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A Study of Designer Familiarity with Product and User During Requirement Elicitation

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A STUDY OF DESIGNER FAMILIARITY WITH PRODUCT AND USER DURING REQUIREMENT ELICITATION

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Abstract

It is important to recognize the effects of a designer's source of information and decision making during requirements elicitation. Requirements are widely recognized as an important step in the design process. Designers may have perspective based on their experience which results in a level of familiarity with the design. This paper reports on a study that explores the effects of designer familiarity with a project and its user on their ability to elicit requirement specifications. Two familiarity constructs, product and user, are measured as low or high and used to study requirement elicitation with varying familiarity. A high familiarity study using five graduate students and a low familiarity study using a team of five students during senior capstone design are compared for their requirements elicitation. The results of this study include an analysis of the requirements developed and participant survey results from the elicitation process. The results revealed familiarity does in fact have an effect on the ability of elicit requirements. Participants in the low familiarity study expressed difficulty and eliciting requirements while those in the high familiarity study were able to generate more requirements at a faster rate.

Keywords

Requirements, Design Product and User Familiarity, Requirements Elicitation, User Centered Design.

1. Introduction

In this time of competition amongst corporations, those who are not able to develop products which accurately reflect the requirements of its stakeholders are putting themselves in risk [1]. A designer's objective is to design and develop a product that functions to satisfying a particular set of requirements. As a result, it is important to understand the designer's source of information and decision making during the requirements elicitation. Individuals have a perspective based on their experience [2,3], and this experience may cause them to possess a specific familiarity with a product or user. This research investigates the influence of the designer's familiarity with a product and its users on the elicitation of requirements. This is performed through two studies of opposing designer familiarities to view the designer's ability to elicit requirements and the thought process through the elicitation. The results of this study include an analysis of the requirements developed and survey results from the elicitation process.

Requirements are expressed as written statements and are the result of interpreting the need underlying the raw data gathered from the users [4]. This raw data, in the form of a requirement list, is retrieved from users who the designers project will use the product. Such requirements may also be collected from a marketing team or from previous projects, such as legacy requirements. Once requirements are collected as raw data, they are interpreted as characteristics, attributes, and specifications that can be related to what the product must accomplish [4]. In some design approaches, the requirement list incorporates a hierarchical sorting based on the requirement's importance and priority [4]. Additionally, importance rating or weightings may be incorporated with each requirement to signify its priority.

Due to the complex evolution of requirements, starting from the raw data collected from users to interpreted requirements translated by designers, rarely in design is one able to develop products that do everything the stakeholder's raw data had initially communicated. Through the design process, it is analyzed that more than half of the design requirements will change before it is completed [5,6]. Requirement changes occur frequently and can at times determine as much as seventy to eighty percent of the final cost of a product [7]. This is partially due to the inaccuracies subjected to requirements during their elicitation, interpretation, and management [8]. As a result, it is critical to correctly and completely elicit requirements which accurately meet the stakeholder's needs. However, determining what stakeholders want, and specifying those requirements in a precise and unambiguous manner is challenging [9]. The challenges pertain to understanding and maintaining the true underlying requirements and the ability to accurately interpret and maintain those requirements throughout the product design process. To account for these issues, many designers stress the use of user-centered design approaches to maintain the focus on the user throughout the design process as to minimize any gap that could occur between the designer and the user.

While the use of many user centered design approaches assists a designer in developing requirements focused on the user, a designer may need further knowledge and information to ensure a successful product is delivered. This knowledge includes the designer's familiarity with the product. A designer may possess high user familiarity; however lack familiarity for the product. Does this affect the requirements elicitation process?

This study aims at understanding if a designer's familiarity of the user and product affect their ability to elicit requirements. In this study, two teams of students are provided designs problems of opposing familiarity with the product and user to examine their ability to elicit requirements.

1.1. Research Objectives

This paper will examine, through a study, if a designer's familiarity with the user and product affect the requirement elicitation process. We investigate requirements because of their importance throughout the design process. Requirements are the basis for every project, defining the needs of stakeholders such as users, customers, suppliers, developers, and businesses and how each need is to be satisfied [10]. The requirement lists are evaluated through use of studies which examine the elicitation of requirements under different designer familiarities. It is hypothesized that designer familiarity has an effect on requirements elicitation and the difficulty encountered through elicitation.

1.2. Research Setup

The research presented in this study is presented as an exploratory study, not an explanatory study. This is a critical distinction as the research motivation is to explore if requirements definition and elicitation can be influenced by an individual's familiarity with different types systems, products, and users. As such, the rigors normally attended to explanatory studies, such as participant pool selection and replication count to support statistical analysis with high levels of significance, were not key contributors to achieving the end goal of determining whether there might be differences in how designers develop requirements. In this manner, the objectives of this study align closer with those of case study analysis than user studies in which patterns are sought that might be suggestive and foundations for subsequent experimental studies [11][46]. The first study is a small observational case study of only the activity of developing requirements. The second study was part of a larger case study that investigated the role that requirements play throughout a fifteen week design-build-test senior design project. In the second study, the author served as both observer and as graduate design coach. This approach to research study of undergraduate design teams has proven successful on other projects [12,13,14,15,16,17].

2. Designer Familiarities

Experiences cause individuals to have goals which underwrite their rational agency [18,19]. Further, designers are not expected to be familiar with the pool of users and products they design for, nor are they expected to have experience using every product they design [20]. The phenomenon of designer familiarity is investigated with respect to two familiarity constructs, the designer's familiarity with the user and product. The scope of this paper views this familiarity as a binary relationship; a designer may possess either high or low familiarity. While this may be a limitation, it serves as a starting point for investigating designer familiarity. Further studies will require a higher resolution of familiarity measurements. Further, there exists no datum for familiarity measurements in this study as all familiarities are binary. It is important to note through the measurement of familiarity, designer bias is not considered. A designer may have a bias over a user or product group which will influence their requirement elicitation. However, this bias is not considered in this paper as it is out of scope. A limitation with the familiarity measurements are their lack of gauge. It is difficult to measure if a designer is or is not familiar with a user or product. Familiarity is measured both subjectively and through input from the participants. Using the familiarity constructs and the possible familiarity measures, there are four possible situations a designer may experience.

2.1. User Familiarity

User familiarity is used to describe the designer's familiarity with the end user of the product. While many designers may not possess user empathy, design aiding techniques exist to mitigate this. This includes techniques such as user centered design approaches, used to ensure the user's requirements are maintained throughout the design process. The goal in a design process is to maintain user centeredness so that the designer may not lose focus of end users [4].

In the end, the design product is meant to be used by users other than the designer and, as a result, the users' perspective must be taken into account while designing an end product that fulfills all requirements [21]. One of the main issues with this topic is that the end users and designer's viewpoints do not always integrate well [22]. Further, the designer of the end product may not always be a user. Nonetheless, the designer will always have a perspective as to how the end product may be used. Knowing who your users are, their environment, and their requirements are necessary information in planning and designing a project [23]. By doing so, the designer ensures a useable design is developed before product delivery [24]. It demands that user's cultural background should be considered and is converted into design information that can be used in the final product [25]

Users are a valuable source of information in assisting designers to understand the requirements for the successful design of a product [20]. User familiarity measures how well the designer understands the user as a designer may be especially familiar with the user if the designer is, themselves, a user. Their familiarity is enhanced if they share the same experience or goals as the user. It could also be that the designer knows a similar user through personal experience. An example of user familiarity would be in a scenario in which the designer, who is a veteran of the military, is designing products for disabled individuals. This designer may have been exposed to disabled individuals during his time in service. Another example is designing a baseball glove in which the designers may recall their childhood games or recent history of playing catch with their children. What other experiences influences the designer familiarity with the baseball glove? Has the designer ever played baseball? Such questions comparing the designer and the user depict user familiarity.

2.2. *Product Familiarity*

The second designer construct investigated is the designer's familiarity with the product. This familiarity may root from direct or indirect experience using the product or viewing others use the product. Requirements generated by different members in a design team may be contradictory since designers may have different perspectives on a product [26,27,28]. This results in designers eliciting different requirements due to their different familiarity with the product. How familiar a designer is with what they must design is important since they must go through the systematic design process with this familiarity [29]. If a designer lacks in familiarity with the product, this may have an influence on their ability to confidently make design decisions regarding the final product. The design of systems is shaped by the designer's perception of the technology of the product [30,31]. This perception may root form past experiences as designers come from different social backgrounds [32]. Nonetheless, this familiarity may have an effect on their ability to elicit requirements.

2.3. *Familiarity Examples*

Designer familiarity is a qualitatively measured construct in this study. The designer states their experience with the product and this identifies their familiarity. This study found that this familiarity had an effect on the designer's decision making and their ability in developing a requirement list.

The scope of this paper, in terms of familiarity, is to focus on high and low familiarities. This paper will not investigate different measurements of familiarity. There are four possible familiarities a designer can exhibit for a particular user and product. As seen in Figure 1, these scenarios can be visualized through the use of a matrix. To better explain different designer familiarity, examples are provided to illustrate each familiarity scenario. Each scenario will use the primary author of this paper as the designer. The author will reflect on his familiarity with the user and product in each scenario. Figure 1, shows four scenarios that are used as examples.

Figure 1: Designer Familiarity Matrix

The first quadrant, high user - high product familiarity, could correlate to the design of a cell phone. The designer, in this case, is an everyday user of the cell phone. The designer interacts with the cell phone throughout the day and keeps his cell phone in his possession at all times. The designer relies on the cell phone for many of his everyday activities. This experience allows the designer to have high user familiarity with cell phone users. The designer also uses many of the features on the cell phone. He is able to make phone calls, view calendar appointments, retrieve emails, set up alerts, and navigates the web. The designer custom configured his hotkeys to allow easy access to all his favorite cell phone features. This indicates the designer has high product familiarity because of his experience and knowledge of the product.

The second quadrant, low user - high product familiarity, could be used to explain the design of a basketball for use in a professional setting. The designer plays basketball as an occasional hobby. He is not a professional basketball player. The designer does not know the requirements of any professional basketball players. The designer is not user familiar; he rarely is a user of the product and is not familiar with any professional users. However, the designer understands the functions of the product. The designer understands that this product must be inflated and exhibit elastic behavior. The designer also knows that the product must have a good wear resistance due to its use and have a high surface friction to allow good grip. The designer may not have high familiarity with the user, but is very knowledgeable on the product, making him product familiar.

The third quadrant represents a situation in which the designer has low user-low product familiarity. This is a situation in which the designer does not know the product or user. This could be the case where the designer is designing a paintball gun. The designer has never played paintball and has no experience shooting a paintball target. The designer does not know what a user would specifically want in a paintball gun because he is not a user and does not know any users. There could be user weight preferences for ease of mobility or capacity preferences that the designer is not familiar with. Due to the complete lack of experience of playing paintball and not having any empathy toward users of a paintball gun, the designer has low user familiarity. The designer does not know the regulations and laws involved when owning and operating a paintball gun. The designer does not know the velocity at which a paintball must exit the gun barrel or the basic features of the paintball gun. The designer is not product familiar because he has never used the product and does not have complete understanding of all the functions and features of the product. As a result, the designer here is not familiar with the product.

A situation in which the designer has high user-low product familiarity is shown in the fourth quadrant. This could be the case if the designer is designing a tablet feature on a PC. The designer has never used a tablet PC but has seen it in use by many users. The designer is a college student; he is in an environment where many use the tablet PC. Furthermore, he has been involved with classes where instructors use the tablet PC to teach. Many of his peers also use it for taking notes. While the designer is not a user, he is

familiar with many other users, which enables the designer to have high user familiarity. The designer knows what the user hopes to achieve with a tablet PC, but does not know the means to which a tablet PC satisfies those requirements. The designer in this case has low product familiarity.

3. Review of Requirements

Requirement statements identify critical attributes, characteristics, capabilities, or functions of the design in order to improve the understanding and focus of the designer [33]. The Rational Unified Process defines a requirement as a condition a system or product must conform to and is either derived from user requirements or stated in a formally imposed document [34]. The International Council on Systems Engineering (INCOSE) defines requirements as statements that identify system or product constraints deemed necessary for stakeholder acceptance [35].

Requirements are one of the initial documents generated throughout the design process [36]. They play an important role within the design process as they present the first set of information that communicates an agreement between the designer and stakeholders. The process of eliciting requirements is an integral part of the larger product development process as it dictates much of the design process [4] as supports many activities subsequent to elicitation [37,38]. As a result, ensuring the requirements elicited are accurate to what the stakeholders need is instrumental to any design process. By defining requirements, an expectation of the design solution is developed which constraints the solution space [39].

The Pahl and Beitz systematic design process introduces requirement specifications early within the design process, after a design problem is introduced. It requires viewing the current market situation and observing the requirements of stakeholders of a product. The purpose of the first phase of the Pahl and Beitz design process is to gather information about the objectives, constraints, and criteria that must be met or achieved [38]. The formulation of the requirement list is of importance because design specifications are derived from system requirements.

Requirements development is a design activity: it includes breaking the system onto subsystems, defining how these subsystems should interact, and specifying their respective requirements [34]. Hazelrigg argues that requirements are design decisions that have been made by high level stakeholders or at a high level of design abstraction [40]. This is started through the initial elicitation of requirement raw data. The elicitation of requirements centers on collecting, interpreting, and translating stakeholder raw subjective data into an explicit and objective requirement specification [4,41]. Ulrich and Eppinger provide guidelines for translating raw data into interpreted requirements. These guidelines are in place to ensure data is not lost and the user's requirements are maintained [42].

3.1. Requirements Elicitation

Requirements development is the process of elicitation in which tacit information about the product is obtained from stakeholders and their respective environment [43]. In some design practice, a design or problem statement is given to the design team, and requirements will be elicited by the team based on the preliminary information provided. In other instances, a populated list of requirements is provided through a marketing team which investigates user requirements, through use of many data collection techniques such as: focus groups, surveys, or interviews. Many of such requirements may be legacy requirements that the designer is expected to maintain. Nonetheless, the design team, in any scenario, is to design and develop an artifact that satisfies the requirements. The design team may also be tasked with populating a requirements list based on the requirements of the user. The primary goal of requirements elicitation is to objectify the nature as well as the boundaries of the problem domain [44]. Additionally, it is the designer's responsibility to identify the stakeholders of their product so that they may retrieve the appropriate requirements from the appropriate individuals [45]

Stakeholders are defined as "a party having a right, share or claim in a system or in its possession of characteristics that meet that party's needs and expectations" [35]. Stakeholders are may be identified through a specific market. Ulrich and Eppinger refer to a market as individuals or groups of individuals who will seek benefits from using the product [4]. This includes members such as the project clients, users and investors [42]. The stakeholders are used as resources for collecting requirement raw data. Ulrich and Eppinger present many means of gathering raw data from stakeholders such as performing interviews and focus groups [4]. Most design teams make use of interviews as it is an efficient data collection technique. Interviews required less man hours and generated the same amount of information as focus groups [42,46].

There are many other techniques available to obtain requirements; as selecting the suitable techniques according to the characteristics of the project is important [47]. An integrated approach for eliciting requirements may be needed which incorporate systematic design processes and other tools specifically aimed at understanding the user [42]. The development of requirements specifications is conceived as an incremental process, in which the stakeholders successively add requirements [48]. However, such a process is critical to the success of any design project. As a result, requirements elicitation requires excellent user communication and effective stakeholder collaboration [49,50].

3.2. The Designer's Role

A designer's role exceeds that of performing technical tasks such as the production of drawings, working models and prototype designs, testing functional specifications, and transferring a manufacturable design to production [51]. Designers play a more significant role within the design of a product as their decisions have implications on its success. Designers possess a chief role within the design process and it is important to understand and consider their familiarity of the user and product while working on a design. It is estimated seventy to ninety percent of the product's costs are determined in the first ten to twenty percent of the design process [52,53]. This is a time when designers are most

vulnerable to error if a lack of familiarity with their product and user exists.

3.3. Requirements and Design Practice

Depending on the product, and if the designer deems the given requirements are inadequate, the designers supplement requirements by creating and sharing their own user related information [54]. This could be based on the designer's perception of a product or user. Due to their control within design, designers are able to develop and change requirements based on what they see fit. What a designer may suggest is not necessarily what the use may wish for. Such misrepresentations can result in failed products.

Requirements are ever changing over time and it is the task of the designer to understand how these requirements have changed [55]. This is also evident in the Pahl and Beitz process as their requirement list layout includes sections where designers may make changes to a requirement, an indication of their awareness of requirement change [38]. Technology will change and improve, deadlines will change, management will change their minds, the competitive landscape will change, and users will change their requirements [56]. This change is of importance as a designer's familiarity may have an effect on how these changes are managed. Though the changing and managing of requirements is important [8], the scope of this paper is to explore how a designer's familiarity with the user and product may be of significance with their ability to elicit requirements.

4. Study of Designer Familiarity

Based on the familiarity constructs and measurements discussed, there are four possible designer familiarity situations. The differences between the scenarios were the designer's familiarity with the user and product. Figure 2 illustrates the familiarity matrix for both observational studies.

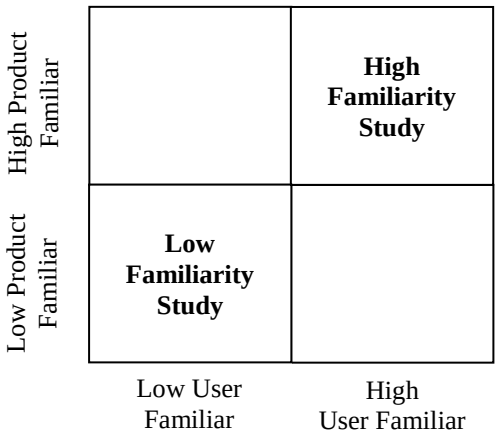


Figure 2: Case Studies Performed

This study was performed by observing teams of students elicit requirements for a product after they given a problem statement and subsequently analyzing the requirements. The students were mechanical engineering graduate students studying engineering design theory and undergraduate students with at least two semesters of design project experience. They were drawn from the Mechanical Engineering department at Clemson University. The teams were randomly assigned from a mix of cultures, genders, and ages. Two different teams were used for the different scenarios investigated. The requirement list elicited was reviewed and a survey was given to the team to collect data on their experience eliciting requirements. Throughout the study, students were given the ability to use any resource available to them to assist in eliciting requirements, including the use of computers or books.

4.1. High User - High Product Familiarity Study

The high familiarity study examined a situation in which the designer exemplified high familiarity with both the user of the product and the product itself. The problem statement given to the team stated:

"Due to the time spent outside of the home, there is a need in the market amongst college students all across the United States for a portable MP3 player for their personal use."

The study viewed the requirement elicitation of an MP3 player by a team of five college graduate students all majoring in Mechanical Engineering and studying engineering design theory. The user of the product, college students, and the product was selected due to the student's familiarity with the user and product. In this scenario, the designers of the system, who were all college students, were designing an MP3 player for fellow college students. Additionally, they were developing requirements for a product each of the participants owned and were familiar with its functionality and features. During the study, there was approximately an hour allotted for the development of the requirement list.

4.2. Results of High Familiarity Study

The requirement list generated from the study is shown in Table 3 in the Appendix. As seen from Table 1, there were fifty one requirements generated, in which ten were requirements that contained values. Value requirements are those requirements which include a value, range or target within the requirement. For instance, if a requirement states "the vehicle must weigh less than 5000lbs," it is a value requirement because the students incorporate a value with the requirement. This is as oppose to stating a requirement such as "the vehicle must be as light as possible." This data was noted because the students stated they felt greater confidence in those requirements where they could place a value. Value requirements accounted for nearly twenty percent of the requirements list. The requirements were developed primarily on the familiarity of the students. Each requirement possessed approximately seven words. Additionally, the rate at which requirements were generated was noted.

Table 1: Quantitative Results of High Familiarity Study

Number of Requirements	51
Number of requirements with values	10 (~20%)
Number of words	341
Requirements elicitation rate	51/hr

A survey was conducted with the team after the requirements elicitation process. Every student in the survey stated they were able to generate requirements through personal preference and experience using the product. The students stated the only source of information needed to elicit such requirements were that of their own. The students did not need the use of computers to view competing MP3 players on the market as many stated they were familiar with leading MP3 players and their capabilities. The sources of information for eliciting the requirements were: personal preference, personal experience with the product, and their experience with other users using the product. The survey indicated the students did not require the assistance of external resources in the elicitation of requirements. Additionally, the students felt the elicitation of the requirements was of relative ease.

4.3. Low User - Low Product Familiarity Study

This study viewed a situation in which the designer familiarity with the user and product were low. The design problem stated:

"Design a device that provides head and spinal support for a handicapped individual which affords crash safety and general comfort for use in a vehicle"

This problem was of particular interest as it was developed for handicapped individuals. Designing for users can be challenging if those users have restricted abilities [57,58]. A team of five undergraduate students participating in their Senior Design Capstone course were tasked with providing a solution to the problem. The students had no previous experience in designing or developing a headrest. While the students were aware of the most basic functions of a headrest, they admitted they possessed weak familiarity with the product and user. The students were not aware of what requirements a handicapped individual would need from a device such as a headrest.

The students used the design knowledge they had gained through their undergraduate design classes to develop the requirement lists. This design knowledge did not include any understanding of user centered design approaches. The project spanned an entire school semester, approximately four months. The deliverables for the Senior Design Capstone course included a final report which included all system requirements and a functional prototype. The scope of this study will view the initial requirements elicitation session, which spanned approximately two hours.

Specially, the application of the headrest was for a wheelchair that could be used in an automotive vehicle and survive and protect the user during an accident. The design solution required a level of robustness to ensure any handicapped individual with a wheelchair could use the product. This design problem posed significant difficulties for the students as the team had to familiarize themselves with the user and the product. The team had to gain an understanding of handicapped users of different physical conditions so all requirements could be taken into consideration during the design of the final product.

4.4. Results of Low Familiarity Study

As the project finalized, the team had developed a long, detailed set of requirements. However, the scope of this study is to view the initial requirement list developed and any effects identified during the development of requirements which could be attributed to a lack of familiarity. The initial requirement list developed is shown in Table 4 in the Appendix. The team used personal preference in attempting to determine the appropriate requirements for the wheelchair headrest.

As seen in Table 2, fifteen requirements were generated. Three of the requirements generated were requirements which contained values, accounting for twenty percent of the requirements. The team exhausted approximately two hours before completing their initial requirement list. The requirements were developed at a rate of 7.5 requirements per hour. The team made use of online resources to assist in eliciting requirements, including searching for vehicle headrest regulations and exploring commercial headrests and wheelchairs.

Table 2: Quantitative Results of Low Familiarity Study

Number of Requirements	15
Number of requirements with values	3 (20%)
Number of words	127
Requirements elicitation rate	7.5/hr

Through a survey with individual members after completion of their initial requirement list, the members commented that their own personal requirements influenced the requirement list development, though they lacked familiarity with the user and product. All of the students stated they imagined themselves in the role of a handicapped individual and tried to empathize with what such a person would need from a headrest. Additionally, every student stated they struggled with developing requirements because of their lack of familiarity with the product. Three of the five students stated they struggled due to their lack of familiarity with a headrest. The remaining two students stated they used a conventional headrest as a foundation for developing requirements. Overall, the students agreed that due to their lack of familiarity with the user and the product, they had to elicit requirements based on what they thought would be appropriate if they were handicapped. Students found that though they were given the availability of external resources, the elicitation process was difficult.

5. Results – Comparison of Familiarities Studies

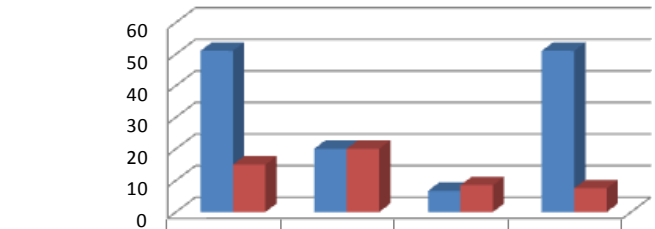
A comparison of the results elicited from both studies is shown in Figure 3. The most apparent difference is the number of requirements elicited. For the high familiarity

study, over fifty requirements were developed in the span of an hour whereas in the low familiarity study, a mere fifteen requirements were developed over the span of two hours. It is apparent from the results that those which possessed high familiarity can produce a greater number of requirements than those of low familiarity. It is important to note that the number of requirements may not be a direct indicator of designer familiarity as some products, being more complex, may poses a greater number of requirements. However, the survey results indicated that those of low familiarity did struggle in eliciting requirements. The students did not possess adequate familiarity with the product nor did they have empathy for the user.

The number of value requirements was investigated because those requirements were noted by the students during the survey as elicited with greater confidence. Since the students were able to attach a metric to the requirements at a relatively early stage of the design process, this was an indication the students were confident enough in those metrics or had found comparable values through their resources. Both studies indicated approximately the same percentage (20%) of value requirements.

The number of words per requirement was measured to compute the detail of each requirement. This number of words per requirement was measured on average, throughout the entire requirement list document. The high familiarity possessed a less number of words per requirement than the low familiarity requirements. The low familiarity requirements possessed 8.5 words per requirement, approximately 25% more words than the 6.7 of the high familiarity. This was found to be statistically significant at a $p<0.05$.

To measure the ease at which requirements were elicited, the number of requirements per hour was measured. This measured how many requirements each team, both consisting of five students, were able to elicit. The high familiarity team was able to elicit requirements at a higher rate than that of the low familiarity. The high familiarity study was able to elicit their fifty one requirements in an hour, while the low familiarity study required two hours to elicit their fifteen requirements.



	# of Req.	# of Value Req (%)	# of Words per Req	Req rate (per hr)
High Familiarity	51	20	6.7*	51
Low Familiarity	15	20	8.5*	8

**Statistically different, $p<0.05$*

Figure 3: Comparison of Studies

As seen in Table 3 and 4 in the Appendix, the requirements were written under requirement classifications. The teams participating in the study were not instructed to do so, but willingly did this. The high familiarity team was able to segment their requirements into classifications of: functionality, geometry, ergonomics, reliability, aesthetics, cost, and schedule. This is a finer level of detail than that of the low familiarity team which classified its requirements through the most basic segmentation of constraints (musts) and criteria (wishes).

6. Discussion

In the high familiarity study, the students, who served as the designers, developed a requirement list based on their personal preference. This was of relative ease for the students as they could empathize with the user. Additionally, through experience of owning a similar product, the students were able to elicit requirements by benchmarking their personal MP3 player. For example, if their existing MP3 player supported use of all music and video formats, they wanted to ensure the MP3 player they designed equally supported those formats. In this study, many requirements were elicited due to the student's natural ease at identifying with the user and their personal experience with the product.

In the low familiarity study the team was given no immediate directions as to how to form their requirement list. Similar to the high familiarity study, they were to choose any method or approach they saw fit and were given the choice to use all resources available. The team struggled to develop a requirement list for a user and product they were not familiar with. The team had to resort to using an external aid such as the internet and reviewing safety regulations. The team attempted to identify different individuals who might be end users of the product to assist in developing requirements. Additionally, the team researched headrests and their functions to gain a greater understanding of the product. The team used this to identify requirements within a headrest that may not be immediately apparent for those with low familiarity. The survey also indicated the students expressed difficulty in developing requirements. The students attributed their difficulties with their lack of familiarity with the user and inexperience with handicapped individuals.

The low familiarity team was eventually able to develop a detailed requirement list. However, this came through identifying and contacting a handicapped individual to assist them. This individual offered the team information on her condition and reasons a handicapped individual, like herself, may need a headrest in a vehicle. The individual provided the students everyday situation where she could use her headrest. The team's lack of familiarity on the user caused many incorrect requirements in their original requirements list. The handicapped individual stated to the students that many of their requirements contained errors and were incomplete. Many iterations and evolutions of the requirement list were developed due to the design team's misrepresentation of the user. While the design team focused on the user, their lack of empathy as a handicapped individual caused the team to make inaccurate assumptions. The use of a handicapped individual for help enabled the team to elicit a requirement list the team and user (the handicapped assistant) agreed on. Further, the team was able to develop a functioning prototype that fitted on the chair of

the handicapped individual that assistant them. The development of prototypes assisted the students as they were able to use prototype demonstrations to find new requirements.

An interesting finding within the study is the statistically significant difference in the number of words per requirement between the studies. The low familiarity study exhibited a much greater number of words per requirement over the high familiarity study. This was an interesting finding as it indicated familiarity tends to decrease the requirement statement length. A hypothesis to this may be that high familiarity increases the information density of the requirement and decreasing its length. However, there are many other factors which could have contributed to this result as they are differing projects written by students of differing intellectual.

It is evident from the study performed that familiarity has an effect on the elicitation process. This paper does not aim at finding means for improving designer familiarity or identifying metrics for measuring designer familiarity. Rather, it is intended to identify if the experience of designers, specifically their familiarity with the users and products, will have an impact on their ability to elicit requirements. Though this may be perceived as intuitive, there may be differences in the effects of user versus product familiarity. This is important as designers have significant control over requirements elicitation, management, and satisfaction. As this study indicates, familiarity does in fact play a role in the designer's ability to elicit requirements, which in turn is of significance to the success and cost associated with a product. Further it provides insight as to the ease in which designers are able to elicit requirements when pertaining to a user and product they are familiar with.

The difference in categorizing requirements observed could be due to the confidence of the designer during elicitation. For example, the team in the low familiarity study did not realize there were aesthetics constraints on a headrest, while the team in the high familiarity study knew there would be from their personal preference and experience. This confidence was also exhibited during the elicitation of value requirements, as students stated they had greater confidence in their requirement. This additional layer of information within requirements could reveal a level of familiarity related confidence some designers possess in their ability to elicit requirements due to their familiarity.

7. Conclusions

Evaluating elicited requirements and attempting to evaluate them for their correctness is difficult and challenging. There are problems with assessing the internal validity of the requirements [9]. This is particularly the case here as the teams were free to use their own requirement elicitation methodology or procedure. It is difficult to compare requirement lists based on their context. Further work would include developing requirement lists of similar products under different designer familiarities. Valuable data was extracted from this study that confirmed the effects of familiarity on requirements elicitation. During the study, the ease of eliciting requirements for those who are familiar with the user and product was apparent, through review of the requirements and surveys with the participants. Additionally, the requirements developed by the low familiarity team required multiple iterations and were completely different before the project's completion. The low familiarity team required several more iterations than that of the high familiarity team to develop a user accepted requirements document.

If provided the same problem statement, designers will elicit different requirements based on their familiarity and experience with the user and the product. This does not infer that design projects should incorporate only those designers with particular experience or exposure to a field of products and users, as those designers may include personal biases. However, it is important to note that this phenomenon must be understood and accounted for. Further exploration is required into this study to investigate other avenues that affect designer elicitation outside of their familiarity with the user and the product. Additionally, a greater resolution of familiarity is required, one which could incorporate a datum to serve as a control for subsequent studies.

A limitation of this study was it was only focused on student designers due to their availability. While such students are the next generation of designers, this introduces bias as this is a younger audience. Outside of design practice, this study is of great importance for engineering design education as students tend to use their personal experience, even if those experiences are limited.

Subsequent studies include exploring the other two quadrants of the familiarity matrix as to differentiate between the user and product. This will assist in investigating if product and user familiarity are completely independent of one another. Most importantly, studies such as those presented in this paper aid in determining the formation of design teams. For example, a highly technical design problem may require the formation of a highly experience group of individuals while a project needing innovation and novelty is better suited for designers who don't possess high familiarity.

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APPENDIX

Table 3: Generated List of Requirements for the high familiarity study

Classification	
Functionality	Must hold sufficient memory to hold at least 2000 songs
	Must be capable of playing radio (AM/FM/XM)
	Battery life must be greater than 8 hours
	Must be capable of automatically going to stand by mode
	Must be capable of automatically shutting off
	All cords must be retractable
	Must allow for wireless earplugs (Bluetooth)
	Must possess built in speaker
	Must offers lap time and timer
	Must have built in locater (GPS maybe)
	Must have ability to transfer songs between player
	Must support all formats
	Must automatically update
	Must have internet connectivity
	Must have bio-sensors (heart-rate, pulse-rate, temperature)
	Must offers connections where needed (wall charger, car charger, solar, kinetic charger)
	Must have A.I. to recognize needs based on input (time of day, shock(running), GPS movement)
	Controls must be Touch screen for functions (scrolling, organizing, grouping)
	Must display recommends songs (TiVo, Blockbuster)
	Must function as PDA (calendar, note taking)
	Must come in different models (rounder or angular, or if you want both)
	Must have a low battery indicator
	Must accommodate for an optional attachable to docking station
	Accommodate expandable memory through USB
	Must supply speaker jack output
	Must possess internal speaker
	Must have built in camera
	Must have calculator software
	Must have laser pointer
	Must allow for voice recording
	Must have built in alarm
	Must have 15hr courteous/45hr standby battery life
	Must function as flash memory
	Must cost less than $350
	Must weigh less than .5lbs
Geometry	Must be smaller than the size of a smartphone
Ergonomics	Must come with attachment clip
	Music loading interface must be easy to use
	Must conforms to hand (audio scrollers, skip song, pause, shuffle, on/off)
Reliability	Must withstand 300lbs impact force
	Must withstand 3ft drop into concrete
	Must be waterproof (while swimming)
	Must be water resistant (sweating)
	Must not be sensitive to continuous motion
	Must be shock resistant
Aesthetics	Must come in different color variations
	Must be modifiable (coordinate with outfit)
Cost	Services should be optional (download, phone/internet, warranty)
	Must come with optional insurance ($50 for one year, max 2 years)
	Must allow discounts for trade-in
Schedules	Must be on the market by December

Table 4: Generated List of Requirements for Low Familiarity Study

Classification	
Constraint	Require no vehicle modification,
	Weigh no more than 15% of initial chair weight,
	Last 20+ years (lifetime of chair)
	Meet or exceed the WC-19 standard for wheelchair performance in a crash test
	Require the assistance of no more than one additional person to operate
	Not limit or interfere with entry or exit from vehicle
	Not adversely affect comfort of the user
	Provide support for the head and shoulders of the user
	Must lay within confines of wheelchair
Criteria	Be as light as possible
	Be aesthetically pleasing to the majority of a sample audience
	Have a target retail cost of less than $500
	Enhance the ride comfort of the user in a vehicle and in daily activities
	Be as small as possible
	Affect wheelchair balance as little as possible