IDENTIFYING A RELATIONSHIP BETWEEN DESIGN CONCEPT REPRESENTATION STYLE AND CONSUMER PRODUCT PREFERENCE

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Product designers are constantly seeking insight into the mind of the consumer in efforts to get a better idea as to what the market demands. Feedback from consumers informs designers on changes that need to be made to a product and can provide information about what end-users expect. To explore possible improvements to the design process, a study was conducted on concept representation style and its effects on consumer preferences. The study employed statistical testing to identify a relationship between representation style and consumer preference consistency, lending insight into the best practices for conveying critical information throughout the design process. The study described in this thesis consists of conducting a series of surveys, introducing hand drawings, solid models, and realistic renderings as representations of eyeglass frames to participants, eliciting preference data from those participants, and comparing their preference ratings to those of physical models of the same frames. This study was supplemented with an eye-tracking system to establish a connection of where the effective details lie in the design representations, as well as suggest some decision-making strategies at play. Results indicate that a significant difference in consistency between representation styles does exist, and that CAD solid models are inconsistent with preferences of physical models. When only participants with an engineering background were evaluated however, this relationship did not exist, suggesting that a familiarity with a particular design practice may impact how individuals judge a particular representation style. It is also suggested by eye-tracking analysis that participants were more likely to give semantic responses when observing physical models.

IDENTIFYING A RELATIONSHIP BETWEEN DESIGN CONCEPT REPRESENTATION STYLE AND CONSUMER PRODUCT PREFERENCE

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Chapter 1: Introduction

1.1 Overview

Communication presents an ambiguous issue in the design process. Problems can arise in both designer-designer and consumer-designer communication. Concurrent engineering practices provide a chance for designers to develop an idea in an iterative fashion with feedback for adjustment collected throughout the process. However, there are challenges that come with collection of that crucial feedback which can lead to valuable information becoming muddled. This can be caused by a lack of understanding of critical features by the reviewer, over or under detailing by the designer, or the method of delivery chosen to communicate ideas. Studies show that effective communication in the design stage benefits concurrent engineering processes significantly and is critical to product design [1].

When designers present ideas to consumers, or even other designers, the stage in the product development process they are in can define the appropriate amount of resource allocation that goes into representing that product. In many cases, the number of resources that design firms are willing to contribute to a product defines the level of detail a product is represented in. For instance, early in the design process, a product may be represented as a simple sketch, to not dedicate too much time or money into an idea that does not pan out. The question is raised then: what degree of detail in a design representation is sufficient for effective consumer feedback? The form of visual representations of design has been studied in a varying degree of detail [2]. This study investigates the impact of design presentation medium on consumer preference by presenting product prototypes of varying fidelity to consumers and comparing their real-world preferences of those same products.

1.2 Aim

This study aims to suggest whether consumer preferences of a product across varying representation styles are consistent with final physical product preferences. In doing so, it is intended to identify critical features of specific representation styles that inform those preferences.

1.3 Hypothesis

A difference in consistency of preference between conceptual representations and physical products exists and is dependent on the level of detail in which the concept is shown in.

1.4 Nomenclature

Preference Rating – The collected 1-10 score a participant provided on their liking of a particular design shown to them.

Frame – The five eyeglasses shown to participants are referred to as A, B, C, D, and E.

EXP – (Exposure) refers to the first or second viewing by a participant of a particular frame/representation.

Representation – The medium in which a concept is shown to a participant.

HD – Hand Drawing

SW – (SolidWorks) Solid Model

RD – Photoshop Rendering

PM – Physical Model

AOI – (Area of Interest) A defined area of a still image representing an area where participants gazed during testing.

Duration – The amount of time in milliseconds that a participant spent on a single gaze event

Hit – An instance of a participant's gaze landing in one of the defined AOIs

Chapter 2: Background

Previous research into the effects of product representation on consumer preference using simple sketches and renderings have concluded that while consumer opinions and inferences differ between the two mediums, future works should examine the effect of higher fidelity models [3-5]. The first section of background information will cover the future recommendations of previous consumer preference studies. The nature of sketch and silhouette studies that have been conducted in the past can introduce another issue of design fixation within the design process [6]. The collaborative process of product design requires outside-the-box thinking to overcome the challenges of complacency in design. The second section of this background information will highlight the collaborative and communicative methods emerging in the design world and their implications on this research. Communicating the ideas designers produce to consumers is critical, and this research is meant to explore viable methods of presenting those ideas. One consideration designers face is the question of at what point in the design process is it effective to present concepts to consumers? Previous research suggests that physical prototypes and high-fidelity renderings yield higher end-user agreement than sketches and silhouettes [2,7]. The third section of the background information will detail the implications of research regarding success of the feedback-driven iterative process in engineering design.

2.1 Past Consumer Preference Studies

Several silhouette preference studies have been conducted, each evaluating the preferences and information inferred from subjects, and drawing conclusions of detail and shape change within the silhouettes contributing to those preferences [3-5]. These studies lack in their novelty of presentation and make recommendations for future work for higher fidelity models.

These research suggestions would fulfil a recommendation made by Bloch in 1995 stating that future work should explore the consumer's perception of difference between designs with respect to changes in the presentation [8]. Reid et al. followed these recommendations testing the effect on consumer preference, inference, and spatial evaluation made by more realist renderings of sketches presented to study participants. This study still resulted in inaccuracies in predictability [9]. The Reid study recommended expanding their model to include 3D models of products to widen the scope of comparison. In another study conducted by Macomber et al., some sketch drawings were preferred by subjects over renderings, contradictory to the notion that higher-fidelity representations would be preferred [2]. Both studies acknowledge the limitation of rendering quality and environment playing a possible role in sketch over rendering preference. The study detailed here will focus on the use of high-quality designs to evaluate differences in consumer preference of conceptual models against final products.

2.2 Collaborative Methods of Design Communication

Co-creation presents an important practice in the engineering design process. Mandolfo et al. presented a study of consumer willingness to co-create and proposed a set of studied personality traits which affect the co-creation process. Future research suggestions were made in this study to research the quality of idea generation in consumer co-creation [10]. The implications of this research include the confounding variables that could explain some of the preferential differences between subjects in sketch/rendering studies. One of the more novel methods of communication being employed in co-creation engineering design involves the use of virtual reality (VR) and mixed reality (MR). Ong and Shen developed a system for design firms to collaboratively use SolidWorks in a MR environment where clients can see real-time real-scale design changes and provide feedback to designers [11]. The implication of their system is that consumers would find this system incredibly useful for understanding the product design process, warranting further study of the MR environment representation method. Tang et al. explored the benefits of using a VR/MR system in teaching design to engineering students [12]. The students in this study experienced quantifiable learning benefits that Tang et al. attributed to visualization techniques the VR/MR system made possible. This research culminates in presenting another high-fidelity design presentation method that can be tested. Since VR/MR is being used for clients in co-creation settings, as well as teaching design principles to engineering students, it makes for a promising new prototyping medium.

2.3 The Design Processes' Evolutionary Implications

The iterative product design process in engineering takes a concept and, through continual evaluation and improvement, reshapes and works that concept into reality. Yang studied the role of concept generation in engineering through a project life cycle and determined the early-stage sketch volume was far more important than total volume throughout the duration of a project [13]. Yang proposed that future work should consider the importance of early work and prototyping in the design process. This study also suggested the importance of reflection on sketches and the timing of detailed concept generation throughout the design process. The implication of this study made by Yang's sketch research is the notion of project success not from idea generation quantity but quality. Yang followed up on the future work recommendations with a study on the efficacy of prototype generation in the early stages of an engineering design project. In this study, the students who act as designers are their own proverbial consumers who generate feedback as well. The result of this study was the growing success of end results due to the generation of physical prototypes of varying degrees of functionality in the early phases of design [7]. These results make the implication that physical prototypes, even when not fully functional, provide an excellent source of design insight otherwise unavailable to designers or consumers. These findings are mirrored in the consumer preference findings by Macomber et al., where polished hand sketches outperformed rudimentary CAD renderings in consumer preference [2]. The implication of the Macomber et al. study is that the highest fidelity model provides the best feedback, sometimes regardless of medium. The research summarized in this section points to a need for studying sketch quality differently, and, in comparison to physical prototypes.

2.4 Previous Eye-Tracking Studies

As a result of a consumer-oriented product design approach coined “kansei engineering” popularized in the 1970’s, studying the perceptive evaluations of a product by the consumer has become an essential task by many design firms. Mitsuo Nagamachi says in an overview of Kansei engineering “When a consumer wants to buy something, he/she will have a kind of feeling and image (Kansei in Japanese) in his/her mind. If the consumer’s feeling could be implemented in the new product, he/she would be more satisfied with the product.” [14]. An important caveat of these Kansei engineering studies is the methodology of gathering the perceptions that consumers have of a product in a quantifiable way. One study proposed bridging this gap via eye-tracking to measure the attention of subjects viewing product designs. Köhler et al. proposed that in eye-tracking product comparison studies, it is crucial to evaluate how subjects view differences between models [15]. Reid employed the use of eye-tracking in a product representation style study, and suggested evaluation fixation times of the eye-tracking data as an indication of decision-making strategies at play [9].

2.5 Consumer Judgement Approaches

The consumer response to a product was categorized into three types in a paper on product form by Crilly et al. [16]. Product judgment can be considered to fall in the categories of “aesthetic”, “semantic”, or “symbolic”. Aesthetic response is defined as a consumer judgment resulting from a judgment of positive or negative perception of attractiveness. Semantic response is defined as a consumer assessment of functionality in one of many ways. Symbolic response refers to judgments made pertaining to an inference of product identity, via brand or other means. These categories have been discussed under other names in literature [17-20], but the descriptions of their contents generally fall under the same umbrella, form, function, and emotion.

In a paper investigating the effects of product packaging aesthetics on consumer perceptions, Vladić et al. proposed that packaging aesthetics carry weight in terms of marketing due to the predictable perceptions that can be communicated through design principles [21]. This paper also suggests that the more complex (less “typical” in prototype theory), a shape becomes, the stronger the consumer’s attention is provoked. This is the reasoning for selecting the specific individual frames in this study, as they were intended to be less familiar designs. In a paper by Rafaeli and Vilnai-Yavetz, the different perceptions that consumers draw from a product’s aesthetics are discussed. In this paper, it is highlighted that professionals of different fields view the same aesthetic artifact under different connotations, leading to drastically differing perceptions. The results of this study indicated that engineers, designers, and advertisers draw different conclusions relative to their field. The paper also makes the warning that marketing professionals tend to focus on eliciting symbolic responses from consumers, but aesthetic and semantic responses play an equally important role in creating an emotional response from consumers [22].

2.6 The Intersection of Design Research and Marketing

As early as 1993, the effects of product aesthetics on consumer judgments were being investigated. In a paper by Robert Veryzer, the relationship between standard artistic principles used in product design and consumer preference was tested. It was suggested that unity and proportionality of a product positively affect consumer judgment. This was based off the emerging notion that in a marketing context, “good design translates into quality products”. This study put forth that design principles play a larger role in explaining consumer preference than prototype theory [23]. In another study by Veryzer, prototype theory is examined in conjunction with the design principle of unity and together are suggested to be useful to designers presenting products as they can be used to highlight differences in products [24]. This is especially useful in marketing as consumer judgement between competing brands can be predicted when assessed in a purely stylistic manner.

Bringing consumers in on the design process all throughout the project life cycle allows for outside perspective that can stifle designer oversight. Athaide et al. examined the different approaches marketing firms take when involving the consumer in the new product development (NPD) process. Two highlighted methodologies covered in this paper are those firms that co-create with knowledgeable consumers, and those that design/market for mass markets and have minimal consumer-involved iterative design processes [25]. Svendsen et al. covered the commitment that a firm must make to a particular design/marketing approach, and how other aspects of their product line, such as branding, may impact consumer involvement willingness [26]. As mentioned in the previous section, commitment to branding may also affect the way consumers perceive products symbolically. One way that this co-creation NPD process can be improved is through the use of more reliable design representation. Mary Alexander called for increased visual consumer feedback throughout the product design process in a multiple case study marketing review where failed products design processes are evaluated [27].

2.7 Background Summary

The research covered in the three background sections highlights a need for study of high-fidelity methods of design representation. This, however, does not mean simple sketches up against high-quality renderings, it means industry-accurate hand sketches, solid models, and renderings being compared to physical models. Past studies have sufficiently demonstrated how to quantify product form study data through use of preferential studies, eye-tracking, and objective spatial understandings. The gap in those studies was simply the use of low-fidelity models that did not yield substantial results. Using the statistical models of past studies, such as ANOVA testing, with a new emphasis on quality of design representation, consumer feedback will be measured against actual preference ratings to determine adequate methods of design concept presentation for aesthetic response. It is important in design research to acknowledge where the results will be useful and gear experimental design towards the practical applications of those results. For this reason, the focus of the hypothesis tested in this study is geared towards design and marketing firm resource allocation and increasing communication effectiveness.

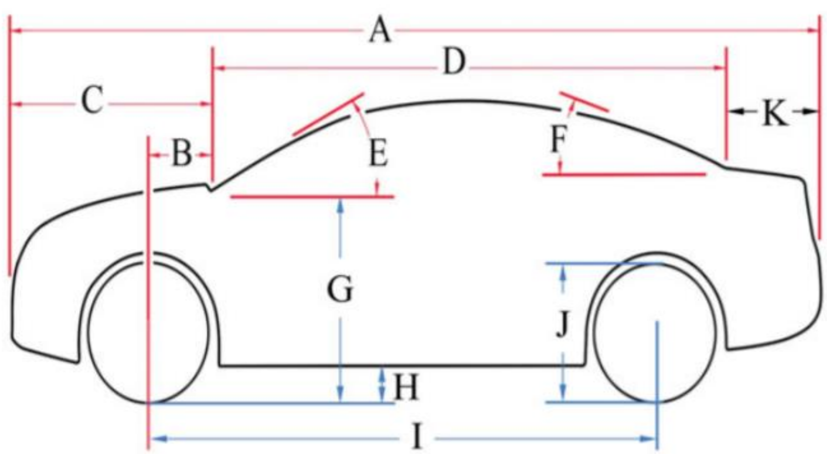
Chapter 3: Literature Review

3.1 Product Form Representation

The method of design representation to consumers leads to an effect on the consumer's critique of the design. This is true in product design where design form presentation can vary heavily in detail and realism. Presenting products in varying configurations can give insight to designers in the efficacy of a prototyping method by the way consumers interact with those designs. One way to quantify the effect of change in form on consumers' perceptions is by design manipulation and discrete choice analysis. Orsborn et al. quantified aesthetic form preference using a discrete choice conjoint analysis by manipulating seven attributes of an SUV's silhouette geometry [5]. An individualized survey was created using the Bradley-Terry-Luce method which assigns weights to features of preference as they change within the survey. This study developed a utility function for analyzing consumer preference and generating individual results. The implication this research made is that simple design changes that are important to consumers could be quantified and predicted.

Following this research, consumer perception of form in product development was studied using vehicle silhouettes again. Sylcott et al. explored the concept of the tradeoff between perception of form and understanding of function neurologically using vehicle silhouettes [4]. This study uses meta-conjoint analysis as opposed to a more standard conjoint analysis method such as the method used by Orsborn et al. as an attempt to combat the conflict between form and function responses to options presented to subjects. While this study goes into greater depth in understanding the subjects' decision-making process, the models presented to the subject are of low fidelity. These low fidelity models limited the scope of the comparison and leaves future work to be done using a wider degree of designs.

Bi et al. studied the impacts of side profile silhouettes on consumer perception of environmental friendliness [3]. This 2016 study acts as a follow-up to a 2009 study using the same silhouettes. The notable discovery of this study is that there is a reverse in the results of the study, indicating that design trends and familiarity with novel designs affect the perception of technological functionality. The limitation of this study is the low fidelity of the designs. This allowed for quantifiable model manipulation but limited the study in respect to possible influences on consumer perceptions. This study used twenty different design configurations by varying vehicle geometry in a mathematically calculable method outlined below in Figure 1.



A	Overall Vehicle Length
B	Cowl to Front Wheel Center
C	Cowl to Front Bumper
D	Cab Length
E	Windshield Angle
F	Rear Glass Angle
G	Beltline Height
H	Rocker Height
I	Wheelbase
J	Wheel Diameter
K	Rear Crumple Zone

Figure 1. Diagram of Manipulated Geometry [3]

Higher fidelity models being the next logical step, Reid et al. studied the impact of degrees of detail in consumer preference surveying of vehicles and coffee pots while using eye-tracking software on subjects [9]. The psychological theory of constructed preferences serves as a basis for this study as it suggests that preference of an object or idea changes depending on context. The Bradley-Terry-Luce model was used in this study as well for establishing consistency in choice of a strength of preference (SOP) survey for the renderings and sketches shown in Figure 2 below. Two patterns were noticed in the eye-tracking data collection: significantly more focus/time was spent on the preferred choice, or on the non-preferred choice. This difference points to the notion of two different selection methods, eye-tracking proving to be indicative of how a subject is comparing two objects. Another result of this study included a lack of dimensionally accurate spatial understanding of products. This research points to future research issues regarding the choice of design representation and other models for comparison such as hand sketches and 3D animations, and different angles of renderings. Further studies should address these issues by evaluating subjects using metrics such as selection preference using several prototype representations, compared to real-world design preference.

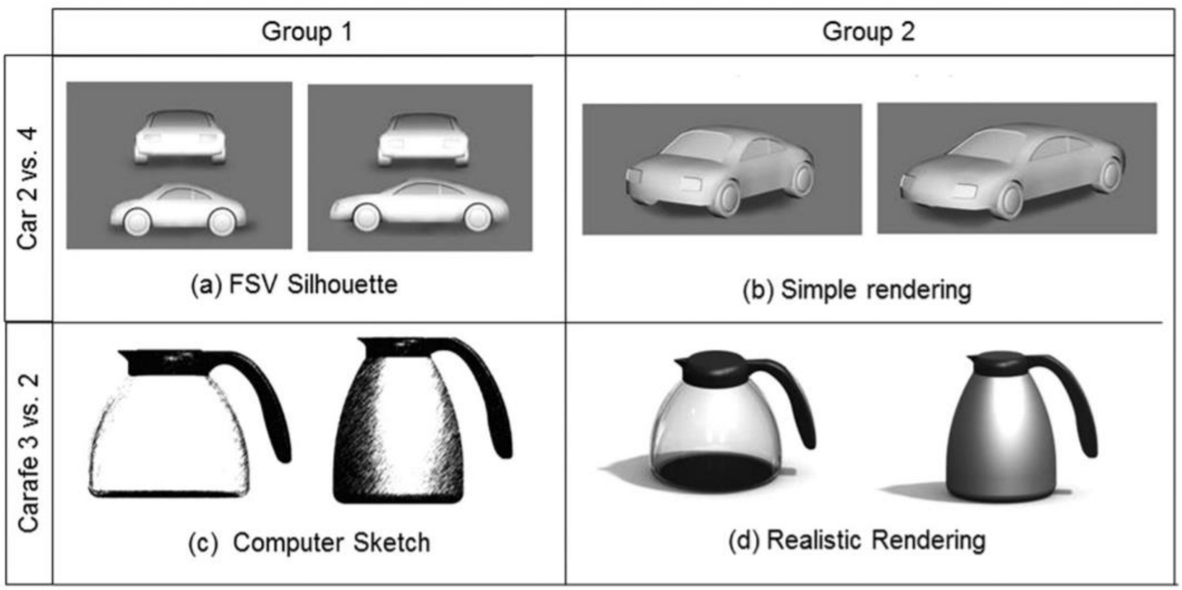


Figure 2. Design Configurations Presented in Eye-Tracking SOP Study [9]

Section Summary

The literature in this section indicates that consumers have varying degrees of functionality expectations based on their perception of designs. These studies accepted that people's preferences, inferences, and objective understandings shift over differing mediums of presentation of design. There is a mental tradeoff between form and function in the mind of the consumer that changes depending on the degree of detail or realism that the design is presented in. A consideration of design familiarity should be considered in new product design, as research suggests that novelty of design in a product wears off along with consumer perception of that design. Future work presented in this section sums up to necessitate studies with varying degrees of detail in well-known products and how those different mediums change effect preferences.

3.2 Designer-Consumer Communication

In marketing of product development, the term co-creation refers to the continuous involvement of clients throughout the design process. Mandolfo et al. presented a study into the efficacy of the co-creation process in the engineering management field [10]. Through the use of surveying consumers, personality trait analysis, and published barriers to co-create, recommendations for co-creation were established. The structural model used in this survey for high touch product co-creation is shown below in Figure 3. The result of this study presents the effect that personality and motivation had on willingness to co-create. The implication and reason for the inclusion of this research in this review is that like in consumer preference testing, the confounding variable of personality is at play on a second level. The willingness to participate in consumer preference testing (a form of co-creation) is a confounding variable.

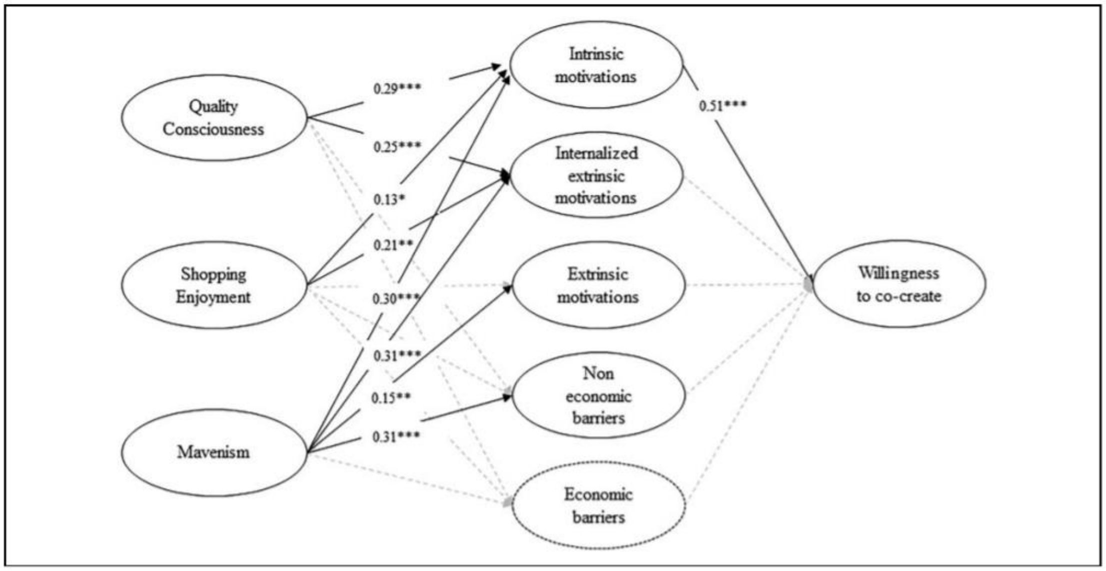


Figure 3. Structural model results—High-touch products. Hypotheses testing results ($N = 203$; *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$).

Figure 3. Structural Model for Co-creation Survey [10]

One way co-creation and design form analysis begin to converge is by using mixed reality. Mixed reality (MR) refers to a virtual reality (VR) environment that is overlayed on to physical space. Ong and Shen present the construction of a mixed reality environment specifically for product design co-creation [11]. This study acts as a proof of concept for future work in VR design tool implementation. This study also takes into consideration expertise of clients in the co-creation process. This is a likely scenario for any realistic application and why consumer preference testing uses household products to assume background knowledge. The MR environment constructed uses SolidWorks on a live interactive feed for all users as seen in Figure 4. The flow path for this process can also be seen in Figure 5. This MR environment presents a solution to a problem of medium presentation which was highlighted in the eye-tracking software study by Reid et al., units and dimensions can be 1:1 scale with the physical environment to convey a realistic scale for consumers.

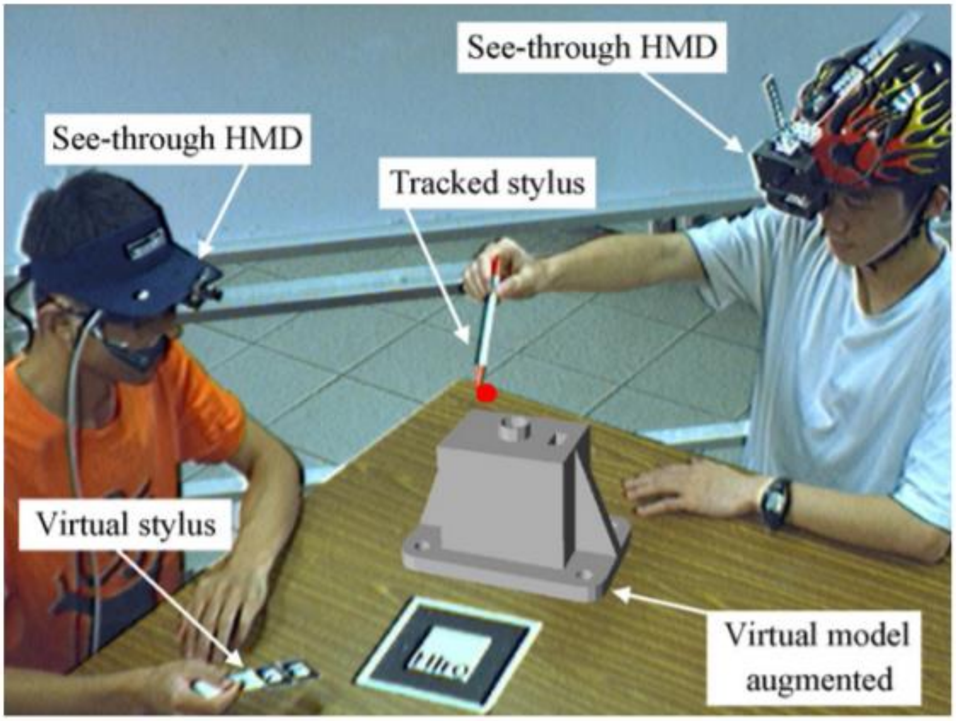


Figure 4. Mixed Reality Collaborative Environment [11]

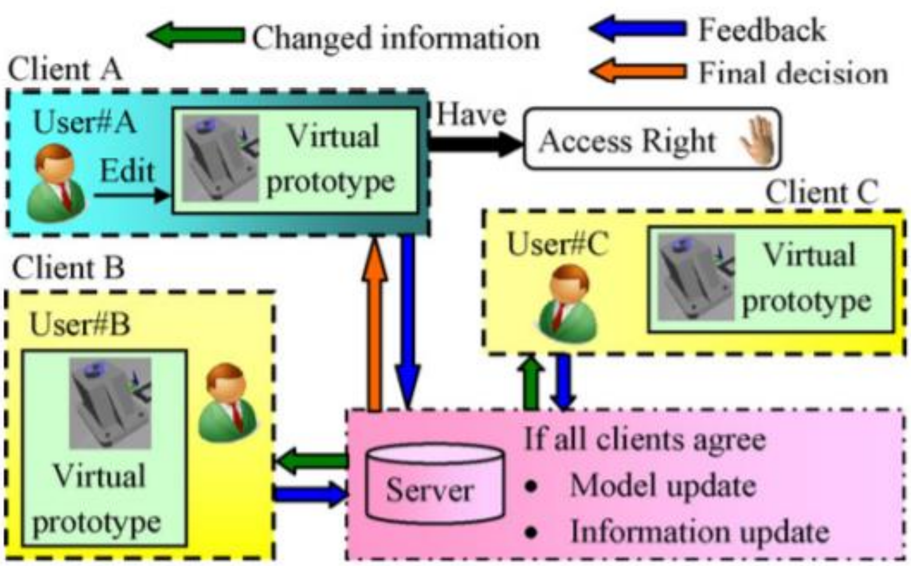


Figure 5. Mixed Reality Co-creation Flow Chart [11]

One of the ways MR has been implemented into the engineering design process is in teaching design. Tang et al. studied the efficacy of using MR in conveying design concepts to students [12]. Three metrics for MR educational improvement were assessed in the study: model visualization abilities, geometric analysis, and creativity. This study employs the use of a Microsoft HoloLens VR system. Students in the study were given a pretest on their understanding of 2D designs of an internal combustion engine. After this test, students were given instruction on use of the HoloLens system, so as to not be distracted by any conceptions of novelty or complication with the device. After this course, they were given time in the machine to interact with an aircraft turbofan in a constructed MR environment. The HoloLens allowed students to view individual components and 3D animations of the model as seen below in Figure 6. A control group that did not use the HoloLens to study the turbofan was also evaluated. The Wilcoxon signed rank test was used in this study for comparison of the two learning methods. This study concluded with improvements across the board in design abilities due to the use of the MR teaching technique. This study carries the implication that transmission of critical design information, namely geometric analysis, can be most effectively communicated using 3D animation.

Figure 6. Aircraft Turbofan MR Environment [12]

Section Summary

The research outlined in this section describes the practices of designer communication with consumers and potential methods therein. The greater implication of this research is the idea of personalizing communicative methods for use of consumer understanding of a product. Mandolfo et al. contributed to the idea that there are confounding variables in the design feedback process, but recommended future work in understanding co-creation creativity levels, which was evaluated by Tang et al. using the MR technology pioneered Ong and Shen. This section presents the use of methods recommended in the first section (3D animation in higher fidelity) and showed a higher degree of product understanding. Future work should test the impact of this understanding of high-fidelity concepts on consumer feedback.

3.3 Prototype Function in Design

The three studies in the first section all used vehicle silhouettes to evaluate consumer preference, while this was effective for establishing framework of prototype representation differences, these studies fell victim to an engineering design concept that must be considered in the scope of this research: design fixation. Design fixation as studied by Linsey et al. involves the mental block designers subconsciously face when going through the design process and develop a sense of tunnel vision in their alternatives [6]. In this study, participants who were engineering faculty with design experience, were tasked with producing ideas for a peanut-shelling device and their design proposals were evaluated based on novelty and deviation from expected design features. The study presented results with implications crucial to this research; those engineering academics with extensive experience in engineering design exhibited a statistically significant amount of fixation in their design alternatives. These faculty were coached in the process to use analogy to drive home the importance of recognizing fixation and still experienced an unnoticed amount of fixation. Design fixation is present in designers and consumers alike in their perception of what a product should have, so combatting efforts should be acknowledged and implemented to avoid fixation in this study.

A common method of eliminating fixation in the early stages of development is generation of alternative by means of sketching. Yang studied this concept generation strategy to evaluate ways to improve early-stage product design idea quality [13]. This study conducted an analysis of generated sketches by undergraduate students in an advanced mechanical design class at the California Institute of Technology. These sketches were preliminary ideation of electro-mechanical devices used in a competition in the class. Sketches were analyzed by their level of detail and dimensioning, and the quantity of sketches produced throughout the duration of the project into its fabrication period. In this study, the individual designers acted as the end-user/consumer who is providing feedback. As the fabrication process took place, sketches were generated for ideation and tracked throughout. The results of this study suggest that prototyping (which coincides with sketch idea generation) in the early stages of the design process, tends to lead to better end design.

This study was followed up by Yang in a study evaluating the usefulness of physical prototype generation in the engineering design process [7]. One measurement taken in the study was the number of parts in each design as milestones were achieved. Time data was also collected in the study where hours spent on each activity were evaluated on a weekly basis. The Spearman Ranking Correlation for nonparametric populations was used in the study to evaluate the correlations between design plans and outcomes. Analysis of the collected data consisted of an evaluation of the number of parts in the final milestone and the final grade for each student, which yielded a statistically significant negative correlation. This correlation indicates that the simpler the prototype, the higher the performance. Another result of the study is the positive correlation between time spent debugging and design success. This indicates the amount of spent fine tuning a functioning device, rather than actual fabrication time leads to greater success. The study presents the notion that physical prototyping in the early stages of a design project, while likely throwaway prototypes, aid in the final success of that product. Unforeseen errors and details are more likely to arise when early-stage prototyping is implemented. The study also implies the significance of a debugging period in the design stage for product success. The greater implication of this study is the idea of a physical rapid prototype and its use for validation of design parameters.

Section Summary

This research covered in this section covers the mitigation of design fixation via alternative generation and the implications of different concept development methods. The main research takeaway in in this section is the notion that the engineering students in the studies by Yang are acting as their own feedback providers, but their design process can be applied to co-creation with consumers as the consumers act as the critics and engineers provide alternative sketches/prototypes.

3.4 Literature Summary

In the first section of the review, existing studies regarding consumer preference to design representation were covered. Orsborn, Sylcott, and Bi used silhouette preference studies each building off the last [3-5]. These provided a framework for the field of study, but experienced limitations in model fidelity and medium variation. Reid presented a study using higher fidelity models but fell short in model presentation angles and 3D animation of models [9]. This section established a need for future work using higher fidelity models in conjunction with statistical evaluation methods developed in the covered works. The second section of the review detailed possibilities for higher fidelity design communication methods, as well as guidelines established by Mandolfo et al. for understanding consumer co-creation and feedback collection in product design [10]. The third section of the review detailed studies regarding concept generation in engineering design and guidelines suggested by Linsey et al. for combatting design fixation [6]. The concept generation methods described in the third section provide insight into the iterative design process and the efficacy of consumer feedback. It also indicated that early-stage physical prototype production is a driver of product debugging, leading to a more successful product. This research must be taken into consideration for a third form of design presentation to consumers: physical models. The culmination of the research in this literature review points to a need for study of variable representation mode, high-fidelity design concepts and the consumer judgment changes caused by that varying degree of detail.

Chapter 4: Methods

4.1 Objective

The overall objective of this thesis research project is to identify a relationship between design concept representation detail level and a consumer's final-product preference. This will aid designers in eliciting feedback for the design process most effectively.

4.2 Subject Inclusion and Exclusion Criteria

This study consisted of eliciting preference and eye-tracking data from male and female college students and employees. The sample size originates from a general number of 30 participants from previous studies, with an anticipated margin for dropout of 10 subjects added. Forty participants were sought, and at the time that 39 participants had been processed through the study, subject recruitment ceased in the interest of time. All subjects were required to wear eyeglasses or contacts and eyeglasses. Subjects had to be proficient in the English language. The Pernice-Nielsen criteria for conducting eye-tracking surveys were implemented and their entry survey was used for subject filtering (see Appendix D) [28]. All students and employees invited to participate had to meet the specified criteria selected from the Pernice-Nielsen guidelines. No special populations were considered for this study.

4.3 Subject Recruitment and Consent / Study Location

The study's subjects were recruited from East Carolina University. The study subjects were identified and recruited by the principal investigator and the co-investigator through the following avenues: verbal, email, or flyer invitation. A detailed consent form was provided upon agreement to participate in the study stating that participation in this study was voluntary and confidential and that all results were to be kept in a locked cabinet in Austin Hall, Room 324A, where the study took place. This study was reviewed and approved by the Institutional Review Board (IRB) at ECU before testing began. The IRB letter of approval, the informed consent forms, and the subject recruitment letters are included in Appendices C, E, and F respectively.

4.4 Procedure

The product of interest in this study was selected to be eyeglass frames. Eyeglasses fall into a unique category of products because they convey very little performance information in their design. This is to say that when a design of eyeglasses is evaluated, consumers are expected to respond with an opinion informed in its majority by the form of the glasses, rather than by an inference of their functionality. This assumption of a purely aesthetic response lays the groundwork for the testing carried out in this study as it allows for comparisons to be made across frames by only asking for a consumer's rating of the design.

4.4.1 Surveying Structure

This study makes use of two surveys which elicit preferential scores from participants. These preferences are of eyeglass frames shown in varying representations modes. Participants were asked to rate each frameset 1-10 based on their preference. Five framesets were shown, each in three mediums of representation, and each shown twice, totaling thirty trials per subject. Participants were shown all the representations for the first time, in random order, and after having seen and scored each of those, they were presented with all the same representations, again in random order, a second time. These two separate assessments will be referred to moving forward as the first and second exposure. After completing this survey digitally, subjects were prompted with the same question for the physical models of the same glasses, each twice, resulting in ten trials per subject, forty in total, each.

4.4.2 Range of Fidelity Concept Preference Surveying

Since the subject body is comprised of glasses-wearing participants, and those individuals already wear, and buy eyeglasses, they do already have stylistic preferences. For this reason, multiple framesets of wide stylistic variety were selected as the surveying group. Three mediums of representation for those glasses were used in the study. The first conceptual style used consists of eyeglasses represented in the form of sketches. Sketches were produced by a professional product designer, by hand and in black and white, maintaining the shape and proportions of the glasses they are representing. An example of one of these hand drawings is shown in Figure 7.

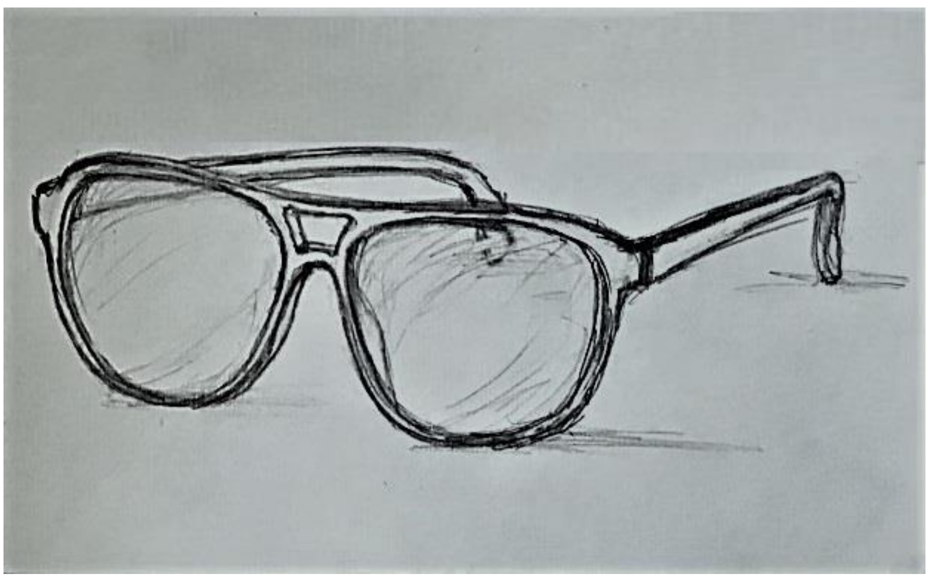


Figure 7. Example of Hand Drawing Representation Style

The second set of conceptual models were presented as solid models in the form of isometric CAD generated renderings of each frame design. These renderings were shown in a grey background and the neutral color that CAD software defaults models to. This was done to keep consistency with the hand drawings being shown as black and white line drawings: to be true to the design process stages being emulated. An example of the corresponding frameset from Figure 7, made as a solid model is shown in Figure 8. The models were produced by the principal investigator, who has professional experience as a draftsman, to maintain artistic credibility of the representations.

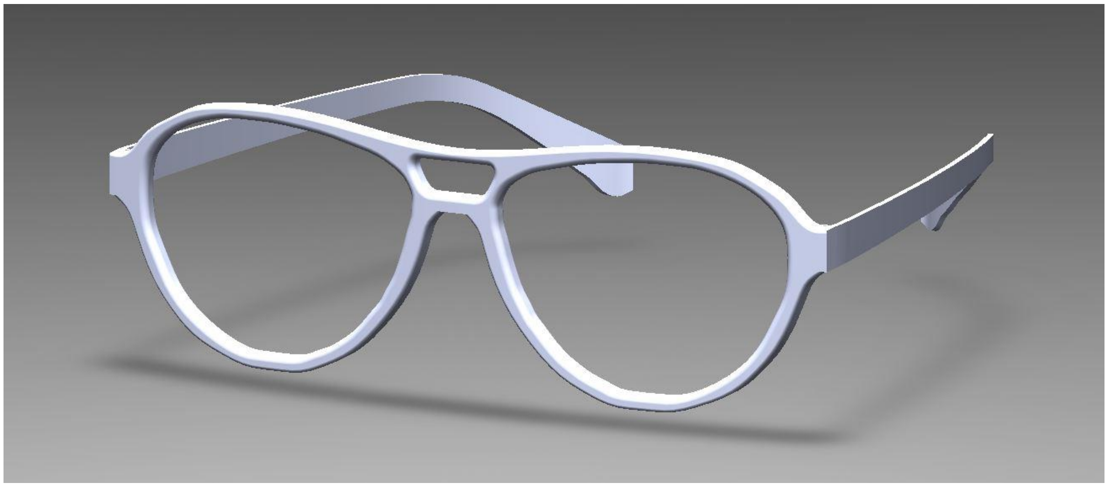


Figure 8. Example of SolidWorks Model Representation Style.

The third set of concepts shown to participants consisted of polished renderings. These renderings were taken from the original manufacturer's website and placed over a contrasting background in Photoshop. The serial numbers and branding visible on the original manufacturer's renderings were also removed to avoid "symbolic" response and the chance of participants associating identity of the frames. An example of a polished rendering of frameset B is shown below in Figure 9. A key of all the models generated in this study are shown in Figure 10.

Figure 9. Example of Polished High-Fidelity Rendering

	HD	SW	RD
A			
B			
C			
D			
E			

Figure 10. Representation Key

4.4.3 Eye-Tracking

Eye-tracking software and hardware was used in the study to map the subjects' focus locations and times as concepts are observed throughout the three representation modes, and during observation of the physical models. Tobii Glasses 3 were used to collect eye-tracking data throughout the study. Eye-tracking data was collected and stored using Tobii Pro Lab. An example of a participant's view of the study is shown in Figure 11.

Figure 11. Qualtrics Survey Eye Tracker Recording

4.5.4 Physical Product Rating Survey

In the second survey of the study, the typical eyeglass purchasing process was emulated where the same participants from the first survey were able to inspect the physical versions of the reverse-conceptualized framesets from the first survey. Ratings 1-10 were collected after allowing subjects to view the physical models the same as in the first survey. Participants were not allowed to handle the glasses, merely visually inspecting them from the same angle at which they saw them in the first survey. An example of a participant's perspective is shown in Figure 12. The full preference survey is included in Appendix B.

Figure 12. Physical Model Surveying Eye-Tracking Recording

4.4.5 Pre-Screening

A pre-screening survey was constructed using Qualtrics to determine participant eligibility and demographics, as well as collect contact information to set up meeting times. Subject eligibility was determined with questions from the Pernice-Nielson Criteria for Conducting Eye-Tracking Studies [28] as well as through determining if participants did in fact have corrected vision. The pre-screening survey is shown in Appendix A. Of the participants accepted and used in this study, 26 of the 38 were engineering students or faculty. On average, a participant had worn glasses for 10.4 years, purchased glasses every 2.3 years, and had purchased glasses in the last 1.5 years.

4.4.6 Data Collection Software

For the first survey, data was collected using Qualtrics for the ratings and Tobii Glasses 3 for the eye-tracking recordings. The Qualtrics data was exported into excel and sorted once testing was complete, while the Tobii data was kept in Tobii Pro Lab software for sorting. The physical model surveying data was entered into excel as it was collected, since participants gave verbal scores.

4.5 Risks

There were no risks associated with participation in this study. Informed consent was maintained during participation in the study, and subjects were made aware that they could stop at any time if they wanted.

4.6 Confidentiality

The records of this study were kept confidential. The principal investigator did not include the name of any participant involved in this research in any scientific reports. Research records were kept in a locked filing cabinet in Austin Hall, Room 324A at East Carolina University. The principal investigator and the co-investigator were the only people who had access to these records.

4.7 Considerations

Some potential considerations about the participant responses have been made and will be addressed as outlined in this section. One consideration that has been made is the inclusion of counterbalancing in the study design. Counterbalancing was done in this study by randomizing the order of the representations between participants' observations to reduce the bias created by seeing the same order of stimuli throughout the survey. Another decision-making consideration that was addressed is recency bias. Recency bias refers to the tendency to fixate on the last information one is presented with as the most favorable [29,30]. Recency bias was mitigated by blocking the questions into two sections (first and second exposures) and prompting preference score at each exposure.

Chapter 5: Data Processing and Analysis

5.1 Processing Qualtrics Data

Sorting of all the ratings data was done by placing the scores into a data layout table where ratings are sorted relative to participant row-wise, and representation column-wise. After data was exported to excel from Qualtrics, there were several missing values, which upon inspection of the corresponding points in the eye-tracking software, could be manually entered into the data table. From the Qualtrics data, only one participant had their data disqualified, because their eye-tracking recording was low-quality, and some of the points could not be filled in.

5.2 Processing Eye-Tracking Data

The eye-tracking data was processed using Tobii Pro Lab. This is also the software that was used for accessing the recordings for reference as mentioned above. To manage the recordings, the first thing done in the software was to create event flags for when participants were presented with each representation. The nomenclature consists of three letters, the first corresponding to the frameset shown (A-E), and the second two letters corresponding to the representation style that frame was shown in (HD–Hand Drawing, SW-SolidWorks, RD-Rendering, PM-Physical Model). The next step in processing this data was creating an arbitrary AOI image that could be used to map the gaze points in the recordings. The AOI locations on the map such as “Right Lens 1 and Left Lens 1” are arbitrary because they were added together after data was exported from Tobii. The top and bottom however represent the first and second exposure of each representation that participants saw in the survey. The reason the AOIs were drawn onto the referencing map this way was simply to streamline the mapping by making it intuitive – when mapping the gaze points from the recordings, a click in the same place as the screen would result in an AOI hit of the corresponding area. This image is shown in Figure 13. As a point, another way to do this would be a simple diagram with “bubbles” labeled as each AOI.

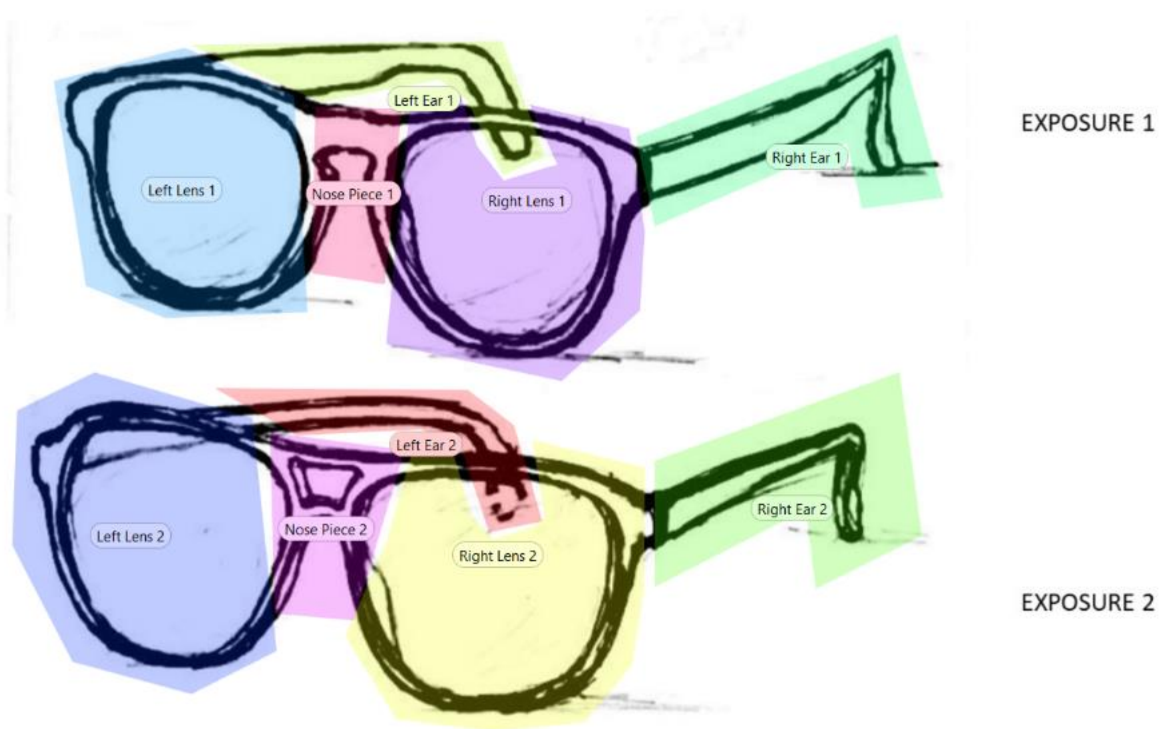


Figure 13. Assisted Mapping AOI Image

This process was completed for both the first and second survey recordings, and then exported separately and combined in excel after being processed further in MATLAB.

5.3 Sorting Eye-Tracking Data in MATLAB

Two sorting processes were developed in MATLAB to handle the large amount of raw data exported from Tobii Pro Lab. The first of which consisted of creating a .mat file that held the contents of a condensed export file that held the participant number, event tags, AOI hits, and gaze durations in milliseconds. After this file was created, the event tags that had been manually inserted at a specific point in Tobii Pro Lab could be assigned to all corresponding points in the exported file. Next, rows where no AOI hits existed could be removed from the data set, and matching rows could be summed to create a total number of hits for each exposure for each participant. This process was carried out twice, for the first and second exposures, and exported into two corresponding spreadsheets.

The second sorting process carried out in MATLAB was similar but focused on extracting the gaze durations. These were not treated the same as the number of hits because the AOI hits are represented as a binary 1 or 0 for each point in the recording, the gaze durations on the other hand were reported as sums of time spent over a specific period defined by the Tobii software. This means that the gaze durations had to be parsed as unique events, then summed based on matching qualifiers including participant, representation shown, and specific AOI hit. This resulted in a gaze duration output which was a sum of all the times that a particular participant looked at a certain AOI for each representation, even if they had looked at other AOIs in between gazes. This output from MATLAB was also exported into the two results spreadsheets corresponding to the first or second viewing of the models.

5.4 SPSS Data Analysis

IBM SPSS was used to analyze the data collected in this study. Repeated-measures ANOVA was conducted on the different combinations of data points. Pairwise comparisons were evaluated with a Bonferroni correction. These tests were conducted with a 95% confidence interval to test for significance (mean difference is significant at $p < .05$) where the null hypothesis (H_o) was that there is no difference in the two sets of data, and the alternative hypothesis (H_a) was that a significant difference does exist between the data.

5.5 Descriptive Statistics in Excel

Using Microsoft Excel, the collected data was also evaluated to describe the Inter Quartile Ranges (IQR) and medians (MED) of the Likert-scale Qualtrics data. Excel was also used to examine individual-based assessments of the frames between the first and second exposures.

Chapter 6: Results

6.1 Descriptive Statistics on Scoring

Data for subject 35 was not used in the analysis due to a corruption in data collection that could not be corrected, resulting in a total of n=38 participants included. Table 1 contains the medians and interquartile ranges of all the participants for each frame and representation style. In this table "A1" indicates frame A and exposure 1, likewise, "B2" represents frame B and exposure 2 and so on. Table 2 contains the ranges for each participant and frame, separated by the first and second exposures. Table 3 contains the average range of scores for the composite of all subjects by frame for exposure one and two, as well as the percent change from the first to second exposure. Figures 14 and 15 show box and whisker plots for the scoring distributions for the first and second exposures, respectively.

Table 1. Descriptive Statistics for Qualtrics Preference Ratings

REP.	**HD**		**SW**		**RD**		**PM**		**AVERAGE**	
	IQR	**MED**	**IQR**	**MED**	**IQR**	**MED**	**IQR**	**MED**	**IQR**	**MED**
A_1	3.5	6	6	5.5	4	6	5.25	6	4.69	5.88
A_2	5.25	6	4	5	5	5	5	7	4.81	5.75
B_1	2.25	4	3	3	2.25	3	2.25	4	2.44	3.50
B_2	3	3.5	2	3	3	3	2	4	2.50	3.38
C_1	3.25	7	4	6	3.25	5.5	4.25	5	3.69	5.88
C_2	4.25	6	3.25	5	6	5	4	5	4.38	5.25
D_1	3	5	3	5	3.25	5	2	5	2.81	5
D_2	3.25	5	4	5	3	5	2.25	5	3.13	5
E_1	4	5	3	5	2.25	5	2	6	2.81	5.25
E_2	3.25	5	3.25	4	4	4	3	5.5	3.38	4.63
AVG 1	3.2	5.4	3.8	4.9	3	4.9	3.15	5.2	/	
AVG 2	3.8	5.1	3.3	4.4	4.2	4.4	3.25	5.3		

Table 2. Descriptive Statistics of Participant Scoring Ranges

	RANGE OF SCORES											
SUBJECT	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**	**D1**	**D2**	**E1**	**E2**	**ALL1**	**ALL2**
1001	6	6	5	4	3	5	3	4	4	4	7	7
1002	1	1	2	1	3	2	5	1	4	2	6	3
1003	2	2	1	1	3	4	4	2	5	3	6	6
1004	1	2	2	0	2	1	4	2	3	2	7	6
1005	2	1	4	2	1	1	4	3	5	3	8	8
1006	5	3	2	2	4	5	6	4	1	4	7	6
1007	3	1	1	0	4	0	1	1	5	2	9	7
1008	1	3	0	0	0	2	5	1	7	1	7	7
1009	1	6	3	2	5	6	3	1	1	2	6	6
1010	6	1	6	4	3	5	3	4	4	3	8	6
1011	2	0	0	0	2	2	2	1	1	1	5	5
1012	5	3	5	3	2	5	3	4	3	2	7	5
1013	1	4	2	5	2	6	6	2	2	2	9	8
1014	2	2	2	1	2	1	1	2	2	3	6	6
1015	5	2	1	1	4	2	2	0	1	1	6	4
1016	2	3	2	1	3	3	3	1	3	1	4	4
1017	1	0	0	1	3	1	7	3	2	2	8	4
1018	0	0	3	1	7	0	1	3	0	1	7	7
1019	8	6	6	0	6	8	4	3	2	5	8	8
1020	4	4	2	1	4	4	1	1	1	3	5	5
1021	1	2	2	0	5	2	1	1	0	2	7	7
1022	0	0	0	0	4	4	1	1	5	5	9	8
1023	1	3	2	1	3	1	3	4	4	6	7	9
1024	2	1	3	5	4	3	3	5	6	4	7	6
1025	3	1	2	1	1	1	2	1	4	4	5	4
1026	2	1	1	1	1	2	1	2	2	0	4	4
1027	8	8	1	4	9	7	6	1	5	3	9	8
1028	3	3	2	2	2	1	2	2	2	2	4	4
1029	6	6	3	2	7	6	4	6	3	4	7	6
1030	2	1	0	1	5	6	2	3	2	2	6	6
1031	1	1	3	1	2	1	3	2	1	2	6	5
1032	3	6	2	2	1	5	5	5	3	3	7	7
1033	2	1	1	0	1	0	2	3	4	1	6	6
1034	3	3	2	3	2	2	3	2	3	4	6	7
1036	1	2	4	3	2	3	4	1	2	2	8	8
1037	1	0	1	1	1	2	1	2	3	2	3	3
1038	2	1	2	1	2	2	1	1	3	2	6	4
1039	5	1	2	1	3	2	2	3	2	2	5	5

Table 3. Average Range of Scores for all Subjects

	A	**B**	**C**	**D**	**E**
EXPOSURE 1	2.74	2.16	3.11	3.00	2.89
EXPOSURE 2	2.39	1.55	2.97	2.32	2.55
CHANGE %	-12.50	-28.05	-4.24	-22.81	-11.82

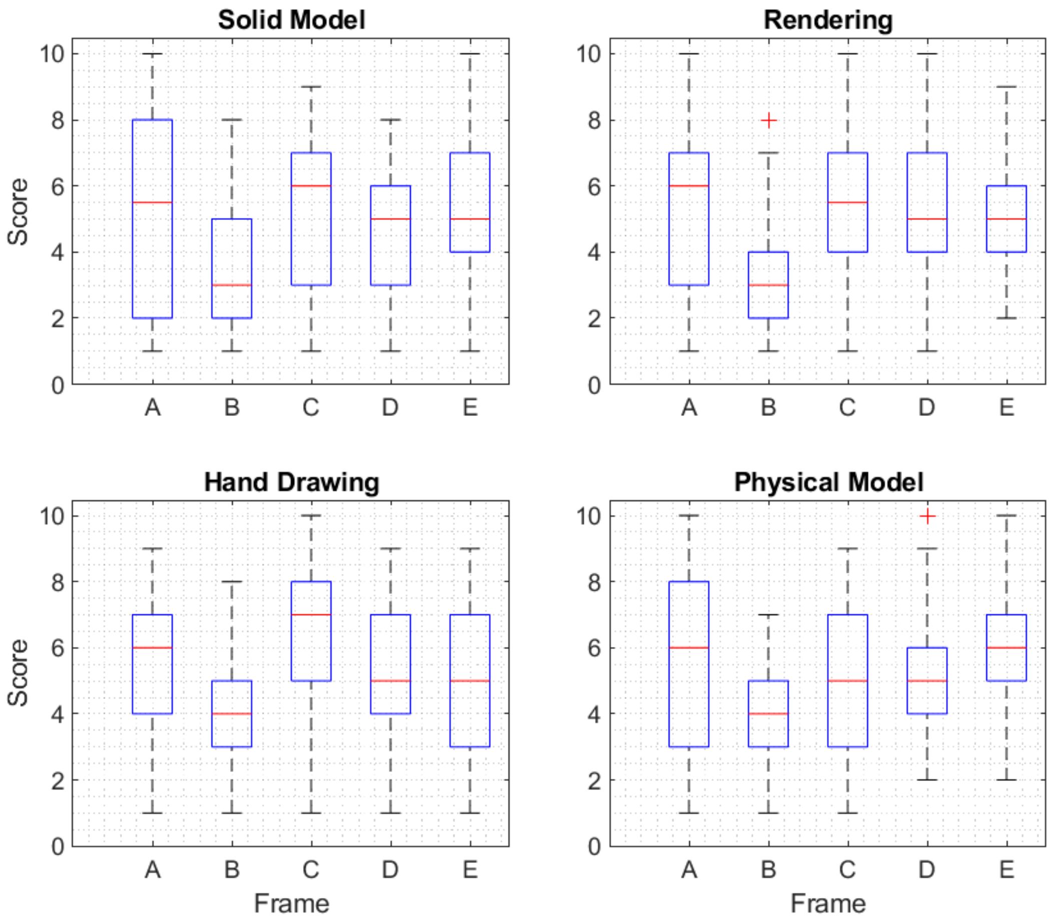


Figure 14. First Exposure Score Distributions

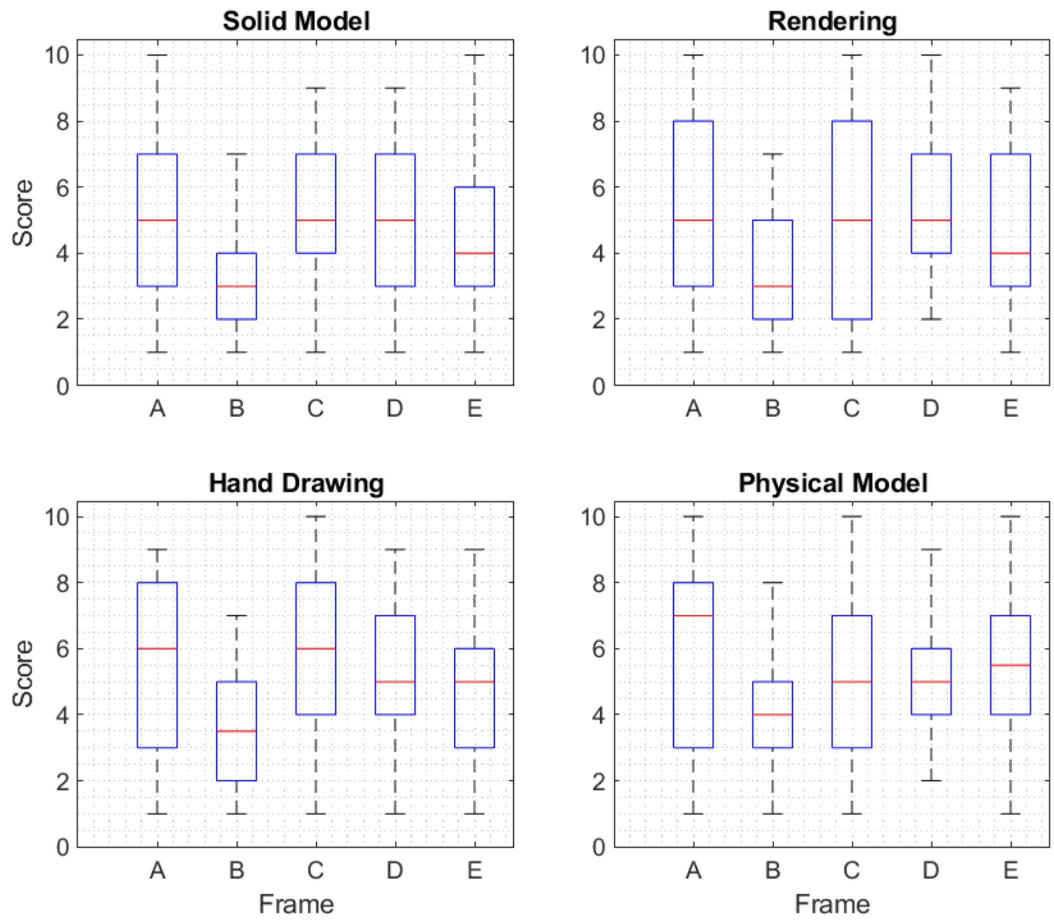


Figure 15. Second Exposure Score Distributions

6.2 Excel Descriptive Statistics on Durations

For the eye-tracking data, subjects 1,4,17, and 35 were excluded from analysis, due to low recording resolution. Their data was unusable, bringing the n for eye-tracking analysis to 35. Figure 16 contains a bar plot of the average hit count and fixation durations for all participants in each frame and representation style. Figures 17 and 18 contain the average duration length for each frame and representation style in the first and second exposure, respectively. Tables 4 and 5 contain the average duration data for each frame in each representation mode for all participants in the first and second exposures, respectively. Tables 6 and 7 contain the average durations (ms) for each representation and AOI for all subjects first and second exposures, respectively.

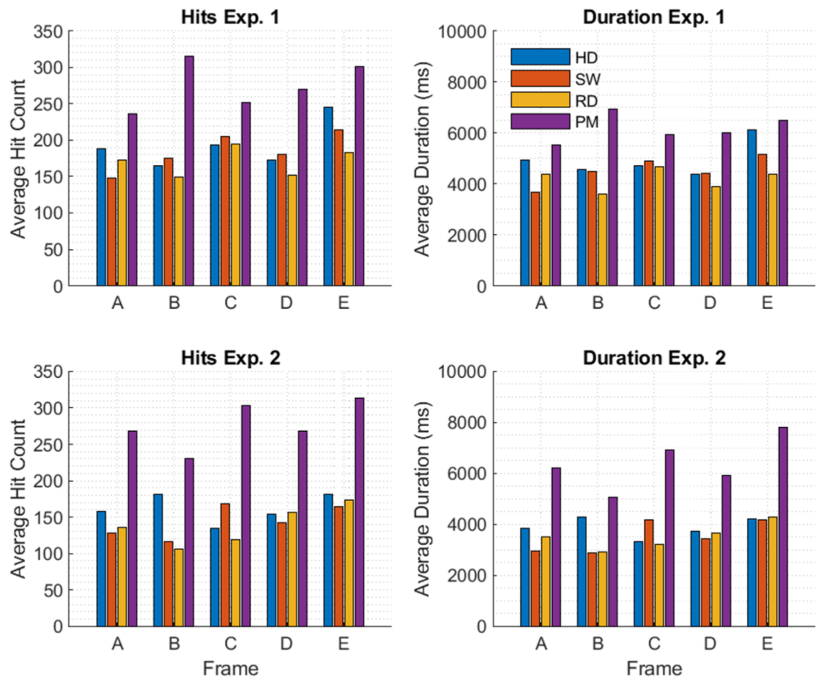


Figure 16. Average Hits and Duration in Each Frame and Representation

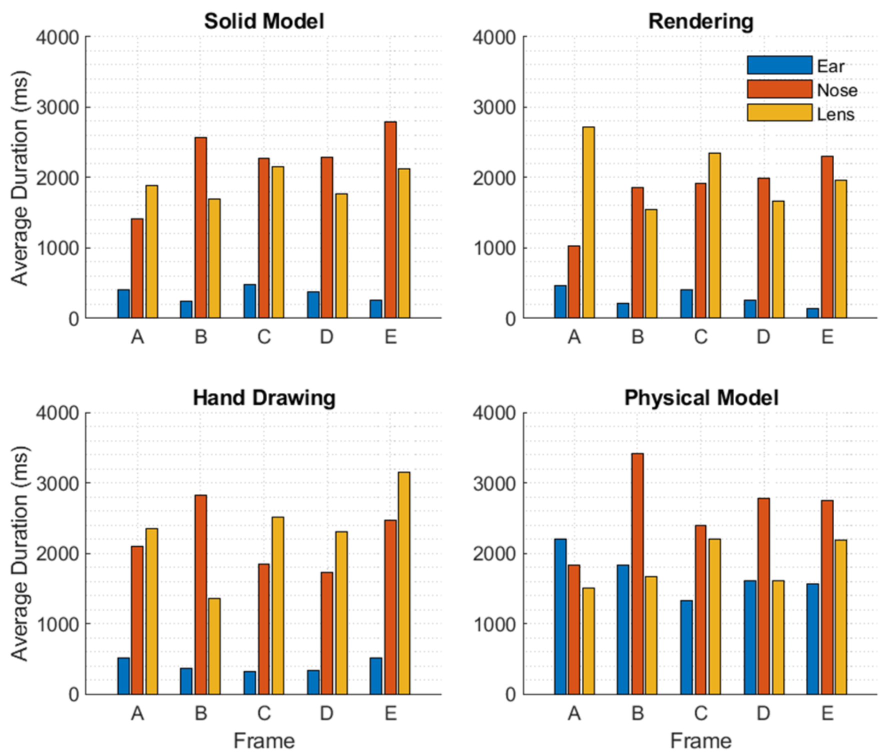


Figure 17. First Exposure Average Duration Length by Frame and Representation

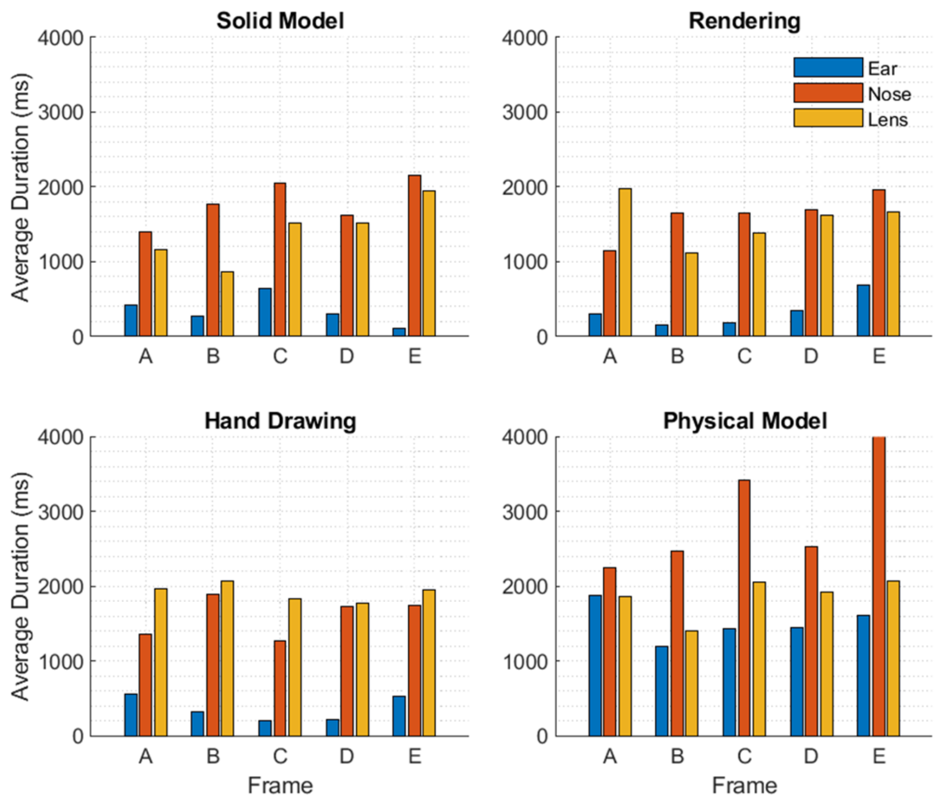


Figure 18. Second Exposure Average Duration Length by Frame and Representation

Table 4. Average Durations for all Participants Exposure 1

AVERAGE DURATION				
EXP 1	**HD**	**SW**	**RD**	**PM**
A	4945.0	3658.5	4393.8	5525.1
B	4551.7	4480.7	3604.0	6921.4
C	4695.3	4900.3	4667.1	5937.3
D	4365.7	4421.8	3903.5	5993.8
E	6134.9	5170.1	4384.6	6508.6

Table 5. Average Durations for all Participants Exposure 2

AVERAGE DURATION				
EXP 2	**HD**	**SW**	**RD**	**PM**
A	3832.5	2942.4	3493.8	6215.7
B	4297.9	2877.7	2904.7	5079.2
C	3318.7	4190.9	3208.7	6911.7
D	3721.4	3436.0	3647.6	5906.5
E	4217.9	4190.7	4302.0	7825.4

Table 6. Average Duration for each Representation and AOI by Frame Exposure 1

AVERAGE DURATION												
EXP 1	**HD**			**RD**			**SW**			**PM**		
FRAME	**LENS**	**EAR**	**NOSE**	**LENS**	**EAR**	**NOSE**	**LENS**	**EAR**	**NOSE**	**LENS**	**EAR**	**NOSE**
A	2349.6	516.9	2103.8	2708.4	454.4	1027.2	1884.5	402.5	1403.1	1504.5	2200.1	1828.0
B	1356.2	371.5	2823.9	1548.4	205.4	1850.1	1687.6	233.6	2559.5	1673.3	1827.3	3420.8
C	2517.1	325.7	1852.5	2341.8	408.1	1917.2	2157.5	471.1	2271.6	2210.7	1329.1	2397.5
D	2308.8	333.1	1723.8	1662.9	250.7	1989.9	1769.5	367.5	2284.7	1607.3	1608.5	2778.0
E	3146.8	519.1	2469.0	1960.7	127.6	2296.3	2123.3	254.2	2792.7	2195.3	1565.0	2748.3

Table 7. Average Duration for each Representation and AOI by Frame Exposure 2

AVERAGE DURATION												
EXP 2	**HD**			**RD**			**SW**			**PM**		
FRAME	**LENS**	**EAR**	**NOSE**	**LENS**	**EAR**	**NOSE**	**LENS**	**EAR**	**NOSE**	**LENS**	**EAR**	**NOSE**
A	1968.0	551.5	1364.3	1970.7	293.5	1137.9	1158.5	411.3	1394.3	1860.3	1881.1	2250.5
B	2072.8	327.5	1897.7	1108.3	152.8	1643.6	856.3	262.2	1759.1	1407.6	1192.8	2478.8
C	1838.3	208.9	1271.5	1384.3	174.6	1649.8	1515.1	632.0	2043.8	2060.2	1428.8	3422.7
D	1775.7	220.9	1724.8	1623.0	335.5	1689.2	1518.8	295.9	1621.3	1915.9	1453.4	2537.2
E	1950.4	526.0	1741.5	1662.4	678.9	1960.6	1936.5	98.4	2155.9	2078.5	1613.7	4133.2

6.3 Excel Descriptive Statistics on Hits

Tables 7 and 8 contain the average duration data for each frame in each representation mode for all participants in the first and second exposures, respectively. Tables 10 and 11 contain the average number of hits for each representation and AOI for all subjects first and second exposures, respectively.

Table 8. Average Number of Hits for all Participants Exposure 1

AVERAGE NUMBER OF HITS				
EXP 1	HD	SW	RD	PM
A	187.8	148.6	172.3	236.5
B	164.3	174.9	149.6	314.9
C	193.3	205.1	195.1	251.7
D	172.6	180.7	152.0	270.4
E	245.5	213.6	182.9	301.2

Table 9. Average Number of Hits for all Participants Exposure 2

AVERAGE NUMBER OF HITS				
EXP 2	HD	SW	RD	PM
A	158.4	127.4	136.1	268.8
B	181.7	116.9	105.7	230.1
C	134.1	167.9	118.8	302.8
D	153.9	142.3	156.3	267.8
E	180.6	163.7	173.0	313.8

Table 10. Average Number of Hits for each Representation and AOI by Frame Exposure 1

AVERAGE NUMBER OF HITS												
EXP 1	HD			RD			SW			PM		
FRAME	LENS	EAR	NOSE	LENS	EAR	NOSE	LENS	EAR	NOSE	LENS	EAR	NOSE
A	101.76	20.91	66.35	103.38	22.76	37.97	78.71	16.50	55.32	54.15	111.26	70.35
B	58.51	15.34	90.40	64.40	10.69	74.49	70.26	11.66	93.03	78.03	89.89	146.94
C	104.17	14.31	74.86	108.86	17.23	69.06	88.83	21.46	94.83	93.94	56.49	101.31
D	100.94	12.17	59.46	74.74	12.51	64.77	76.49	17.51	86.74	75.80	76.37	118.23
E	125.74	25.97	93.74	89.17	6.20	87.57	100.74	10.86	101.97	101.03	76.89	123.31

Table 11. Average Number of Hits for each Representation and AOI by Frame Exposure 2

AVERAGE NUMBER OF HITS												
EXP 2	HD			RD			SW			PM		
FRAME	LENS	EAR	NOSE	LENS	EAR	NOSE	LENS	EAR	NOSE	LENS	EAR	NOSE
A	78.68	27.50	54.68	78.29	14.00	39.50	52.88	19.68	56.76	85.71	94.09	83.71
B	91.83	15.63	74.23	38.49	7.29	59.94	40.00	11.80	65.06	66.63	54.89	108.63
C	77.71	10.43	46.00	54.97	8.74	55.06	59.31	31.91	76.69	97.29	69.94	135.57
D	80.03	10.83	63.03	73.23	16.20	66.91	60.06	11.60	70.69	95.40	67.51	104.86
E	91.34	26.94	62.34	70.17	27.03	75.77	86.86	4.94	71.91	83.66	70.89	159.26

6.4 SPSS ANOVA on Scoring

All the scores collected in Qualtrics were statistically tested both by and independent of frame set. Table 12 contains the results of significance for the repeated measures ANOVA tests conducted in SPSS.

Table 12. Qualtrics Scoring ANOVA Results

Comparison	p-value	Significantly Higher Score
HD1 vs. SW1	.007	HD1
PM1 vs. SW1	.015	PM1
PM2 vs. SW2	.045	PM2

6.5 SPSS ANOVA on Durations

After duration data was extracted from MATLAB, it was tested in SPSS using repeated measures ANOVA. The results of the frame-by-frame durations for exposure 1 and 2 are shown in Table 13 and 14 respectively. The duration data was also tested for significance between the AOIs both for all frames combined, and frame-by frame. Tables 15 and 16 contain the results of the ANOVA repeated measures test for all subjects' durations by representation and AOI. Tables 17 and 18 contain the results of the durations ANOVA testing for significance between the representations for each frame.

Table 13. ANOVA of Duration Data all Subjects Exposure 1

Comparison	p-value	Significantly Higher Duration
APM vs. ASW	.026	APM
AHD vs. ASW	.042	AHD
BPM vs. BHD	.007	BPM
BPM vs. BSW	.019	BPM
BPM vs. BRD	.003	BPM
DPM vs. DRD	.013	DPM
EPM vs. ERD	.024	EPM

Table 14. ANOVA of Duration Data all Subjects Exposure 2

Comparison	p-value	Significantly Higher Duration
APM vs. ASW	<.001	APM
APM vs. ARD	.003	APM
BPM vs. BSW	.009	BPM
BPM vs. BRD	.005	BPM
BHD vs. BSW	.023	BHD
BHD vs. BRD	.021	BHD
CPM vs. CHD	<.001	CPM
CPM vs. CSW	.018	CPM
CPM vs. CRD	<.001	CPM
DPM vs. DHD	.020	DPM
DPM vs. DSW	.004	DPM
DPM vs. DRD	.005	DPM
EPM vs. EHD	<.001	EPM
EPM vs. ESW	<.001	EPM
EPM vs. ERD	.002	EPM

Table 15. ANOVA Results for Durations by Representation and AOI Exposure 1

Comparison	p-value	Significantly Higher Duration
PM_EAR vs. HD_EAR	<.001	PM_EAR
PM_EAR vs. SW_EAR	<.001	PM_EAR
PM_EAR vs. RD_EAR	<.001	PM_EAR
PM_NOSE vs. RD_NOSE	.004	PM_NOSE

Table 16. ANOVA Results for Durations by Representation and AOI Exposure 2

Comparison	p-value	Significantly Higher Duration
HD_LENS vs. SW_LENS	.017	HD_LENS
PM_LENS vs. SW_LENS	.040	PM_LENS
PM_EAR vs. HD_EAR	<.001	PM_EAR
PM_EAR vs. SW_EAR	<.001	PM_EAR
PM_EAR vs. RD_EAR	<.001	PM_EAR
PM_NOSE vs. HD_NOSE	<.001	PM_NOSE
PM_NOSE vs. SW_NOSE	<.001	PM_NOSE
PM_NOSE vs. RD_NOSE	<.001	PM_NOSE

Table 17. ANOVA Results for Durations by Representation and Frame Exposure 1

Comparison	p-value	Significantly Higher Duration
APM_EAR vs. AHD_EAR	<.001	APM_EAR
APM_EAR vs. ASW_EAR	<.001	APM_EAR
APM_EAR vs. ARD_EAR	<.001	APM_EAR
AHD_NOSE vs. ASW_NOSE	.045	AHD_NOSE
BPM_EAR vs. BHD_EAR	.001	BPM_EAR
BPM_EAR vs. BSW_EAR	<.001	BPM_EAR
BPM_EAR vs. BRD_EAR	<.001	BPM_EAR
BPM_NOSE vs. BRD_NOSE	.036	BPM_NOSE
CPM_EAR vs. CHD_EAR	.009	CPM_EAR
CPM_EAR vs. CRD_EAR	.033	CPM_EAR
DPM_EAR vs. DHD_EAR	<.001	DPM_EAR
DPM_EAR vs. DSW_EAR	<.001	DPM_EAR
DPM_EAR vs. DRD_EAR	<.001	DPM_EAR
EPM_EAR vs. EHD_EAR	.019	EPM_EAR
EPM_EAR vs. ESW_EAR	.002	EPM_EAR
EPM_EAR vs. ERD_EAR	<.001	EPM_EAR

Table 18. ANOVA Results for Durations by Representation and Frame Exposure 2

Comparison	p-value	Significantly Higher Duration
ARD_LENS vs. ASW_LENS	.047	ARD_LENS
APM_EAR vs. AHD_EAR	.001	APM_EAR
APM_EAR vs. ASW_EAR	<.001	APM_EAR
APM_EAR vs. ARD_EAR	<.001	APM_EAR
BHD_LENS vs. BSW_LENS	.033	BHD_LENS
BPM_EAR vs. BSW_EAR	.017	BPM_EAR
BPM_EAR vs. BRD_EAR	.005	BPM_EAR
CPM_EAR vs. CHD_EAR	.010	CPM_EAR
CPM_EAR vs. CRD_EAR	.009	CPM_EAR
CPM_NOSE vs. CHD_NOSE	.014	CPM_NOSE
DPM_EAR vs. DHD_EAR	.001	DPM_EAR
DPM_EAR vs. DSW_EAR	.004	DPM_EAR
DPM_EAR vs. DRD_EAR	.003	DPM_EAR
EHD_EAR vs. ESW_EAR	.034	EHD_EAR
EPM_EAR vs. ESW_EAR	.001	EPM_EAR
EPM_NOSE vs. EHD_NOSE	.002	EPM_NOSE
EPM_NOSE vs. ESW_NOSE	.010	EPM_NOSE
EPM_NOSE vs. ERD_NOSE	.004	EPM_NOSE

6.6 SPSS ANOVA on Hits

Just like the duration data, once the AOI hit data was sorted in MATLAB, it was tested in SPSS using repeated measures ANOVA. The results of the frame-by-frame hits for exposure 1 and 2 are shown in Table 19 and 20 respectively. The hit data was also tested for significance between the AOIs both for all frames combined, and frame-by frame. Tables 21 and 22 contain the results of the ANOVA repeated measures test for all subjects' hits by representation and AOI. Tables 23 and 24 contain the results of the hits ANOVA testing for significance between the representations for each frame.

Table 19. ANOVA of Hit Data all Subjects Exposure 1

Comparison	p-value	Significantly More Hits
APM vs. ASW	.008	APM
APM vs. ARD	.024	APM
BPM vs. BHD	<.001	BPM
BPM vs. BSW	.002	BPM
BPM vs. BRD	<.001	BPM
DPM vs. DHD	.003	DPM
DPM vs. DSW	.008	DPM
DPM vs. DRD	<.001	DPM
EPM vs. ERD	.003	EPM

Table 20. ANOVA of Hit Data all Subjects Exposure 2

Comparison	p-value	Significantly More Hits
APM vs. AHD	.024	APM
APM vs. ASW	<.001	APM
APM vs. ARD	<.001	APM
BPM vs. BSW	.001	BPM
BPM vs. BRD	<.001	BPM
BHD vs. BSW	.016	BHD
BHD vs. BRD	.004	BHD
CPM vs. CHD	<.001	CPM
CPM vs. CSW	.007	CPM
CPM vs. CRD	<.001	CPM
DPM vs. DHD	.003	DPM
DPM vs. DSW	<.001	DPM
DPM vs. DRD	<.001	DPM
EPM vs. EHD	<.001	EPM
EPM vs. ESW	<.001	EPM
EPM vs. ERD	.001	EPM

Table 21. ANOVA Results for Hits by Representation and AOI Exposure 1

Comparison	p-value	Significantly More Hits
PM_EAR vs. HD_EAR	<.001	PM_EAR
PM_EAR vs. SW_EAR	<.001	PM_EAR
PM_EAR vs. RD_EAR	<.001	PM_EAR
PM_NOSE vs. HD_NOSE	.002	PM_NOSE
PM_NOSE vs. SW_NOSE	.028	PM_NOSE
PM_NOSE vs. RD_NOSE	<.001	PM_NOSE
SW_NOSE vs. RD_NOSE	.023	SW_NOSE

Table 22. ANOVA Results for Hits by Representation and AOI Exposure 2

Comparison	p-value	Significantly More Hits
HD_LENS vs. SW_LENS	.012	HD_LENS
PM_LENS vs. SW_LENS	.008	PM_LENS
PM_LENS vs. RD_LENS	.034	PM_LENS
PM_EAR vs. HD_EAR	<.001	PM_EAR
PM_EAR vs. SW_EAR	<.001	PM_EAR
PM_EAR vs. RD_EAR	<.001	PM_EAR
PM_NOSE vs. HD_NOSE	<.001	PM_NOSE
PM_NOSE vs. SW_NOSE	<.001	PM_NOSE
PM_NOSE vs. RD_NOSE	<.001	PM_NOSE

Table 23. ANOVA Results for Hits by Representation and Frame Exposure 1

Comparison	p-value	Significantly More Hits
ARD_LENS vs. APM_LENS	.041	ARD_LENS
APM_EAR vs. AHD_EAR	<.001	APM_EAR
APM_EAR vs. ASW_EAR	<.001	APM_EAR
APM_EAR vs. ARD_EAR	<.001	APM_EAR
BPM_EAR vs. BHD_EAR	<.001	BPM_EAR
BPM_EAR vs. BSW_EAR	<.001	BPM_EAR
BPM_EAR vs. BRD_EAR	<.001	BPM_EAR
BPM_NOSE vs. BSW_NOSE	.037	BPM_NOSE
BPM_NOSE vs. BRD_NOSE	.006	BPM_NOSE
CPM_EAR vs. CHD_EAR	.006	CPM_EAR
CPM_EAR vs. CSW_EAR	.034	CPM_EAR
CPM_EAR vs. CRD_EAR	.009	CPM_EAR
DPM_EAR vs. DHD_EAR	<.001	DPM_EAR
DPM_EAR vs. DSW_EAR	<.001	DPM_EAR
DPM_EAR vs. DRD_EAR	<.001	DPM_EAR
DPM_NOSE vs. DHD_NOSE	.035	DPM_NOSE
EPM_EAR vs. EHD_EAR	.019	EPM_EAR
EPM_EAR vs. ESW_EAR	.001	EPM_EAR
EPM_EAR vs. ERD_EAR	<.001	EPM_EAR

Table 24. ANOVA Results for Hits by Representation and Frame Exposure 2

Comparison	p-value	Significantly More Hits
APM_EAR vs. AHD_EAR	.001	APM_EAR
APM_EAR vs. ASW_EAR	<.001	APM_EAR
APM_EAR vs. ARD_EAR	<.001	APM_EAR
BHD_LENS vs. BSW_LENS	.035	BHD_LENS
BHD_LENS vs. BRD_LENS	.030	BHD_LENS
BPM_EAR vs. BSW_EAR	.008	BPM_EAR
BPM_EAR vs. BRD_EAR	.003	BPM_EAR
CPM_EAR vs. CHD_EAR	.016	CPM_EAR
CPM_EAR vs. CRD_EAR	.015	CPM_EAR
CPM_NOSE vs CHD_NOSE	.010	CPM_NOSE
CPM_NOSE vs. CRD_NOSE	.020	CPM_NOSE
DPM_EAR vs. DHD_EAR	.001	DPM_EAR
DPM_EAR vs. DSW_EAR	.001	DPM_EAR
DPM_EAR vs. DRD_EAR	.003	DPM_EAR
EHD_EAR vs. ESW_EAR	.036	EHD_EAR
EPM_EAR vs. ESW_EAR	<.001	EPM_EAR
EPM_NOSE vs. EHD_NOSE	.002	EPM_NOSE
EPM_NOSE vs. ESW_NOSE	.003	EPM_NOSE
EPM_NOSE vs. ERE_NOSE	.003	EPM_NOSE

6.7 Results Summary

6.7.1 Qualtrics Scores Summary

Inner Quartile Range (IQR) conveys the range of the middle 50% of the data in the distribution. In Table 1, the IQRs across each representation style did not vary greatly, the physical model scores generally had the lowest IQR, while the other three representation styles were all similar. Frame-wise, frame A scores had the largest average IQR, while frame B had the smallest. Average median values for each representation style were near 5 across the board. The average median value across frames, however, shows that frame B was lower (MED_1=3.5 and MED_2=3.375) than the rest which all fell around between 5-6.

The ANOVA results in Table 12 show that during the first exposure, participants gave significantly higher scores to physical models when compared to solid models, and on top of that, hand drawing scores were significantly higher than solid models. In the second exposure, physical models once again were scored significantly higher than solid models. This supports the study's hypothesis that a difference of preference does in fact exist between representation styles of a product. These tests were considering the entire data set, independent of the different frames. In frame-wise ANOVA testing, frame B hand drawings were scored significantly higher than the solid models in the first exposure. In the first exposure frame E physical models scored significantly higher than renderings, and in the second exposure, frame E physical models scored significantly higher than the solid models. The p-values for these relationships are shown in Table 12.

6.7.2 AOI Durations Summary

Table 4 and 5 highlight the average durations for each representation and frame. From the first to second exposure, hand drawing, solid model, and rendering duration all decreased in every instance, while this is not the case for physical models. Tables 6 and 7 show how these data break down for each AOI within those frames and representations. In overall ANOVA testing for the first exposure, frames A and B physical models had significantly longer durations than their solid model counterparts. Frames B, D, and E physical models had significantly longer durations than their rendering counterparts. Frame B physical models also had significantly longer durations than its hand drawings. In the second exposure, there were more instances of significance of note. In fact, the only representations that were *not* significantly shorter than the physical models were AHD and BHD. In the case of frame B, the hand drawings even statistically outperformed the renderings and solid models.

6.7.3 AOI Hits Summary

Like the results of the average durations for all participants, the average number of AOI hits for all participants generally decreased from first to second exposure. The results were not negative at every point for HD, SW, and RD however. There were two instances of increase, albeit slight increase (BHD and DRD). The change in the physical model hit-counts was more likely to be positive from first to second exposure. In Table 19, it is notable that the physical models of frames A, B, D, and E all had significantly more hits than their renderings counterparts. Meanwhile, the physical models for frames A, B, and D also had significantly more hits than their solid model counterparts. Physical models for frames B and D also outperformed the hand drawings of these same frames. In the case of the second exposure, the only case where a representation did *not* have significantly less AOI hits than its physical model counterpart is BHD. As a matter of fact, BHD had significantly more hits than BSW and BRD.

Chapter 7: Discussion

7.1 Discussion of Statistical Testing on Scores

The ANOVA testing of the Qualtrics data showed that physical models had significantly higher scores than the solid models for both the first and second exposure. This suggests that solid models are not a credible concept communication method for consumers. Put another way, it suggests that "high-fidelity" hand drawings and renderings are sufficient conceptual models to communicate a product's form, as suggested by previous work. The hand drawings were suggested to be especially credible, seeing that solid models were even significantly lower in first exposure. Table 3 contains the average ranges for each frame, and the percent change from first to second exposure. It is interesting that the trend from first to second exposure is a decrease in range across the board. This suggests that there is a gained familiarity from the first to second exposure that tightened participants' opinions of the frames.

One possible explanation for the solid models' poor performance is that participants were unfamiliar with the nature of CAD models. In an effort to be genuine to the levels of the product design process, the solid models used in this study were left without color, and some participants asked during testing if color was to be taken into consideration. When this did arise, they were instructed not to, and to evaluate the models based on frame design only, but this stipulation was only mentioned when the investigator was asked, since it did not come up until several participants had completed the study, and it would have been inappropriate to change the procedure midway. 26 of the 39 individuals who participated in the study were engineering students or faculty. To test a secondary hypothesis that SolidWorks models under-performed due to a lack of experience with CAD, the scoring data from only the engineers was tested for significance between the representation modes. Interestingly, the significant difference between physical models and SolidWorks models disappeared in both the first and second exposure. Previous research has indicated that a familiarity with specific design approaches influences an individual's assessment of something presented in their trained medium [31,32]. It would be worthwhile to test the relationships outlined in this paper for individuals of different backgrounds and compare more thoroughly.

7.2 AOI Analysis

From the first to second exposure, the general decrease in number of hits and fixation duration is possibly due to the familiarity that participants began to develop during the online survey. In the Qualtrics survey, there were five frames shown in three different representation modes, each shown twice. This generated 30 total trials for each participant, which potentially induced fatigue and familiarity. In contrast, the physical models were presented in an entirely different medium, so it is possible that interacted with them differently, affecting their evaluation.

For the first and second exposure, in both the case of hit count and fixation duration, the earpiece AOI was significantly greater than in the case of the hand drawings, solid models, renderings. One possible explanation for this is that the earpiece is seen by participants as more of a functional aspect of the frames. One reason this idea is put forth is because several participants commented on the size and perceived fit of the physical frames while they were evaluating them. That could also lend reason into why the nose piece also saw a significant amount of hits and higher durations over the conceptual models, even though this did not seem to be the cause for the significant difference in scoring. An example of this difference in focus for a single participant across all representations of frame B is shown in Figure 19.

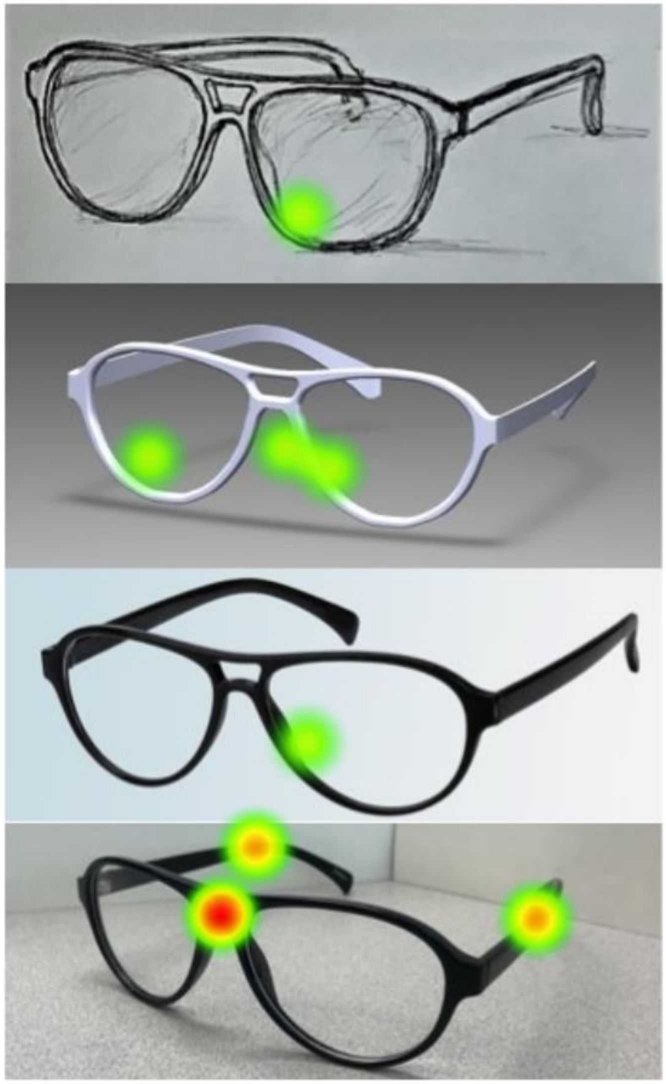


Figure 19. AOI Gaze Map for a Single Participant, Frame, and Exposure

7.3 Frame-wise Analysis

It can be observed in Figures 14 and 15, that frame B performed worse across the board than other frames. All the frames included in the study were carefully chosen because they had clear differences in appearance from one another (see Figure 10). It is notable that many mentioned their dislike for frame B, and due to its recognizable design, participants may have been more likely to become familiar quickly, and their judgement may have not been based on the representation style alone. This is supported by frame B having the lowest IQR

(EXP_IQR=2.44, EXP2_IQR=2.50). On the other hand, participants tended to love or hate frame A, this polarity is reflected by its high IQR (EXP1_IQR=4.69, EXP2_IQR=4.81) despite a median like in the case of the other frames.

In Tables 14 and 20, the physical models of all frames received more significant differences (longer durations and more hits) in the second exposure than in their corresponding first exposures. This indicates that in nearly all cases, after establishing familiarity in the first exposure, participants were more decisive with the conceptual representations than the physical models.

7.4 Implications of This Work

As mentioned in the background section of this paper, in previous work, the idea of concurrent engineering and co-creation necessitates the collection of constant feedback from consumers and clients, the findings of this work imply that hand drawings and renderings are effective (at least in the case of eyeglasses) in conveying aesthetic information to consumers. Further research into other products where stylistic evaluation is important should be conducted to explore this trend.

An important point pertaining to this investigation is that as the level of detail increases from hand drawings to solid models to renderings, the time-to-produce increases, driving resource allocation up exponentially. These resources manifest themselves in the form of time, labor, software requirements, and the defined constraints of a product's final form. This study suggests that for some firms, it may be effective to use professional hand sketches to communicate product form to elicit meaningful consumer feedback early in the product development process, as a way of optimizing resource allocating in the concurrent engineering process.

The background and literature review section of this paper discussed the potential usefulness of virtual/mixed reality models for conceptual communication. VR was discussed for use in this project but was eventually excluded from the study's experimental design due to limitations in the eye-tracking capabilities of the available VR equipment. Previous work has suggested that virtual environments are an effective means for communicating spatial information [31]. This paper's notion that participants were missing fit and finish information from the conceptual models, presents a future work opportunity for studies to assess the AOI hit/duration differences between VR and physical models. To build on this and previous work, evaluating consumer responses, both aesthetic, and semantic in a VR environment would be a meaningful contribution to the field. The eye-tracking results of this study would be useful to integrate into an investigation such as previous work that has evaluated consumer judgement of size estimations to determine if participants were more likely to look at specific features when evaluating in a more spatially conductive medium such as virtual or augmented reality.

Chapter 8: Conclusions

The study demonstrated a method for evaluating the consistency between consumer preferences of eyeglasses across representation styles. This study set out to identify potential decision-making strategies and presents a possible shortcoming of conceptual representation styles in their ability to convey functional details of eyeglasses as evaluation tactics shifted between representations. Future work should consider testing fewer frames on a higher number of participants, or an experimental design that could decrease the potential of familiarity biases. Another recommendation for future work is to include questions for participants about perceived functionality, to assess how that affects their decision making.

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Appendix A – Pre-Screening Survey

Block 2

Please provide your name, phone number (optional), and email.

Default Question Block

Do you wear glasses or own glasses and wear contacts?

- Yes
- No

Do you wear bifocals, trifocals, layered lenses, or regression lenses?

- Yes
- No

Can you read a computer screen and the Web without difficulty with your contacts and/or eyeglasses on?

- Yes
- No

Do you have cataracts?

- Yes
- No

Do you have any eye implants?

- Yes
- No

Do you have Glaucoma?

- Yes
- No

Do you use a screen reader, screen magnifier or other assistive technology to use the computer and the Web?

- Yes
- No

Are either of your pupils permanently dilated?

- Yes
- No

Block 1

How long have you worn glasses?

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
# of Years																					

How often do you wear glasses?

- Every Day All Day
- Sometime Every Day
- Every Few Days

- Once or Twice a Week
- Rarely or Only When Needed

How often do you purchase glasses?

	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
Every _# of Years																					

How recently have you purchased a new set of glasses?

	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
Within the Last _# of Months																

Have you purchased glasses online in the past?

- Yes
- No

If yes, how would you rate your satisfaction with the online-purchased eyeglasses?

- Very Satisfied
- Satisfied
- Somewhat Satisfied
- Somewhat Unsatisfied
- Unsatisfied
- Very Unsatisfied

What is your college degree in?

If you know it, please provide your glasses prescription.

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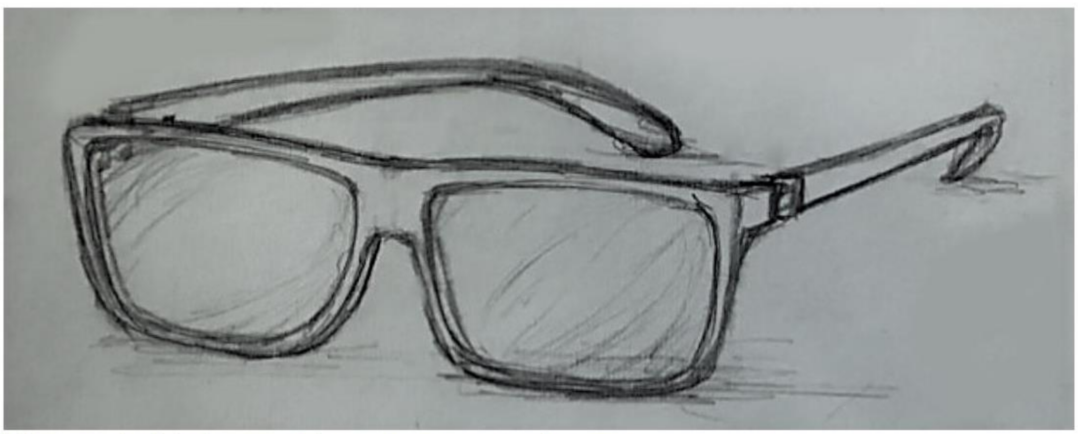
Appendix B – Preference Survey

Intro

Enter Participant ID:

Block 1



Please rate this frameset based on your preference.

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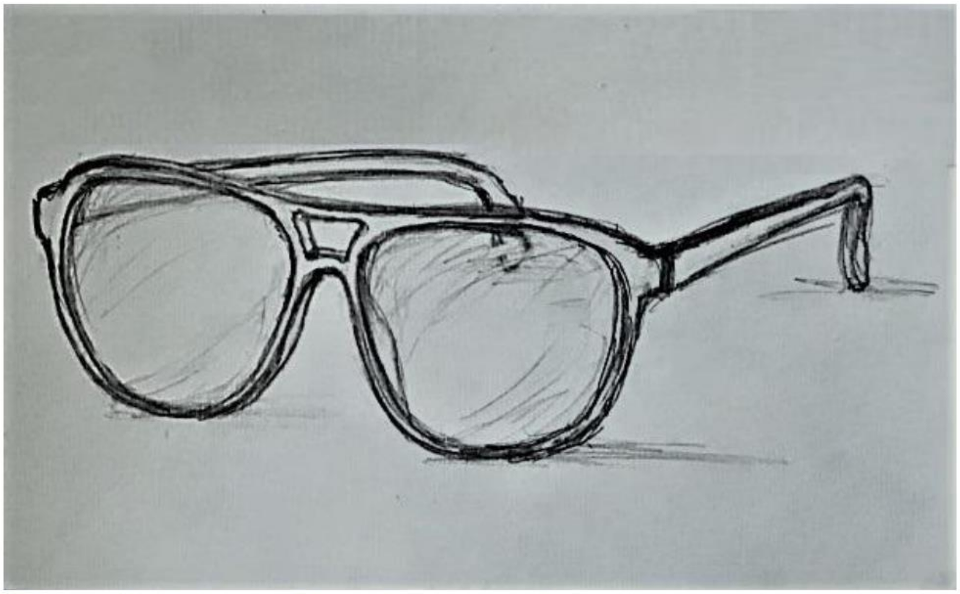

Please rate this frameset based on your preference.

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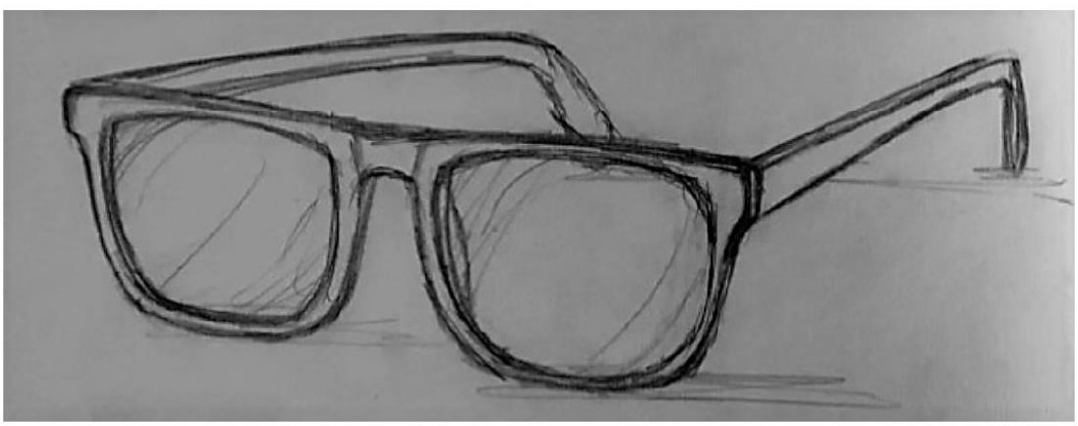

Please rate this frameset based on your preference.

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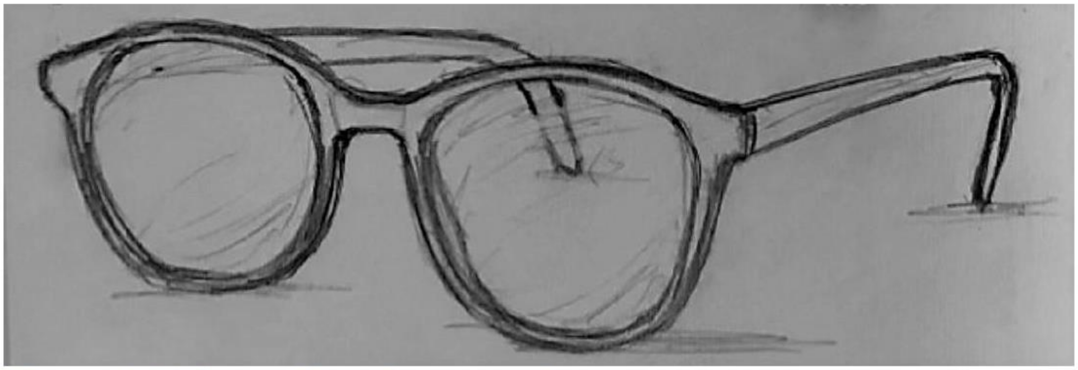

Please rate this frameset based on your preference.

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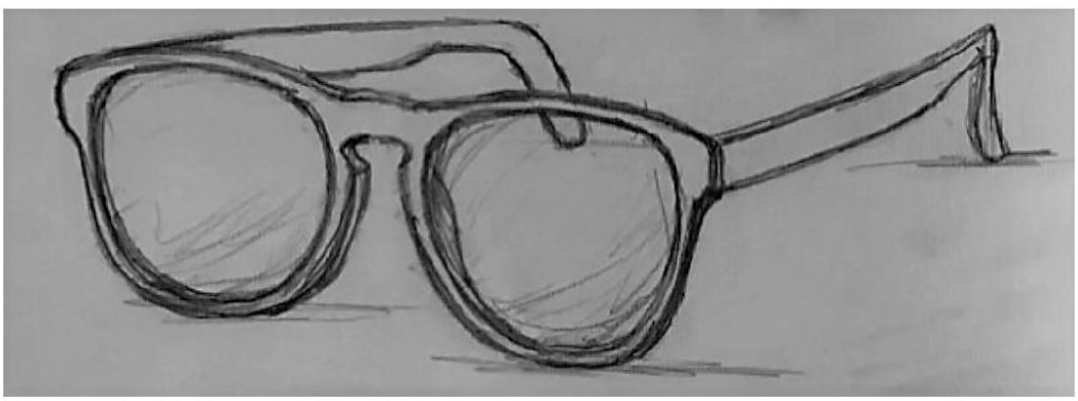

Please rate this frameset based on your preference.

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0-10 (10 being										

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0-10 (10 being highest)										

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0-10 (10 being highest)										

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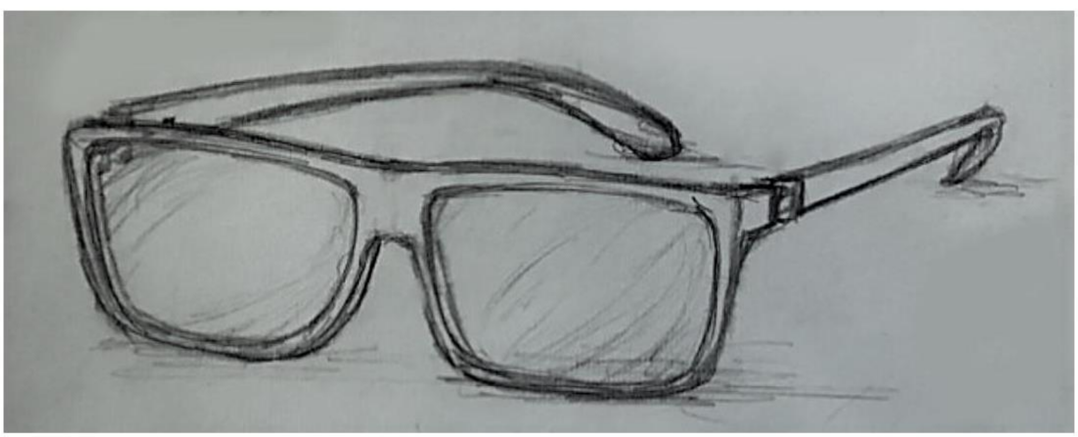
Block 2



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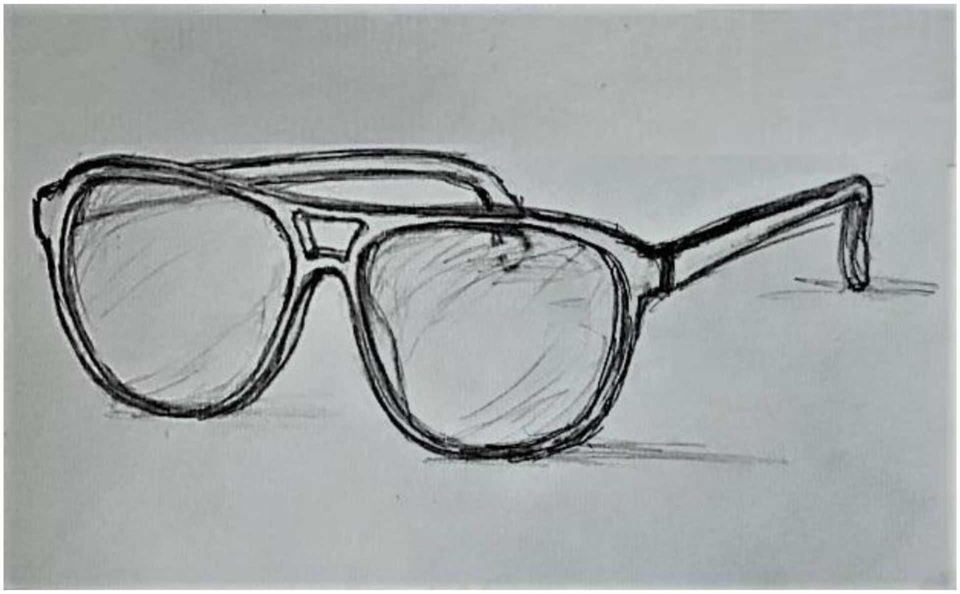

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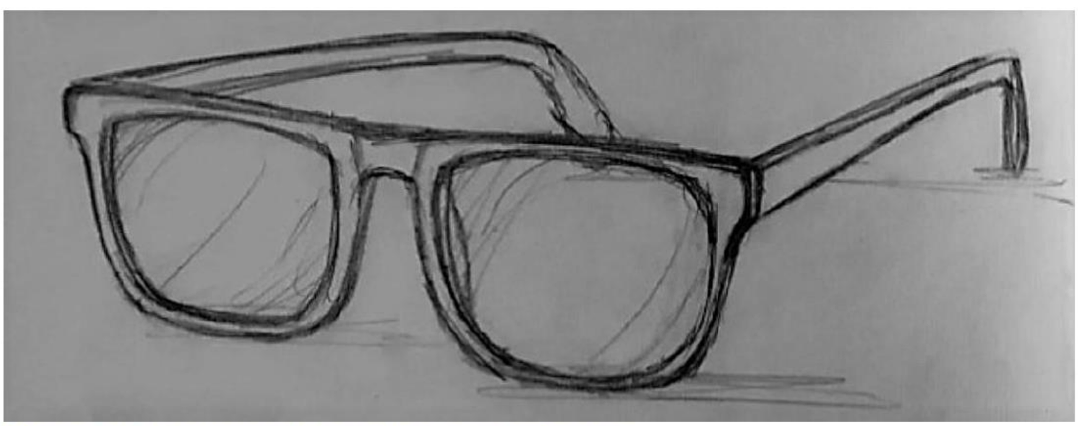

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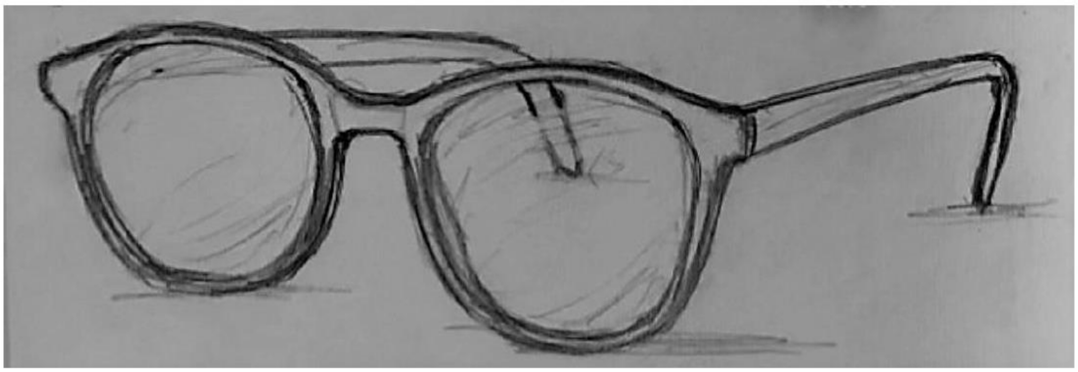

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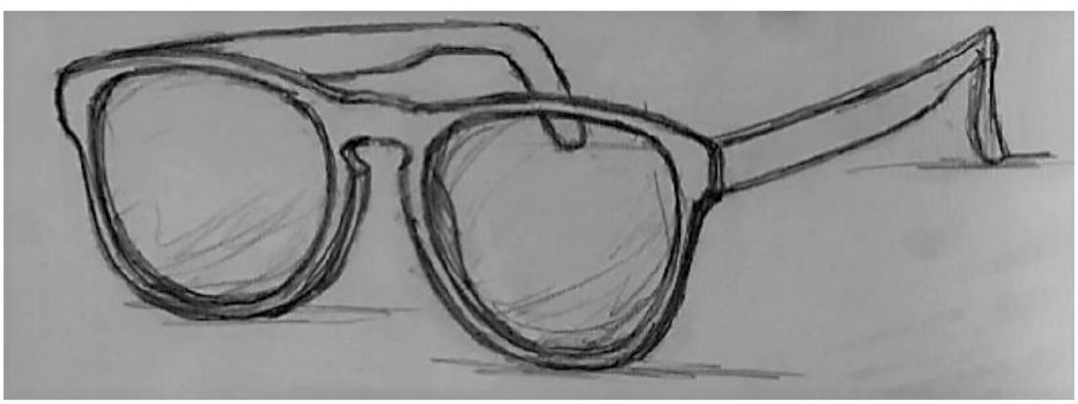

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0-10 (10 being										

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0-10 (10 being highest)										

Please rate this frameset based on your preference.

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0-10 (10 being highest)										

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Appendix C - IRB Approval

RX: Your study has been approved

umcirb@ecu.edu <umcirb@ecu.edu>
Mon 08/15/2022 09:12 AM
To: Echerd, Jon <echerdj18@students.ecu.edu>

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
4N-64 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Initial Approval: Expedited

From: Social/Behavioral IRB
To: Jonathan Echerd
CC: Brian Sylcott
Date: 8/15/2022
Re: UMCIRB 22-001008
Identifying a Relationship Between Design Concept Representation Style and Consumer Product Preference

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) occurred on 8/14/2022. The research study is eligible for review under expedited category # 4,6,7. The Chairperson (or designee) deemed this study no more than minimal risk.

As the Principal Investigator you are explicitly responsible for the conduct of all aspects of this study and must adhere to all reporting requirements for the study. Your responsibilities include but are not limited to:

1. Ensuring changes to the approved research (including the UMCIRB approved consent document) are initiated only after UMCIRB review and approval except when necessary to eliminate an apparent immediate hazard to the participant. All changes (e.g. a change in procedure, number of participants, personnel, study locations, new recruitment materials, study instruments, etc.) must be prospectively reviewed and approved by the UMCIRB before they are implemented;

2. Where informed consent has not been waived by the UMCIRB, ensuring that only valid versions of the UMCIRB approved, date-stamped informed consent document(s) are used for obtaining informed consent (consent documents with the IRB approval date stamp are found under the Documents tab in the ePIRATE study workspace);

3. Promptly reporting to the UMCIRB all unanticipated problems involving risks to participants and others;

4. Submission of a final report application to the UMICRB prior to the expected end date provided in the IRB application in order to document human research activity has ended and to provide a timepoint in which to base document retention; and

5. Submission of an amendment to extend the expected end date if the study is not expected to be completed by that date. The amendment should be submitted 30 days prior to the UMCIRB approved expected end date or as soon as the Investigator is aware that the study will not be completed by that date.

The approval includes the following items:

Name	Description
Data Layout.xlsx	Data Collection Sheet
Email Recruitment - All v2.docx	Recruitment Documents/Scripts
Email Recruitment - Employees.docx	Recruitment Documents/Scripts
Email Recruitment - Students.docx	Recruitment Documents/Scripts
Informed-Consent-Document-Template-No-More-Than-Minimal-Risk Echerd 8 5 22.doc	Consent Forms
Pre-Screening Survey.pdf	Surveys and Questionnaires
Sample Data Collection Survey.pdf	Surveys and Questionnaires
Thesis Proposal Echerd, Jonathan.docx	Study Protocol or Grant Application

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

—

Study.PI Name:
Study.Co-Investigators:

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
4N-64 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Amendment Approval

From: Social/Behavioral IRB
To: Jonathan Echerd
CC: Brian Sylcott
Date: 1/12/2023
Re: Ame1_UMCIRB 22-001008
UMCIRB 22-001008
Identifying a Relationship Between Design Concept Representation Style and Consumer Product Preference

Your Amendment has been reviewed and approved using expedited review on 1/12/2023. It was the determination of the UMCIRB Chairperson (or designee) that this revision does not impact the overall risk/benefit ratio of the study and is appropriate for the population and procedures proposed.

Please note that any further changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a Final Report application to the UMCIRB prior to the Expected End Date provided in the IRB application. If the study is not completed by this date, an Amendment will need to be submitted to extend the Expected End Date. The investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Document	Description
Extending the study end date to 5/1/2023.	

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

Appendix D – Pernice-Nielsen Criteria for Conducting Eye-tracking Studies

Eye Information: I am now going to ask you some different questions. These are about your eye because we are going to use some simple technology to track eye and mouse movements during the study.

1. Do you wear contacts or eyeglasses in order to read the computer screen?

[ ] Yes CONTINUE

[ ] No Skip to 3

2. Are your glasses for:

[ ] Reading only CONTINUE

[ ] Seeing distant objects only CONTINUE

[ ] Both (Do you wear bifocals, trifocals, layered lenses, or regression lenses) TERMINATE

3. Can you read a computer screen and the Web without difficulty with your contacts and/or eyeglasses on?

[ ] Yes CONTINUE

[ ] No TERMINATE

4. Do you have cataracts?

[ ] Yes TERMINATE

[ ] No CONTINUE

5. Do you have any eye implants?

[ ] Yes TERMINATE

[ ] No CONTINUE

6. Do you have Glaucoma?

[ ] Yes TERMINATE

[ ] No CONTINUE

7. Do you use a screen reader, screen magnifier or other assistive technology to use the computer and the Web?

[ ] Yes TERMINATE

[ ] No CONTINUE

8. Are either of your pupils permanently dilated?

[ ] Yes TERMINATE

[ ] No CONTINUE

Appendix E – Informed Consent Form

Study ID:UMCIRB 22-001008 Date Approved: 8/14/2022 Does Not Expire.

Informed Consent to Participate in Research
Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Identifying a Relationship between Design Concept Representation Style and Consumer Product Preference

Principal Investigator: Jonathan Echerd
Address: 324A Austin Building, ECU
E 5th St, Greenville, NC 27858
Telephone #: 828-502-9358

Researchers at East Carolina University (ECU) study issues related to society, health problems, environmental problems, behavior problems and the human condition. To do this, we need the help of volunteers who are willing to take part in research.

Why am I being invited to take part in this research?
The purpose of this research is to identify correlations between product representations and consumer choices. You are being invited to take part in this research because you are eligible and have indicated that you own eyeglasses. The decision to take part in this research is yours to make. By doing this research, I hope to learn how product representation modes of varying levels of detail communicate ideas.

If you volunteer to take part in this research, you will be one of about 40 people to do so.

Are there reasons I should not take part in this research?
You should not take part in this study if you are under 18 years of age, do not own eyeglasses, or if you have eye implants, glaucoma, cataracts, or bifocals/trifocals.

What other choices do I have if I do not take part in this research?
You can choose not to participate.

Where is the research going to take place and how long will it last?
The research will be conducted at in Austin building on ECU's main campus. You will need to come Austin 324A one time during the study. The total amount of time you will be asked to volunteer for this study is about one hour over the next two months.

What will I be asked to do?
You will be asked to do the following:

Complete two surveys (one web based and one physical item survey) regarding your preferences of several sets of eyeglasses.
Wear eye-tracking glasses that video the surveys as you are taking them and record the focus points of your eyes. (This recording will not record you and will not be identifiable in any way.)

What might I experience if I take part in the research?
We don't know of any risks (the chance of harm) associated with this research. Any risks that may occur with this research are no more than what you would experience in everyday life. We don't know if you will benefit from taking

Date: ___*8/5/2022*___________

part in this study. There may not be any personal benefit to you, but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?
We will not be able to pay you for the time you volunteer while being in this study.

Will it cost me to take part in this research?
It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?
ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- The University & Medical Center Institutional Review Board (UMCIRB) and its staff have responsibility for overseeing your welfare during this research and may need to see research records that identify you.

How will you keep the information you collect about me secure? How long will you keep it?

Physical data will be kept in a locked filing cabinet, and electronic data will be stored in a secure departmental network drive.

What if I decide I don't want to continue in this research?
You can stop at any time after it has already started. There will be no consequences if you stop and you will not be criticized. You will not lose any benefits that you normally receive.

Who should I contact if I have questions?
The people conducting this study will be able to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 828-502-9358 Monday-Friday, 8:00-5:00.

If you have questions about your rights as someone taking part in research, you may call the University & Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director for Human Research Protections, at 252-744-2914.

Is there anything else I should know?
Your information collected as part of the research, even if identifiers are removed, will not be used or distributed for future studies.

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) **Signature** **Date**

Appendix F – Subject Recruitment Letter

Hello current ECU students,

My name is Jonathan Echerd, and I am a current master's candidate in the Department of Engineering here at East Carolina University.

I am currently recruiting for participation in a research study looking into the consistency in preferences across different representation styles. By conducting this research, I hope to learn what differences exist in the way different modes of presentation convey information.

You are eligible to participate in this study if you meet the following criteria:

1. Participants must be at least 18 years of age
2. Participants must have corrected-to-normal vision. (Wear Glasses or Own Glasses and Wear Contacts)

This study will take place in Austin Building 324A, on the main campus of East Carolina.

Participants will be asked to take part in two surveys consisting of several eyeglass frames, each of which contain varying representation styles of the different framesets. Participants will be asked to wear eye-tracking glasses throughout the surveys. The surveying should take around 20 minutes.

If you are interested in this study please contact, Jonathan Echerd at echerdj18@students.ecu.edu and/or fill out the survey below:

https://ecu.az1.qualtrics.com/jfe/form/SV_0lbmqXdsM8iy6Nw