that fixation effects are significantly related to the participant's involvement in the dissection activity for the brush head category of both toothbrushes, indicating that the dissection activity could be used to mitigate design fixation in different products. It was also revealed that participants who dissected the Oral-B Advance Power 400 toothbrush were significantly more fixated in their generated designs than those that dissected the Oral-B Cross Action Power toothbrush. This result indicates that the example presented prior to product dissection and thus, idea generation, plays an important role in the amount of fixation apparent in the generated designs, agreeing with prior studies [4]. Engineering educators should consider the products chosen for dissection carefully, as the type of product being dissected can impact fixation effects. One possible reason for the difference in fixation between the two toothbrushes could be that one model of electric toothbrush could have appeared more familiar to the participants than the other. For example, the Oral-B Advance Power 400 toothbrush only utilizes one rotating brush head, as is the standard in the electric toothbrush market. On the other hand, the Oral-B Cross Action Power toothbrush utilizes two brush heads, one that oscillates, and one that pulsates back and forth. Therefore, participants that were exposed to the more typical design of electric toothbrush could have been more fixated on the example than those that were exposed to a more distantly related example, as was suggested by Tseng et al. [13].

Additionally, the results showed that the more an individual participated in the dissection activity for the body design category, the less fixated they appeared to be in their generated designs.

This finding agrees with prior research that suggested that fixation is more likely to affect the design process if the design problem is more familiar to the designer [4]. For example, given that participants likely interact with toothbrush handles and other various kinds of handles regularly, it is not surprising that exposure to this category of dissection played a role on fixation effects. In addition, it was observed that participants generated fewer ideas on average for the body design category than any other category, suggesting less variety in the generated designs of those not exposed to the dissection of this category. Furthermore, the complexity of problems can also impact the role of fixation in the overall design process. For instance, the energy mechanism category was considered to be the most complex of all four categories for first-year engineering design students due to the fact that it involves domains of knowledge not covered within the first-year engineering curriculum. On the other hand, the body design category is considered to be the least complex because it involves concepts that are likely familiar to first year engineering students (grip, comfort, etc.). However, the fact that the body design category was a substantial part of the dissected toothbrush (see Table 1) indicates that fixation effects can be affected by exposure to a dissection activity.

In sum, the results reveal that certain personality traits affect involvement in specific categories of product dissection, and exposure to product dissection of familiar parts impact design fixation effects. They also highlight the positive effects of individual involvement in product dissection activities on design fixation in a classroom setting. This is an important finding because reduced fixation can expose students to a wider variety of design solutions [4] and encourage learning. From this study, the complex nature of individual difference and personality traits was recognized as both a challenge, and something to leverage in engineering education research. For example, while significant relationships were found between exposure to the dissection activity and personality traits, and between exposure to the dissection activity and design fixation, no significant results were found for the direct relationship between fixation and personality traits. These results suggested that personality traits may, in fact, not have a direct relationship with design fixation, but may be a mediating variable in this interaction. In fact, prior research has shown that personality traits are related to creative achievement [48; 45-47], and therefore, may interact with design fixation through other indirect avenues. Furthermore, the existing literature lacks results that link personality traits to creative achievement in engineering domains. Therefore, these results illustrate the complex interaction between individual factors and other design-related parameters, as well as relate personality traits to engineering-specific creativity metrics. The fact that no significant results were found for the direct relationship between design fixation and personality traits suggests the possibility that existing approaches of examining personality-related creativity in engineering design settings may not be sufficient.

While this study successfully linked personality traits, product dissection, and design fixation, it is still exploratory in nature and differs from an experimental design where all factors can be controlled. In the current study, participants self-selected dissection categories to focus on and were allowed to freely interact within their teams, simulating the beneficial team environment that is often associated with product dissection [21]. While this allowed for a more realistic context for studying design fixation, this study does not explore the implications of product dissection on design fixation in more controlled environments. Future studies should address this research gap by exploring the impact of product dissection on design fixation in a more experimental setting, where confounding variables (e.g., gender, semester standing, self-selection) can be removed.

This study also adds to the existing literature on the utility of product dissection in engineering education [7; 16; 20; 21; 22; 23; 24; 25; 51; 52] by establishing a relationship between product dissection and design fixation. Specifically, structured team-based product dissection activities in which each student is given the opportunity to dissect parts of various complexities will help reduce fixation effects in the engineering classroom and thus, expose students to varied solutions. Future studies should examine the exact effect of participating in the dissection activity compared to not participating in the dissection activity at all. This would help understand the extent to which fixating effects are reduced by dissection activities and thus, help determine methods that reduce fixation in the engineering classroom.

CONCLUSION

Overall, the results of this study show that design fixation effects are indeed related to the exposure to a dissection activity and individual personality traits of designers. This has important implications for engineering design research because it builds on our understanding of cognitive processes as it applies to idea generation and thus, the overall design process.

The results of this study have important implications for engineering education. The results agree with prior studies that illustrate the benefits of product dissection in engineering education [7; 16; 20; 21; 22; 23; 24; 25; 51; 52] and also show that design fixation can be mitigated by incorporating product dissection activities into the engineering curriculum. The fact that product dissection is immensely physical in nature [20] only adds to the positive influence that it can have on engineering education. Notably, product dissection can increase the amount of hands-on activities and help in improving learning and retention in the engineering classroom [52]. Furthermore, given that familiarity with a concept can be increased through product dissection

[51], it is recommended that students be encouraged to engage in the dissection of more complex aspects of the product to both reduce fixation in that domain, and to gain valuable understanding of the concept. From this study, it can be seen that each of the personality traits affect an individual's involvement in the specific product dissection categories differently. Therefore, a more structured dissection activity may ensure more equal involvement among the team, and encourage the exploration of more complicated parts. Additionally, ensuring a more balanced involvement in the dissection activity can help maximize the performance of the team [35; 36] and reduce fixation effects. With more exposure to novel concepts and engineering solutions, students' learning in the engineering classroom can be enhanced and more creative approaches to engineering design can be fostered.

Future studies should explore the relationship between idea generation techniques of both the form and function of a product on design fixation. The use of a control group in future studies would also allow for an exploration of the exact impact of participating in a dissection activity on design fixation. Additionally, the complexity of each category being explored in the dissection activity should be examined for its effect on the design fixation apparent in the idea generation process. The effects of different personality traits on different idea generation techniques should also be examined for their impact on design fixation in order to provide a deeper understanding of how design activities impact design fixation.

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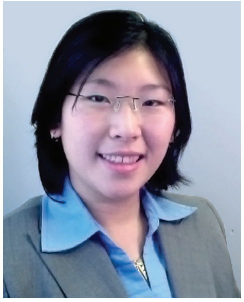
AUTHORS



Christine Toh is a graduate student in the Mechanical and Industrial Engineering departments at the Pennsylvania State University and received her B.S. in Mechanical Engineering from Penn State. Her research interests include engineering design cognition, psychology, and interaction design. Her thesis is focused on studying and applying hands-on activites in engineering design environments.

Scarlett Miller holds the James F. Wills career development professorship in the School of Engineering Design, Technology, and Professional Programs as well as the Harold and Inge Marcus Department of Industrial and Manufacturing Engineering at The Pennsylvania State University. She also holds affiliate appointments in the College of Information Sciences and Technology and the Department of Mechanical Engineering. Her research focuses on developing an in-depth understanding of human physical and cognitive abilities in order to develop next generation products and technologies that support human capabilities. Her research to date has had three main thrusts: design cognition (understanding example usage in design), human-computer interaction (developing tools that support the design process), and ergonomic product design (e.g., laparoscopic surgical tool). More information about Scarlett and her research group The BRITE lab can be found at www.engr.psu.edu/britelab.

Gül E. Okudan Kremer is a Professor of Engineering and Industrial Engineering at The Pennsylvania State University. Her research focuses on decision analysis and design theory applied to improvement of products and systems. She has been a National Research Council-US AFRL Summer Faculty Fellow of the Human Effectiveness Directorate (2002, 2003 and 2004), and a Fulbright Scholar (2010-2011).