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Determination of Salient Design Elements Through Eye Movements, Aesthetics, and Usability

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Determination of salient design elements through eye movements, aesthetics, and usability

By

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The goal of study 1 was to use a remote eye tracker to understand how eye movements change with 7 geometrically varied remote controls to determine design element saliency. 20 participants were used to measure the following eye metrics: number of fixations prior to first fixation of any AOI, time to first fixation of an AOI, number of fixations on an AOI, dwell time of the first fixation on an AOI, total dwell time of an AOI, and the percentage of time spent on an AOI. The results of the study showed that all participants spent between 75-85% of their time fixated on the button layout which was not defined as an AOI. No statistical differences were found in the values measured for all eye tracking metrics across similarly defined AOIs. In study 2, the objective was to determine attitudes towards appearance and usability of the 7 remote control designs using the participants from study 1. Participants were asked to rate their attitudes and preferences, using a Likert-based questionnaire, about the qualities of appearance and usability for the attributes of proportion, shape, and configuration. They were asked open-ended questions about their likes and dislikes regarding the qualities of appearance and usability. Lastly, participants were given a pairwise comparison survey

where they chose their preferred remote design, based on appearance, for 10 paired sets of contrasting remote designs. The hourglass subjacent and hourglass round designs were rated highest for appearance and usability from the Likert questionnaire. The hourglass round design was ranked highest for the pairwise comparison survey. For study 3, the goal was to determine attitudes towards appearance and usability of the 7 remote designs with online participants. 300 participants were asked to rate their attitudes and preferences using the same Likert-based questionnaire from study 2. They were asked the same open-ended questions and administered the same pairwise comparison survey as in study 2. The results of the Likert questionnaire showed that the hourglass subjacent and hourglass round designs were rated highest for appearance and usability. From the pairwise comparison survey, the hourglass round design was ranked the highest.

DEDICATION

This dissertation is dedicated to Melanie – my loving wife, companion, best friend, and most loyal supporter – who stood beside me throughout this entire journey and allowed me to pursue my dream. I could not have dreamed all of this without you. To my beautiful kids, Beia and Calix. You are the reasons why Daddy works so hard. Daddy loves you so much.

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CHAPTER I

RESEARCH OVERVIEW

1.1 Introduction

When we look at that which is beautiful, the object gives rise to a certain kind of pleasure within us (Kieran, 1997). Kieran (1997) mentions that philosophers have defined aesthetic value in terms of our delighting in and savoring an object with pleasure. An object is of intrinsic aesthetic value if it gives rise to pleasure in our contemplation of it (Kieran, 1997). Aesthetics is widely considered as a primary highly effective factor in the success of product design (Kieran, 1997; Page & Herr, 2002; Postrel, 2001). According to Postrel (2001), there is ample anecdotal evidence that people do put a higher premium on the look of things than they once did. Until the first quarter of the 20^{th} century, the design of commodities and mass production artifacts were devoid of aesthetic considerations (Tractinsky, Katz, & Ikar, 2000).

The concept of aesthetic value has long been contemplated. From Kieran (1997), beauty has traditionally been considered the paradigmatic aesthetic quality. Kieran (1997) states that "we are tempted to generalize from our analysis of the nature and value of beauty, a particular aesthetic value" (p. 383). He states that "aesthetic value is characterized in terms of that which affords us pleasure" (Kieran, 1997, p. 383). The core thought about aesthetic value "is that what we take delight in is itself delightful, in terms of unity, harmony, coherent structure and complex development" (Kieran, 1997, p. 384).

Birkhoff (1933) mentions that there are many visual perceptions that "are accompanied by a certain intuitive feeling of value, which is clearly separable from sensuous, emotional, moral, or intellectual feeling" (p. 3). The branch of knowledge concerned primarily with this aesthetic feeling and the aesthetic objects which produce it is called aesthetics (Birkhoff, 1933). For aesthetics, it is of primary importance that objects belonging to a definite class can provide a direct intuitive comparison with respect to aesthetic value (Birkhoff, 1933).

An understanding of how to create beautiful objects that elicit aesthetic responses is fundamental to the profession of design (Hung & Chen, 2012). Hung & Chen (2012) mention that all design disciplines, including product design, combine a knowledge of aesthetics with knowledge of the different embodying technologies of that discipline. The most fundamental characteristic of a product is its exterior form (Bloch, 1995). Crilly, Moultrie, & Clarkson (2004) mention that "judgements are often made on the elegance, functionality, and social significance of products based largely on visual information" (p. 547).

There is much literature that refers to the exterior properties of a product such as aesthetics, appearance, attractiveness, and user experience and how users respond to these properties (Chang, Lai, & Chang, 2007).

The word 'aesthetics' comes from the Greek word aesthesis which refers to the sensory perception and understanding of sensuous knowledge (Hekkert, 2006). In this research paper, the term aesthetics is used to reference the visual appearance of a consumer device as it relates to geometric form. Many product manufacturers today have adopted a consumer-oriented design and development approach to enhance consumer satisfaction (Chang, Lai, & Chang, 2004). In the design procedure, product designers investigate and define consumer's preferences and establish those as design objectives (Moulson & Sproles, 2000). It is difficult for a product designer to exactly translate design intentions from consumers into a product to be sold to consumers; consumer knowledge and communication barriers are some of the difficulties in this process. Developers commonly experience difficulties in understanding the preferred product form from a consumer's standpoint because most consumers lack the necessary skill to describe their desire for [product] form clearly and comprehensively (Chang, Lai, & Chang, 2004).

Attempts have been made to create design tools for improving aesthetic qualities more objectively. Pham (1999) proposed a systematic approach for looking at the relationships between aesthetic properties and design variables by integrating knowledge from other disciplines such as philosophy, psychology, and arts. Chuang, Chang, & Hsu (2001) studied the relationship between user perception of mobile phones and their form design elements. Cawthon & Moere (2007) investigated the results of an online survey of 285 participants where they measured perceived aesthetic and the efficiency and effectiveness of retrieval tasks from a set of 11 different visualization techniques. Hsiao, Chiu, & Chen (2008) analyzed the relationships between product image, color area, and aesthetic measurement of a product. Zain, Tey, & Soon (2008) created the Aesthetic Measurement Application (AMA) to measure the aesthetic aspect of web page interfaces.

Yadav, Jain, Shukla, Avikal, & Mishra (2013) adopt a fuzzy Kano model for the calculation of the relative importance of different aesthetic attributes.

Aesthetic value is hard to measure because it is a qualitative measure (Postrel, 2001). According to Alben (1996), one of the criteria that defines a successful interaction design, that leads to quality experiences, involves the aesthetic experience. The consumer industry lacks a design approach towards consumer products that is quantitative, methodical, repeatable, and reliable.

In general, there are many aspects about usability that need to be considered for a product to be good. Gould (1997) introduces various aspects about usability which are often mutually dependent. The field of human-computer interaction (HCI) stresses the prominence of usability over aesthetics (Tractinsky, Katz, & Ikar, 2000). From (Tractinsky, Katz, & Ikar, 2000), "The concepts of aesthetics and usability represent two orthogonal dimensions of HCI" (p. 128). Usability is measured by relatively objective means with efficiency as its foremost criterion (Butler, 1996). From (Alben, 1996), another criterion that defines a successful interaction design that leads to quality experiences involves usability. Alben (1996) explains that usability is "How well does the product support and allow for different ways people will approach and use it, considering their various levels of experience, skills, and strategies for problem-solving" (p. 3). Usability engineering has emphasized objective performance criteria including time to learn, error rate, and time to complete a task (Butler, 1996).

The influence of aesthetics on usability has been well documented with experiments confirming that perceived usability was positively influenced by a product's aesthetics (Sonderegger & Sauer, 2010). Crilly, Moultrie, & Clarkson (2009) state that

"The visual appearance of products has a profound effect upon the way in which they are interpreted, approached, and used" (p. 1).

1.2 Research Aims

The consumer product market is fast-paced and highly competitive. With many companies competing in certain product categories (mobile phones, laptops, tablets, headsets, televisions, etc.), gaining a competitive edge over competition can be a lucrative opportunity. Many products are released to market, while select few receive positive consumer reception. Products that gain the attention of consumers also gain the market share. The aims of this research are to understand how eye movement changes with respect to design changes of geometric form to 7 different remote control designs, understand participants' responses about aesthetics and subjective usability with design changes to geometric form of the 7 remote control designs, and analyze responses about aesthetics and subjective usability to the 7 remote designs from online participants. The learnings from this research will contribute to the study of Human Computer Interaction (HCI). Customers make judgements about products based on the initial interaction with a device; this initial interaction is often a visual one. In this initial interaction, the visual appearance of a remote can communicate its usability. The results will also contribute to the study of ergonomics where the interaction of consumer products would be improved from a usability standpoint. From this study, product designers will have a better understanding of a consumer's aesthetic preferences concerning geometric form of a remote control. Product designers that can synthesize the findings of this research and incorporate these preferences into their products will more likely design a successful product in a competitive and flooded market place. Companies that fail to design products that attract the consumer's attention will likely succumb to those products with greater aesthetic appeal.

1.2.1 Study 1: Observing Changes in Eye Movements to Design Changes of Geometric Form

Few studies exist that attempt to quantify aesthetics as it applies to product design. Even fewer studies attempt to discern the design elements of a specified product to identify which elements have a desirable affect to eye movement. Khalighy et. al (2015) has shown that eye movement changes when study participants are asked to select between a series of geometrical images. The study by Khalighy et. al (2015) calculated factors such as beauty, appropriateness, and novelty; the resultant calculations are then correlated to user-stated preferences of a chair to show that there is a relationship between eye movement and user-stated preferences. The proposed study attempts to further understand how eye movement changes when different images of a remote control are shown to participants. 7 differently designed remote controls will randomly be shown in alternation. Before measuring eye movements for each remote control design, participants will be presented with clear instructions about a specific task scenario that will describe the actions they are to perform. While each image is shown, the following eye measures will be recorded: number of fixations prior to first fixation of any area of interest (AOI), time to first fixation of an AOI, number of fixations of an AOI, dwell time of the first fixation of an AOI, total dwell time on an AOI, and percentage of time spent on an AOI. It is expected that there will be a distinct set of eye movements when a participant is shown an image that is aesthetically appealing compared to those images that are not as appealing. The objective of this study will be to identify those design elements that correspond to an aesthetically appealing remote control. Once design elements have been identified to have high aesthetic value, the results can be applied to products in a similar design category with the intent of receiving similar reception of being an aesthetically appealing product.

1.2.2 Study 2: Understanding Participants' Attitudes Towards Aesthetics and Subjective Usability for Geometrically Varied Remote Control Designs Using Visual Questionnaires

The need to consider aesthetics when designing products has become more important with recent studies showing strong correlation between product aesthetics and subjective usability. The responses of consumers vary widely when asked to rate the usability of a product with high aesthetic appeal versus one that is unappealing. A study performed by Sonderegger & Sauer (2010) using two different versions of a phone, one with high visual appeal versus one with less visual appeal, showed that participants with the higher visually appealing phone rated their experience as being more usable than the participants with the unappealing phone. The same study showed that the visually appealing phone led to a positive effect on the performance leading to reduced task completion times; an impact on user performance. A Likert-based visual questionnaire will be used to elicit participants' preferences and attitudes towards aesthetics and subjective usability for each remote control design. While being shown a specific remote control design, participants will be asked to rate their responses, on a 5-point scale, to items concerning the qualities of appearance and subjective usability of geometrically varied remote designs to understand their attitudes. Open-ended responses will be solicited about participants' likes and dislikes regarding appearance and subjective usability for each remote design. A pairwise comparison survey will be administered to understand participants' preferences towards a remote control design, when compared against another remote control. Preferred design elements will be identified from the results of the pairwise comparison survey.

1.2.3 Study 3: Administering Visual Questionnaires of Aesthetics and Subjective Usability to Online Participants

The questionnaires mentioned in Section 1.2.2 will be administered to an online audience. Online participants will be solicited to provide their preferences and attitudes towards aesthetics and subjective usability using the remote control designs mentioned in Section 1.2.1. There will be a wide ranging set of participants to provide a broad understanding of the comparisons made between aesthetics and subjective usability.

CHAPTER II

OBSERVING CHANGES IN EYE MOVEMENTS TO DESIGN CHANGES OF GEOMETRIC FORM

2.1 Introduction

Aesthetic value is characterized in terms of that which affords us pleasure (Kieran, 1997). Customers usually obtain their first impression of a product from visual stimuli, including geometric form (Hsiao & Chen, 1997). Of primary significance for aesthetics is the fact that objects belonging to a definite class can provide a direct intuitive comparison with respect to aesthetic value (Birkhoff, 1933). It is the fundamental problem of aesthetics to determine, within each class of aesthetic objects, those specific attributes upon which the aesthetic value depends (Birkhoff, 1933). Appearance plays an important role in the evaluation process of a product (Sauer & Sonderegger, 2011). Sauer & Sonderegger (2011) mention there are a number of concepts that refer to the exterior properties of a product and how users respond to properties such as aesthetics, appearance, attractiveness, and user experience. Perceived impression is a key factor in the design of a physical product (Hekkert, 2006). Hekkert (2006) states that the term aesthetics is used to reference the visual appearance of a consumer device as it relates to its geometric form. Consumer satisfaction with geometric form plays an essential role in determining the success of a product. Many product manufacturers have adopted a consumer-oriented design and development approach to enhance consumer satisfaction (Chang, Lai, & Chang, 2006). During the product form design procedure, product developers investigate and define consumers' preferences and establish these preferences as objectives of the latest design stages (Moulson & Sproles, 2000). However, developers commonly experience difficulties in truly understanding the preferred product geometric form since most consumers lack the necessary skill to describe their desire for form clearly and comprehensively (Chang, Lai, & Chang, 2006). There could be arguments made against the usefulness of quantifying aesthetics. Asking a user to state their attitude towards aesthetics is subjective in nature. It is not clear what can be done, to aesthetics directly, to maximize aesthetic appeal. Therefore, it is important to know what design factors influence the test outcomes and to what nature they are influenced.

Customers make judgements about products based on initial impression. A challenge with designing consumer products is not knowing how a consumer will respond to product aesthetics upon initial impression. There are no good methods to gauge how customers will respond to product aesthetics prior to release in the market. In consumer electronics, aesthetic appeal could determine if a device is widely accepted. Depending on which category of consumer device is being considered (laptops, mobile phones, tablets, e-readers, mp3 players), aesthetic appeal is a major attribute of differentiating one device from another in the same category. Many companies invest heavily in Industrial Design to give itself a competitive edge often hiring top talent within the industry, monetary spending on appearance models to showcase how maximum aesthetic appeal can be realized and dictating subject matter that Research and Design groups should focus their efforts towards. Companies like Apple emphasize beauty and aesthetic appeal when designing their products to an extent where their Industrial Design group is on top of the hierarchy of groups above Design, Quality Assurance, Manufacturing, Marketing, and Operations.

Some companies withhold sharing the designs of their products to the public, prior to release in the market, to avoid competitor infringement and to prevent losing their competitive edge. With company reputations on the line and many vying to earn business, companies need a way to predict how customers will respond to their product's visual qualities. Many resources and investments are expended when bringing a product to market such as those associated with designing, analysis, testing, manufacturing, and marketing; the stakes are high for a product to be well-received.

Industrial Design teams use colorful adjectives in communicating and describing designs in general discussions. The adjectives used are typically subjective in nature with no quantifiable basis. Adjectives such as warm, light, soft, harsh, pop, and flow are used in describing design content. These same adjectives are used to convey design intent to hardware teams; these teams transform design intent into an actual working design that can be realized. It is common in the communicative exchange between Industrial Design and Hardware teams for design intent to be misinterpreted due to the of subjective language in discourse. Providing a method for quantifying aesthetics could prevent design intent from being lost in translation and could maximize aesthetic appeal and subjective usability within consumer devices since design intent would be objectively communicated without ambiguity.

2.2 Background

“If you want to [typically] know what people are paying attention to, follow what they are looking at” (Davenport & Beck, 2001, p. 19). Where you place your gaze is typically associated with what you pay attention to and think about (Hoffman, 1998). Researchers have found that vision is the most important sense in the product-buying experience (Fenko, Schifferstein, & Hekkert, 2010). Vision is the main channel for users to gather information about a product (Guo, Ding, Liu, Liu, & Zhang, 2016). Vision is the first channel to obtain information about a product and impact the user’s future behavior and intention to experience the product (Moshagen & Thielsch, 2010). A user’s perceptions and responses to a product are mainly affected by the product’s aesthetics (Ho & Lu, 2014). “Previous studies have shown that people generally tend to consider vision as more important for a product experience than other sensory modalities” (Fenko, Schifferstein, & Hekkert, 2010, p. 1326). User experience has received special attention as a quality of product design; this experience is recognized to contain affective aspects of user experience such as pleasure an aesthetic experience (Law & van Schaik, 2010).

Proposed methods for improving aesthetic qualities more objectively are not efficient, useful, and feasibly applicable in the design process because the divert nature of aesthetics consists of emotional and rational aspects (Bloch, 1995). Evaluation of aesthetics combines areas such as art, engineering, and psychology which are all inherently different (Khalighy S. , Green, Scheepers, & Whittet, 2014).

In order to develop a method for quantifying aesthetics, it is necessary to clearly define factors of aesthetics (Khalighy, Green, & Whittet, Product aesthetics and creativity, 2012). Coates (2002) has characterized four factors for product aesthetics:

design principles, consumer features, contrast, and novelty. To define factors of aesthetics, it is important to start with fundamentals (Khalighy S. , Green, Scheepers, & Whittey, 2015). The appearance of product plays an important role in attracting users' attention (Guo, Ding, Liu, Liu, & Zhang, 2016). Salient stimuli can attract attention, even though the subject had no intentions to attend to these stimuli (Schreij, Owens, & Theeuwes, 2008; Theeuwes, 1991; Theeuwes, 1992)

More research on the mechanism of vision perception can provide insight for product designers which can lean more consumers to purchase the intended product (Guo, Ding, Liu, Liu, & Zhang, 2016). When users are exposed to a product, they cannot gather all information but only a fast and holistic impression (Lindgaard, Fernandes, Dudek, & Brown, 2006). Given a large amount of visual information with limited perceptual capacity, users will extract information they care about and pay their visual attention to selective product features (Clement, Kristensen, & Grønhaug, 2013). There is a difference in eye movements when users look at a variety of products with different features (Nagai & Georgiev, 2011).

2.3 Research Objective

The objective of this study is to understand how eye movements change when geometrically varied remote controls, comprised of unique design elements, are shown to participants. It is expected that images of differently designed remote controls will elicit different eye movements when judging aesthetics. When a participant is looking at a remote control design that is aesthetically appealing, a unique set of appealing design elements can be determined based on results from their eye movements. When asked to evaluate each remote control in alternation and focus attention on those design features that make each remote control design visually appealing, the participant's eye movements towards those unique design elements of each remote will vary significantly. When all eye movement metrics have been recorded for each remote control for all participants, each design can be analyzed individually to determine those design elements that are salient. When analyzing all results together, relative comparisons can be made for each design to determine which design elements are most salient.

When participants are asked to compare a set of designs based on aesthetic value, those designs that have been selected with higher aesthetic value will have noticeable differences in eye metric values than those designs with lower aesthetic value.

When saliency towards an aesthetically pleasing design and its design elements has been established, an aesthetic design preference can be determined. The established aesthetic design preference can be used for future design purposes. It is believed that when an aesthetic preference of a broad group has been determined, the remote control design linked to that aesthetic preference should be highly considered for implementation into a realistic product because there would be a high likelihood that it will be well-received and accepted by consumers in comparison to a design that did not receive similar scrutiny.

Measuring a participant's eye movements for specific design elements within each remote control design and comparing these movements to other remote control designs with unique design elements, helps to understand what elements are attracting the user's attention and what is salient. Eye movement is the dominant mechanism when gathering information about a product and evaluating its aesthetics. Once design elements have been determined to add high aesthetic value, the results can be applied to products in a similar design category with the intent of receiving similar reception of being an aesthetically appealing product.

There is minimal literature and research on methods for quantitatively measuring a product's aesthetic value relating to geometric form. Much of the recently designed consumer products are based on subjective approaches where the final outcome can be determined by the designer's perceptions (You, Ryu, Oh, Yun, & Kim, 2006).

2.4 Methods

2.4.1 Participants

The study included 13 male and 7 female participants who were all employed at Spanner Product Development. Participants were at least 18 years of age, with the age range between 21 and 60 years. All participants had adequate literacy and fluency in English. Since an eye tracker was used, exclusion criteria included anyone with a pre-existing eye disorder that could affect the quality of data being collected; all participants had normal or corrected-to-normal vision. 14 participants had design experience with consumer electronics; preferential selection for the study went to those participants with experience in designing consumer products. Every participant was a current user of a remote control design.

2.4.2 Experimental Design

2.4.2.1 Remote Control Design Investigation

To get a better understanding of the design field of remote controls, observations were made at local stores where consumers could purchase remote controls. There were many differently designed remote controls, with each type of remote addressing a specific functional use. A substantial amount of remote controls shared similar features including but not limited to numeric buttons, navigation buttons, volume buttons, channel buttons, menu buttons, and power button. Pictures were taken of all the different remote controls for sale at these stores, and the remotes were then categorized into 7 distinct categories based on geometric outline. Table 2.1 shows the different categories of remotes based on form: hourglass flat, hourglass round, hourglass subjacent, rectangular with rounded corners, rectangular stout, rectangular subjacent, and trapezoidal.

Table 2.1 Taxonomy of Remote Controls.

Hourglass Flat	Hourglass Round	Hourglass Subjacent	Rectangular with Rounded Corners	Rectangular Stout	Rectangular Subjacent	Trapezoidal
						

Originally, there were a total of 20 remote control designs to be used for the experiment. After reviewing with the research committee, it was decided to narrow the selection to 7 remote controls designs to limit the test-taking time for each participant and to prevent boredom.

2.4.2.2 Remote Control Design Conceptualization

7 different renderings were created to be used for the study. While utilizing the same button layout and design for each of the 7 renderings, the profile design elements

concerning geometrical form of the remote control varied including overall size of the remote, curvature, splines, and radii with varying magnitude and placement.

Design iterations involving color were excluded from this study to limit the amount of design variables affecting aesthetic value and subjective usability although it is known that color does impact aesthetic measurements (Hsiao, Chiu, & Chen, 2008). Viewing perspective was also excluded from this study since remote controls can be viewed from many different perspectives; only the front perspective button view was studied since this view contained the most design features that could be manipulated for the purposes of this study.

2.4.2.3 Eye Tracker

When participants were shown each remote control image, an eye tracker measured the following eye metrics: number of fixations prior to first fixation of any AOI, time to first fixation of an AOI, number of fixations on an AOI, dwell time of first fixation of an AOI, total dwell time of an AOI, and percentage of time spent on an AOI.

It has been documented that there are over a hundred different eye tracking measures ranging in complexity. Holmqvist et al. (2011) has identified four main types of eye tracking measures: movement measures, position measures, numerosity measures, and latency and distance measures. This research focused on the eye tracking measures most applicable to aesthetic value and perceived usability; metrics concerning attraction and performance are part of the User Experience (UX) field of study.

. There are two main types of UX questions that can be answered with eye tracking measures: attraction-related questions and performance related questions (Bojko, 2013). Table 2.2 lists three main groups of attraction measures: measures of area noticeability, measures of area interest, and measures of emotional arousal. Measures of area noticeability help determine how easy something is to notice; measures of area interest help assess how much interest something received once it was noticed; and measures of emotional arousal give an indication of the object's desirability (Bojko, 2013). Table 2.2 shows the eye-tracking measures that were used for this study.

Table 2.2 Three groups of attraction measures and their respective eye metrics.

Group of Attraction Measures	Eye Measures
Area Noticeability	Percentage of participants who fixated on an AOI
	Number of fixations prior to first fixation of an AOI
	Time to first fixation of an AOI
Area Interest	Number of fixations on an AOI
	Dwell time of first fixation of an AOI
	Total dwell time on an AOI
	Percentage of time spent on an AOI

2.4.3 Procedure

Before the experiment began, participants looked at a warm-up remote control image to familiarize themselves with the test; this test image was not used in the actual study. After the warm-up image, the 7 chosen remote control designs were shown to each participant in random alternation. Between each shown image, participants directed their gaze to a crosshair located at the middle of the screen for two main reasons: all eye measures should start from the same area on the screen to uniform the data of all participants for obtaining accurate results and calibration of the eye tracker is performed each time the participant's gaze fixates on the crosshair. This process was repeated until all 7 images were shown. Eye movements for each image was recorded for analysis. A remote control was used for this study for two main reasons: its geometric form can be varied in many ways with different design elements and a remote control is well-known among the general public making it easy to discern.

Since multiple design iterations were presented to participants, a within-subject design setup will be performed as opposed to a between subject design setup. Carry-over effects were avoided by randomly presenting each image to participants.

The tasks for the participants to complete during the study were administered using a moderated guide including clear instructions directed towards the participants. This approach ensured that instructions were presented to each participant clearly and consistently without negatively affecting data collection or introducing bias into the study results. The moderated instructions are shown in Figure.2.1.

Moderator: Before we begin the eye tracking study, I want to provide the setting for this experiment.

Imagine you are looking for a new remote control for your television at the electronics supply store. There are 7 different designs to choose from on the shelf. All remote controls can perform the same function (change channels, volume, power on/ off, setup, etc.) To narrow your selection of the 7 designs, you need to base your decision on appearance only. I want you to evaluate each remote control I show you and look at those design features that make its appearance most attractive.

Moderator: Go through warm-up session with participants to familiarize them with the test. When warm-up is complete, start actual test.

Figure 2.1 Prompt of moderated instructions for eye tracking study.

2.4.4 Tools

For eye tracking, the GP3 eye tracker from Gazepoint in Figure 2.2 was used for this study. Table 2.3 lists the GP3's product specifications.

Figure 2.2 Gazepoint GP3 eye tracker.

Table 2.3 GP3 Gazepoint eye tracker product specifications and system requirements.

	GP3
Sampling Rate	60 Hz
Accuracy	0.5 – 1 degree
Spatial Resolution (RMS)	0.1
Eye Tracking Mode	Binocular
Operating Distance	50cm – 80cm
Tracking Range (Head Box)	25cm x 11cm
Calibration	5 or 9 point
Tracking Recovery Time	< 50ms
System Latency	< 50ms (end to end from event to API output)
Data Connection	USB 2.0
Dimensions	320mm x 45mm x 40mm
Weight	145g
Eyewear Compatibility	Works with most glasses and contact lenses
Processor	Intel i5 (i7 recommended)
Memory	4GB (8GB recommended)
OS	Windows 7/8/10, 32/64 bit

In conjunction with the eye tracker, a laptop was used. For generating and rendering different designs of a remote control, Solidworks 2013 CAD software was used

2.4.5 Laboratory Setup

The study was conducted at Spanner Product Development in San Jose, CA. The office was about 15 feet in length and 15 feet in width. Lighting conditions of the office were considered to ensure avoidance of extreme light or dark conditions. Sound was kept at a minimum to avoid distraction of the participant's eye movements. The eye tracker was placed on a firm desk to minimize vibrations from peripheral motion.

2.5 Data Analysis

2.5.1 Qualitative Analysis

For qualitative analysis, heatmaps were generated from the Gazepoint Analysis software to analyze fixations of each participant for each remote control design.

Heatmaps were colored coded using the Absolute Gaze Duration option to further dramatize the colors for maximum visual effects. All heatmaps were collected and analyzed for trends across each remote control design using the aggregate tools available in the Gazepoint Analysis software.

2.5.2 Quantitative Analysis

For quantitative analysis, 4 AOIs throughout the periphery of each remote control design were defined as in Figure 2.3. The location and size of the AOIs were identical across all remotes to allow for consistency of comparing between designs. To compensate for the eye tracker's accuracy in visual angle, all AOIs were sized to be greater than 1 inch by 1 inch on the screen.

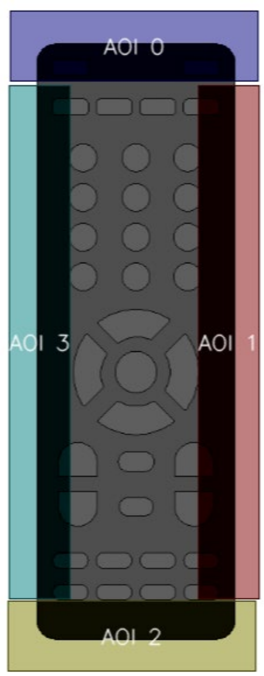


Figure 2.3 Example remote control design with AOIs defined around the perimeter.

Once the AOIs were defined for each remote design, measured values were extracted from the Gazepoint Analysis software and tabulated using the spreadsheet in Table 2.4. For analysis, the median and median ranks were calculated among all participants for each AOI for each remote control design. Median values for all eye tracking metrics were analyzed and compared amongst each participant to determine which AOI is most salient within each design.

Demographic data concerning gender, age, and design experience were analyzed in comparison to the eye movements for each AOI of each remote control design.

Table 2.4 Eye tracking measures for each remote control design.

	Number of fixations prior to first fixation of any AOI (#)		Time to first fixation of an AOI (sec)				Number of fixations on an AOI (#)				Dwell time of first fixation on an AOI (sec)				Total dwell time on an AOI (sec)				Percentage of time spent on an AOI (%)			
			AOI				AOI				AOI				AOI				AOI			
	#	AOI	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
P01																						
P02																						
P03																						
P04																						
P05																						

P19																						
Median		0																				
		1																				
		2																				
		3																				
Median Rank																						

2.6 Eye Tracking Results

Eye tracking results, AOI definition, and heatmaps are presented for each design iteration in the sections below. From the 20 participants that were originally tested, 1 participant's eye tracking results had to be rejected. After reviewing this participant's results, it was found that the visual replay showed the points of fixation were sporadic and did not follow a smooth motion through each part of the designs that was observed. From Gazepoint, there are about 3-5% of people where remote eye tracking does not work due to physiological incompatibility such as pupil shape or size. The number of rejected results falls within range of the stated percentage.

2.6.1 Comparison of In-Person Eye Metric Values for Similar AOIs

After performing Kruskal-Wallis' test for median values across all participants for the time to first fixation of any AOI of similarly located AOIs across remote designs, no statistical differences were found ($p > 0.05$). Table 2.5 shows the measured values for the time to first fixation of any AOI for similarly located AOIs.

Table 2.5 Comparison of median values for time to first fixation of an AOI of similarly located AOIs across different remote designs.

	Rectangular w/ Rounded Corners	Hourglass Flat	Rectangular Subjacent	Hourglass Subjacent	Hourglass Round	Trapezoidal	Rectangular Stout
TOP	**AOI 0**	**AOI 4**	**AOI 8**	**AOI 12**	**AOI 16**	**AOI 20**	**AOI 24**
	2.34	2.40	3.29	8.51	3.50	2.27	4.40
RIGHT	**AOI 1**	**AOI 5**	**AOI 9**	**AOI 13**	**AOI 17**	**AOI 21**	**AOI 25**
	6.32	3.54	7.78	5.56	6.45	3.69	4.90
BOTTOM	**AOI 2**	**AOI 6**	**AOI 10**	**AOI 14**	**AOI 18**	**AOI 22**	**AOI 26**
	9.68	8.16	8.04	15.52	14.41	5.46	10.11
LEFT	**AOI 3**	**AOI 7**	**AOI 11**	**AOI 15**	**AOI 19**	**AOI 23**	**AOI 27**
	5.90	5.83	9.17	9.84	10.90	4.88	6.82

When performing Kruskal-Wallis' test for median values across all participants for the number of fixations on an AOI of similarly located AOIs across remote designs, no statistical differences were found ($p > 0.05$). Table 2.6 shows the measured values for the number of fixations on an AOI of similarly located AOIs.

Table 2.6 Comparison of median values for the number of fixations on an AOI of similarly located AOIs across different remote designs.

	Rectangular w/ Rounded Corners	Hourglass Flat	Rectangular Subjacent	Hourglass Subjacent	Hourglass Round	Trapezoidal	Rectangular Stout
TOP	**AOI 0**	**AOI 4**	**AOI 8**	**AOI 12**	**AOI 16**	**AOI 20**	**AOI 24**
	13.00	9.00	10.00	7.00	7.00	9.00	10.00
RIGHT	**AOI 1**	**AOI 5**	**AOI 9**	**AOI 13**	**AOI 17**	**AOI 21**	**AOI 25**
	6.00	6.50	5.00	8.00	8.00	7.00	10.00
BOTTOM	**AOI 2**	**AOI 6**	**AOI 10**	**AOI 14**	**AOI 18**	**AOI 22**	**AOI 26**
	4.00	2.50	2.50	1.00	2.00	3.00	1.00
LEFT	**AOI 3**	**AOI 7**	**AOI 11**	**AOI 15**	**AOI 19**	**AOI 23**	**AOI 27**
	3.50	4.00	3.00	5.00	6.00	5.00	7.50

When performing Kruskal-Wallis' test for median values across participants for the dwell time of the first fixation on an AOI of similarly located AOIs across remote designs, no statistical differences were found ($p > 0.05$). Table 2.7 shows the measured values for the dwell time of the first fixation on an AOI of similarly located AOIs.

Table 2.7 Comparison of median values for the dwell time of the first fixation on an AOI of similarly located AOIs across different remote designs.

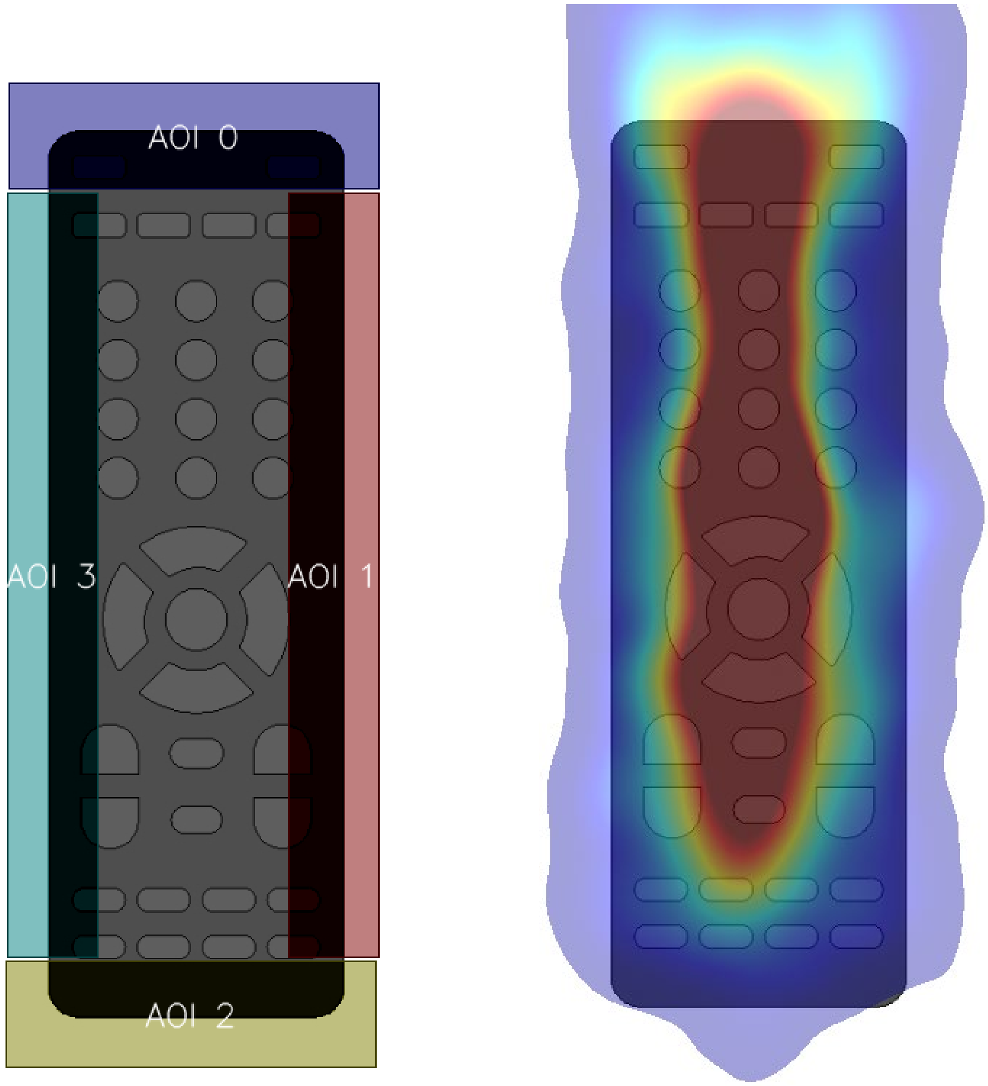
	Rectangular w/ Rounded Corners	Hourglass Flat	Rectangular Subjacent	Hourglass Subjacent	Hourglass Round	Trapezoidal	Rectangular Stout
TOP	**AOI 0**	**AOI 4**	**AOI 8**	**AOI 12**	**AOI 16**	**AOI 20**	**AOI 24**
	0.40	0.29	0.41	0.36	0.45	0.42	0.40
RIGHT	**AOI 1**	**AOI 5**	**AOI 9**	**AOI 13**	**AOI 17**	**AOI 21**	**AOI 25**
	0.27	0.38	0.35	0.40	0.43	0.30	0.33
BOTTOM	**AOI 2**	**AOI 6**	**AOI 10**	**AOI 14**	**AOI 18**	**AOI 22**	**AOI 26**
	0.30	0.53	0.27	0.31	0.36	0.46	0.43
LEFT	**AOI 3**	**AOI 7**	**AOI 11**	**AOI 15**	**AOI 19**	**AOI 23**	**AOI 27**
	0.43	0.53	0.38	0.36	0.35	0.33	0.28

When performing Kruskal-Wallis' test for median values across all participants for the total dwell time on an AOI of similarly located AOIs across different remote designs, no statistical differences were found ($p > 0.05$). Table 2.8 shows the measured values for the total dwell time on an AOI of similarly located AOIs.

Table 2.8 Comparison of median values for the total dwell time on an AOI of similarly located AOIs across different remote designs.

	Rectangular w/ Rounded Corners	Hourglass Flat	Rectangular Subjacent	Hourglass Subjacent	Hourglass Round	Trapezoidal	Rectangular Stout
TOP	**AOI 0**	**AOI 4**	**AOI 8**	**AOI 12**	**AOI 16**	**AOI 20**	**AOI 24**
	3.89	2.65	2.97	1.82	2.28	2.42	2.77
RIGHT	**AOI 1**	**AOI 5**	**AOI 9**	**AOI 13**	**AOI 17**	**AOI 21**	**AOI 25**
	1.20	2.28	1.09	1.80	2.49	1.58	2.75
BOTTOM	**AOI 2**	**AOI 6**	**AOI 10**	**AOI 14**	**AOI 18**	**AOI 22**	**AOI 26**
	0.69	0.60	0.33	0.15	0.53	0.73	0.26
LEFT	**AOI 3**	**AOI 7**	**AOI 11**	**AOI 15**	**AOI 19**	**AOI 23**	**AOI 27**
	0.86	1.08	0.64	1.67	2.38	1.10	1.86

2.6.2 Rectangular with Rounded Corners



(a) **(b)**

Figure 2.4 Paired example of Rectangular with Rounded Corners design. (a) AOI Definition. (b) Heat map.

Figure 2.4a shows the AOI definition relative to the rectangular with rounded corners design. Figure 2.4b shows the absolute gaze duration heatmap. From observation of the heatmap, most of the participants spent their time gazing at the remote control buttons along the central vertical axis. Relative to the AOIs, most time was spent fixated on AOI 0 than any other AOI. Participants, in general, spent some time gazing at AOI 1, and even less time gazing at AOI 2 and AOI 3.

Table 2.9 Eye tracking metrics for Rectangular with Rounded Corners design.

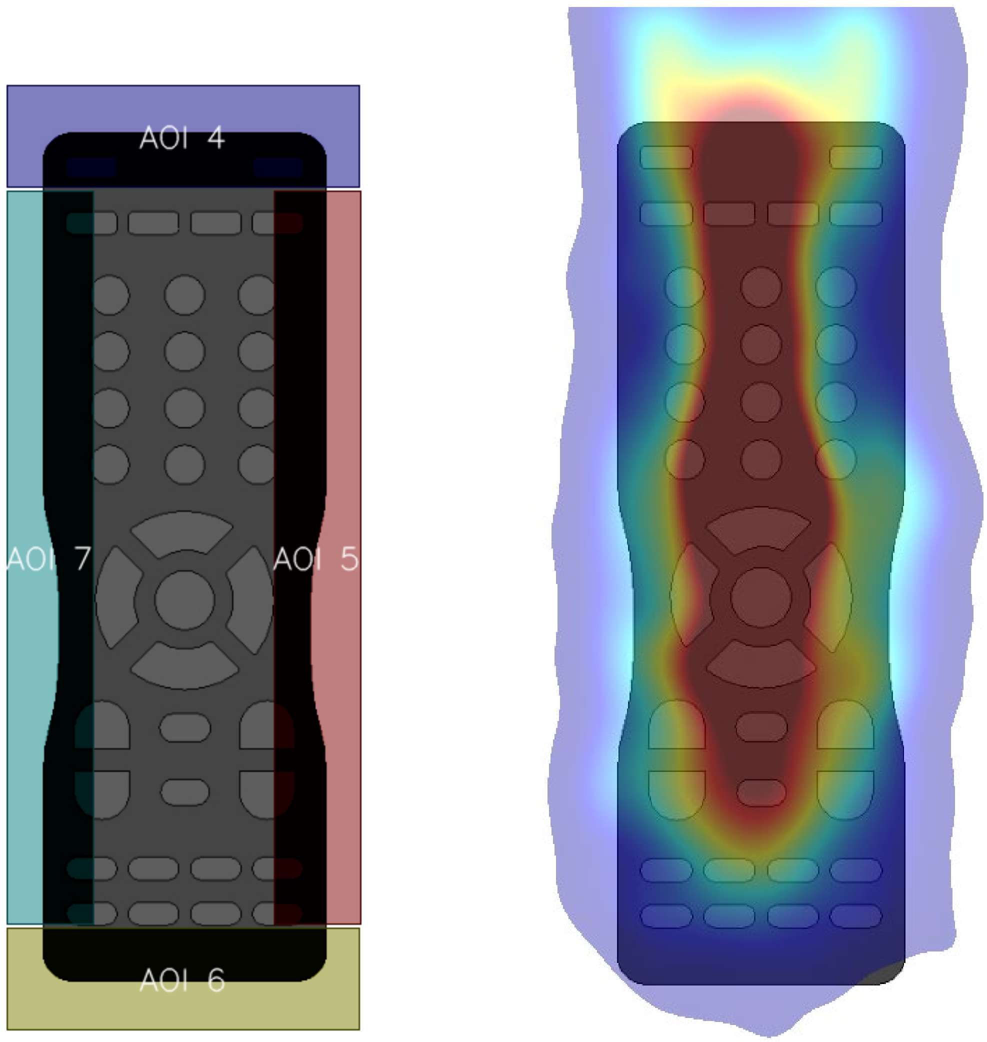
	Number of fixations prior to first fixation of any AOI (#)		Time to first fixation of an AOI (sec)				Number of fixations on an AOI (#)				Dwell time of first fixation on an AOI (sec)			
			AOI				AOI				AOI			
	#	AOI	0	1	2	3	0	1	2	3	0	1	2	3
Median	3.00	0	2.34	6.32	9.68	5.90	13.00	6.00	4.00	3.50	0.40	0.27	0.30	0.43
	3.50	1												
	-	2												
	-	3												
Median Rank			1	3	4	2	1	2	3	4	2	4	3	1

Table 2.9 (continued)

	Total dwell time on an AOI (sec)				Percentage of time spent on an AOI (%)			
	AOI				AOI			
	0	1	2	3	0	1	2	3
Median	3.89	1.20	0.69	0.86	12.96	3.98	2.31	2.86
Median Rank	1	2	4	3	1	2	4	3

From Table 2.5, AOI 0 had the least number of fixations (*Mdn* = 3.00) than AOI 1 (*Mdn* = 3.50) prior to first fixation of any AOI; participants did not have their first fixation on AOI 2 or AOI 3. Participants spent the least amount of time (*Mdn* = 2.34) before fixating on AOI 0. AOI 0 had the most number of fixations (*Mdn* = 13.00) compared to all other AOIs. AOI 3 had the highest dwell time (*Mdn* = 0.43) for the first AOI fixation. AOI 0 had the highest dwell time (*Mdn* = 3.89). In general, participants spent a majority of their time fixated on AOI 0 than all others AOIs (*Mdn* = 12.96%).

2.6.3 Hourglass Flat



(a) **(b)**

Figure 2.5 Paired example of Hourglass Flat design. (a) AOI Definition. (b) Heat map.

Figure 2.5a shows the AOI definition relative to the hourglass flat design. Figure 2.5b shows the absolute gaze duration heatmap. From the heatmap, most participant spent their time gazing at the remote control buttons along the central vertical axis. Relative to all AOIs, most time was spent on AOI 4. A significant amount of time was spent on AOI 5 and AOI 7, while participants spent the least amount of time on AOI 6.

Table 2.10 Eye tracking metrics for Hourglass Flat design.

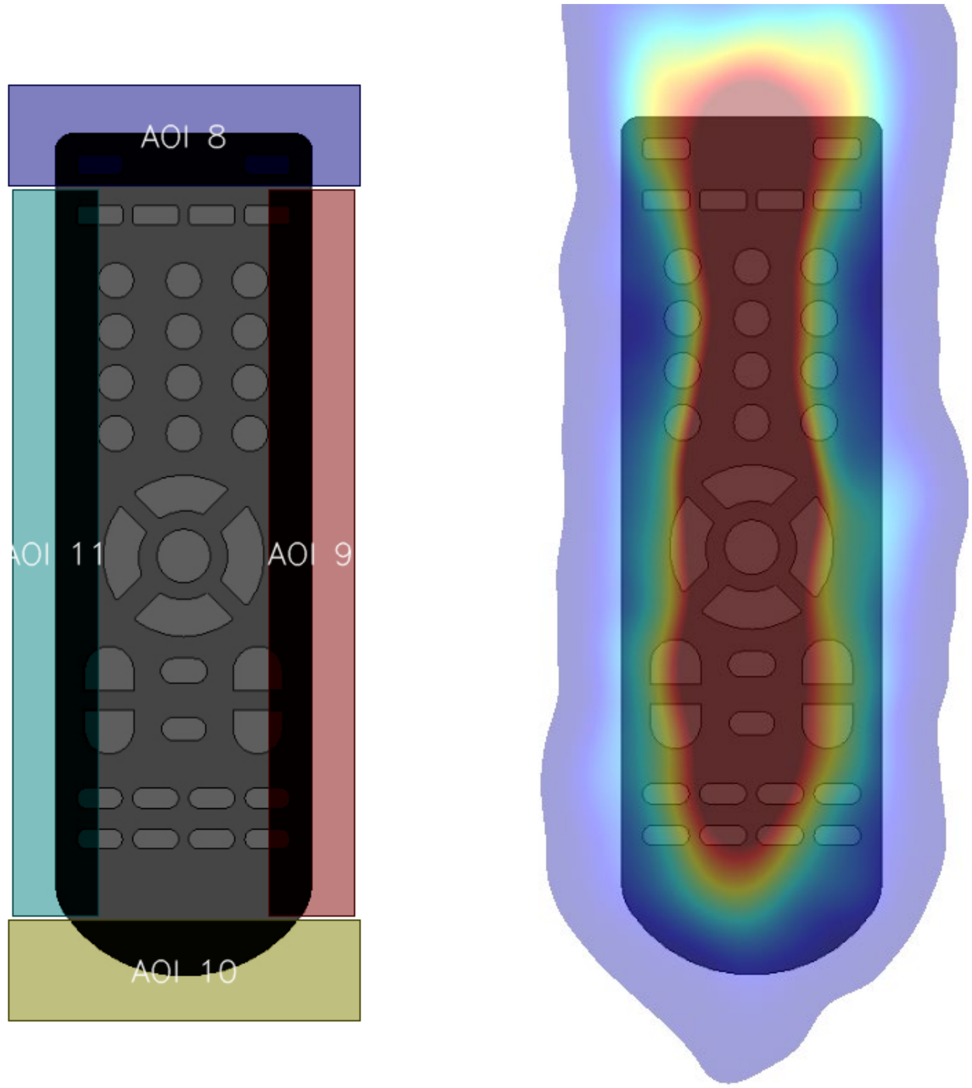
	Number of fixations prior to first fixation of any AOI (#)		Time to first fixation of an AOI (sec)				Number of fixations on an AOI (#)				Dwell time of first fixation on an AOI (sec)			
			AOI				AOI				AOI			
	#	AOI	4	5	6	7	4	5	6	7	4	5	6	7
Median	2.00	4	2.40	3.54	8.16	5.83	9.00	6.50	2.50	4.00	0.29	0.38	0.53	0.53
	2.50	5												
	3.00	6												
	0.00	7												
Median Rank			1	2	4	3	1	2	4	3	4	3	1	2

Table 2.10 (continued)

	Total dwell time on an AOI (sec)				Percentage of time spent on an AOI (%)			
	AOI				AOI			
	4	5	6	7	4	5	6	7
Median	2.65	2.28	0.60	1.08	8.82	7.61	2.01	3.58
Median Rank	1	2	4	3	1	2	4	3

From Table 2.6, AOI 7 had the least number of fixations prior to first fixation of any AOI (*Mdn* = 0.00) compared to all other AOIs. Participants spent the least amount of time (*Mdn* = 2.40) before fixating on AOI 4. AOI 4 had the most number of fixations (*Mdn* = 9.00). AOI 6 had the highest dwell time (*Mdn* = 0.53) for the first fixation. Total dwell time for AOI 4 was the highest (*Mdn* = 2.65) than any other AOI. Participants spent most of their time fixated on AOI 4 (*Mdn* = 8.82%) than all other AOIs; participants spent less time fixated on AOI 2 and the least amount of time on AOI 6.

2.6.4 Rectangular Subjacent



(a) **(b)**

Figure 2.6 Paired example of Rectangular Subjacent design. (a) AOI Definition. (b) Heat map

Figure 2.6a shows the AOI definition relative to the rectangular subjacent design. Figure 2.6b shows the absolute gaze duration heatmap. Most time was spent gazing at the remote control buttons along the central vertical axis. Relative to the AOIs, most time was spent on AOI 8 and lesser time on AOI 9 and AOI 11; the least amount of time was spent on AOI 10.

Table 2.11 Eye tracking metrics for Rectangular Subjacent design.

	Number of fixations prior to first fixation of any AOI (#)		Time to first fixation of an AOI (sec)				Number of fixations on an AOI (#)				Dwell time of first fixation on an AOI (sec)			
			AOI				AOI				AOI			
	#	AOI	8	9	10	11	8	9	10	11	8	9	10	11
Median	0.00	8	3.29	7.78	8.04	9.17	10.00	5.00	2.50	3.00	0.41	0.35	0.27	0.38
	12.00	9												
	2.50	10												
	3.00	11												
Median Rank			1	2	3	4	1	2	4	3	1	3	4	2

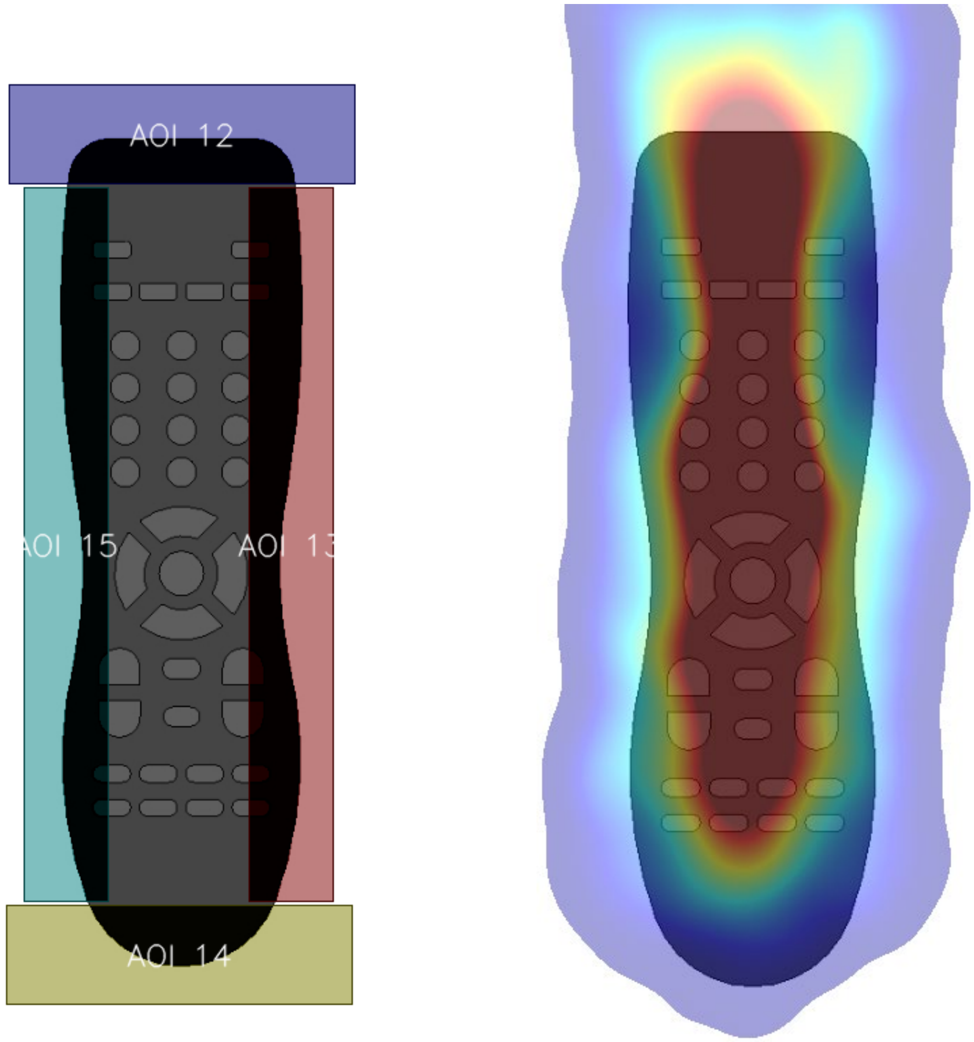
Table 2.11 (continued)

	Total dwell time on an AOI (sec)				Percentage of time spent on an AOI (%)			
	AOI				AOI			
	8	9	10	11	8	9	10	11
Median	2.97	1.09	0.33	0.64	9.89	3.63	1.10	2.12
Median Rank	1	2	4	3	1	2	4	3

From Table 2.7, AOI 8 had the least number of fixations prior to first fixation of any AOI (*Mdn* = 0.00) while AOI 9 had the most number of fixations (*Mdn* = 12.00). The least amount of time was spent before the first fixation on AOI 8 (*Mdn* = 3.29). In total, AOI 8 had the most number of fixations compared to all other AOIs (*Mdn* = 10.00). AOI 8 had the highest dwell time (*Mdn* = 0.41) for the first fixation. AOI 8 had the highest total dwell time (*Mdn* = 2.97) while AOI 9 had the second highest dwell time

(*Mdn* = 1.09). In general, most participants spent a majority of their time fixated on AOI 8 (*Mdn* = 9.89%) compared to all other AOIs.

2.6.5 Hourglass Subjacent



(a) **(b)**

Figure 2.7 Paired example of Hourglass Subjacent design. (a) AOI Definition. (b) Heat map.

Figure 2.7a shows the AOI definition relative to the hourglass subjacent remote control design. Figure 2.7b shows the absolute gaze duration heatmap. Generally, participants spent a majority of their time fixated on the buttons located along the central vertical axis. Relative to the AOIs, most time was spent fixated on AOI 12 and lesser time on AOI 13 and AOI 15; the least amount of time was spent on AOI 14.

Table 2.12 Eye tracking metrics for Hourglass Subjacent design.

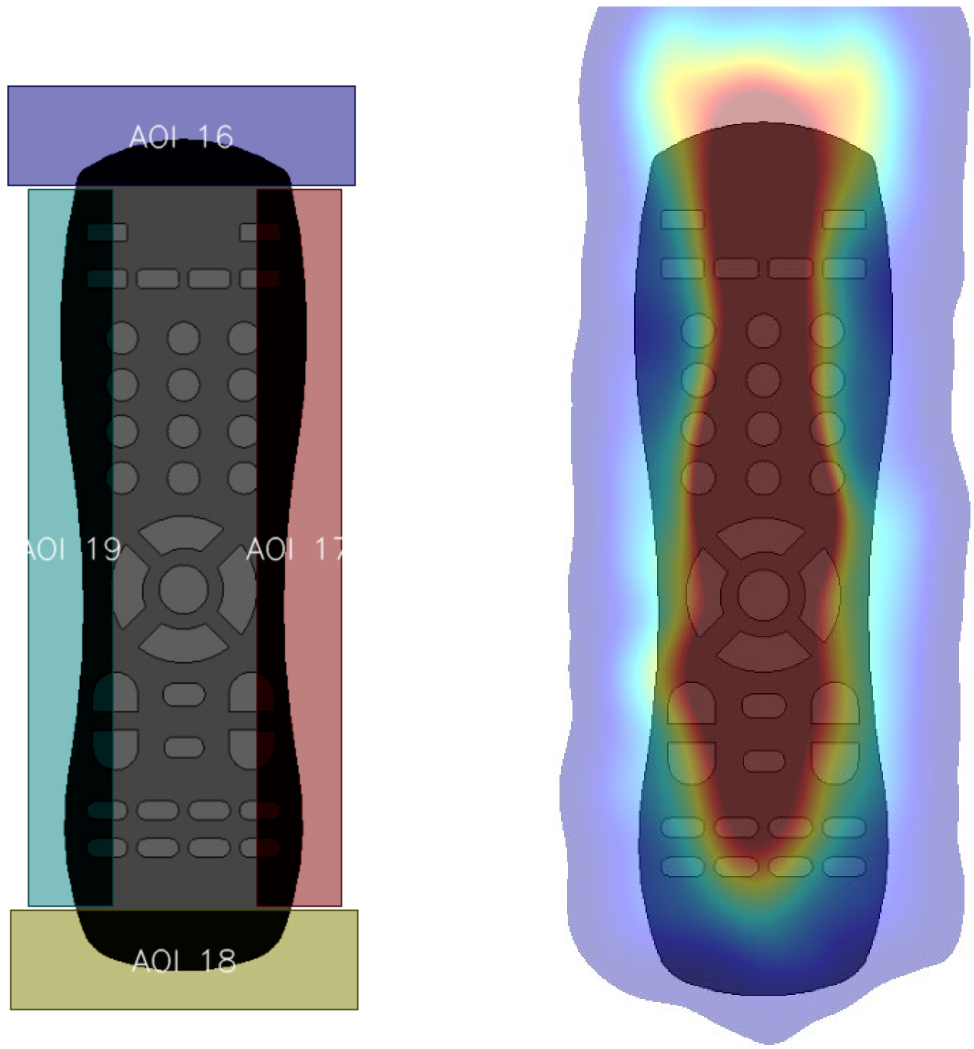
	Number of fixations prior to first fixation of any AOI (#)		Time to first fixation of an AOI (sec)				Number of fixations on an AOI (#)				Dwell time of first fixation on an AOI (sec)			
			AOI				AOI				AOI			
	#	AOI	12	13	14	15	12	13	14	15	12	13	14	15
Median	2.00	12	8.51	5.56	15.52	9.84	7.00	8.00	1.00	5.00	0.36	0.40	0.31	0.36
	7.00	13												
	9.00	14												
	2.00	15												
Median Rank			2	1	4	3	2	1	4	3	3	1	4	2

Table 2.12 (continued)

	Total dwell time on an AOI (sec)				Percentage of time spent on an AOI (%)			
	AOI				AOI			
	12	13	14	15	12	13	14	15
Median	1.82	1.80	0.15	1.67	6.05	5.99	0.49	5.55
Median Rank	1	2	4	3	1	2	4	3

From Table 2.8, AOI 12 and AOI 15 had the least number of fixations prior to first fixation on an AOI (*Mdn* = 2.00). The least amount of time was spent before the first fixation on AOI 13 (*Mdn* = 5.56). AOI 13 had the most number of fixations compare to all other fixations (*Mdn* = 8.00). Dwell time on AOI 13 was highest measured against all other AOIs (*Mdn* = 0.40). Total dwell time for any AOI was spent on AOI 12 (*Mdn* = 1.82); AOI 13 had the second highest dwell time (*Mdn* = 1.80). In general, participants spent a majority of their time fixated on AOI 12 compared to all other AOIs (*Mdn* = 6.05%); participants spent the least amount of time fixated on AOI 14 (*Mdn* = 0.49%).

2.6.6 Hourglass Round



(a) **(b)**

Figure 2.8 Paired example of Hourglass Round design. (a) AOI Definition. (b) Heat map.

Figure 2.8a shows the AOI definition relative to the hourglass round remote design. Figure 2.8b shows the absolute gaze duration heatmap. Typically, participants spent most of their time starring at the buttons located along the central vertical axis of the remote. Regarding the AOIs, most time was spent fixated on AOI 16 and lesser time on AOI 17 and AOI 19; the least amount of time was spent fixated on AOI 18.

Table 2.13	Eye tracking metrics for Hourglass Round design.

	Number of fixations prior to first fixation of any AOI (#)		Time to first fixation of an AOI (sec)				Number of fixations on an AOI (#)				Dwell time of first fixation on an AOI (sec)			
			AOI				AOI				AOI			
	#	AOI	16	17	18	19	16	17	18	19	16	17	18	19
Median	5.00	16	3.50	6.45	14.41	10.90	7.00	8.00	2.00	6.00	0.45	0.43	0.36	0.35
	3.50	17												
	-	18												
	1.50	19												
Median Rank			1	2	4	3	2	1	4	3	1	2	3	4

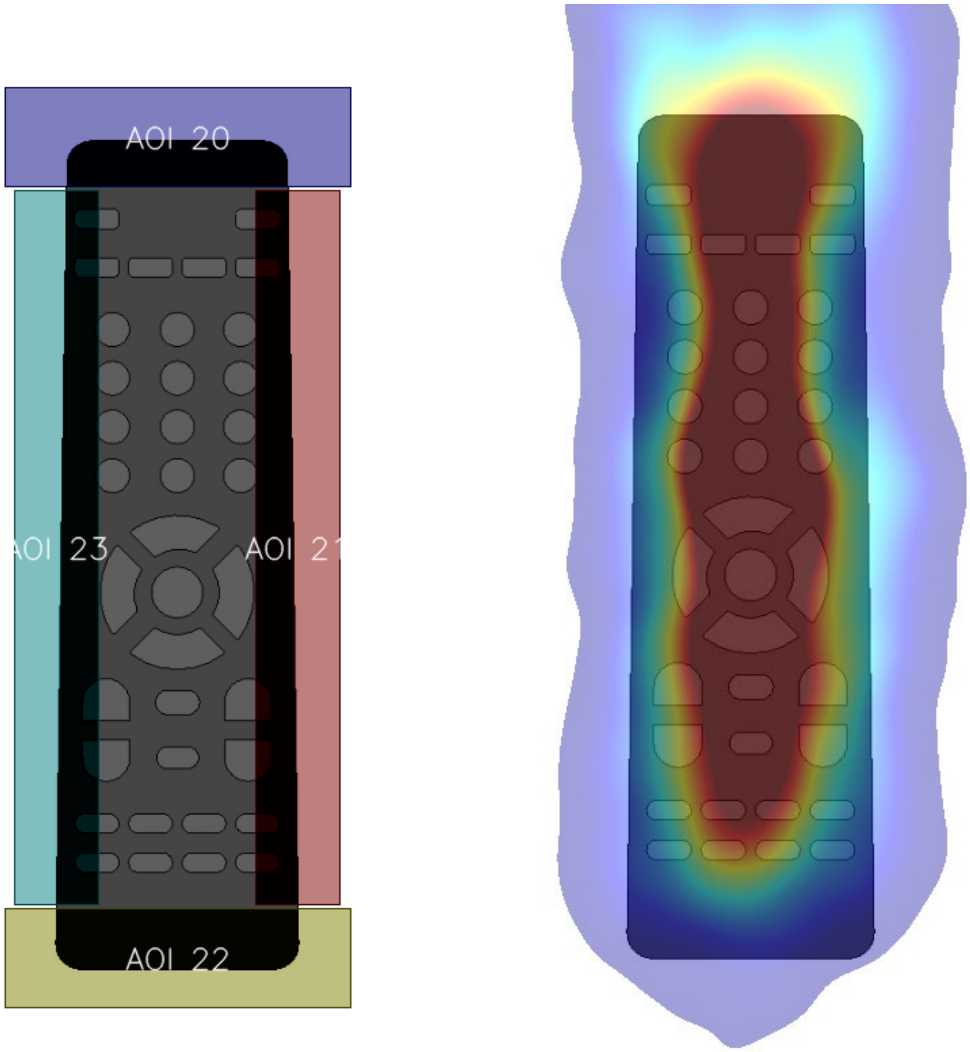
Table 2.13 (continued)

	Total dwell time on an AOI (sec)				Percentage of time spent on an AOI (%)			
	AOI				AOI			
	16	17	18	19	16	17	18	19
Median	2.28	2.49	0.53	2.38	7.59	8.31	1.76	7.92
Median Rank	3	1	4	2	3	1	4	2

From Table 2.9, AOI 19 had the least number of fixations prior to first fixation of any AOI (*Mdn* = 1.50); no participants had their first fixation on AOI 18. The least amount of time was spent before fixating on AOI 16 (*Mdn* = 3.50). AOI 17 had the highest number of fixations (*Mdn* = 8.00); AOI 18 had the least number of total fixations (*Mdn* = 2.00). Dwell time of the first fixation was highest for AOI 16 (*Mdn* = 0.45). Total dwell time on AOI 17 was highest (*Mdn* = 2.49) and lesser for AOI 19 and AOI 16

(*Mdn* = 2.38, *Mdn* = 2.28) respectively. Participants spent most of their time on AOI 17 (*Mdn* = 8.31%) and the least amount of time on AOI 18 (*Mdn* = 1.76%).

2.6.7 Trapezoidal



(a) **(b)**

Figure 2.9 Paired example of Hourglass Round design. (a) AOI Definition. (b) Heat map.

Figure 2.9a shows the AOI definition for the Trapezoidal remote control design. Figure 2.9b shows the absolute gaze duration heatmap. Participants spent most time looking at the button design located at the central vertical axis. Concerning the AOIs, most time was spent gazing at AOI 20 while the least amount of time was spent gazing at AOI 22.

Table 2.14 Eye tracking metrics for Trapezoidal design.

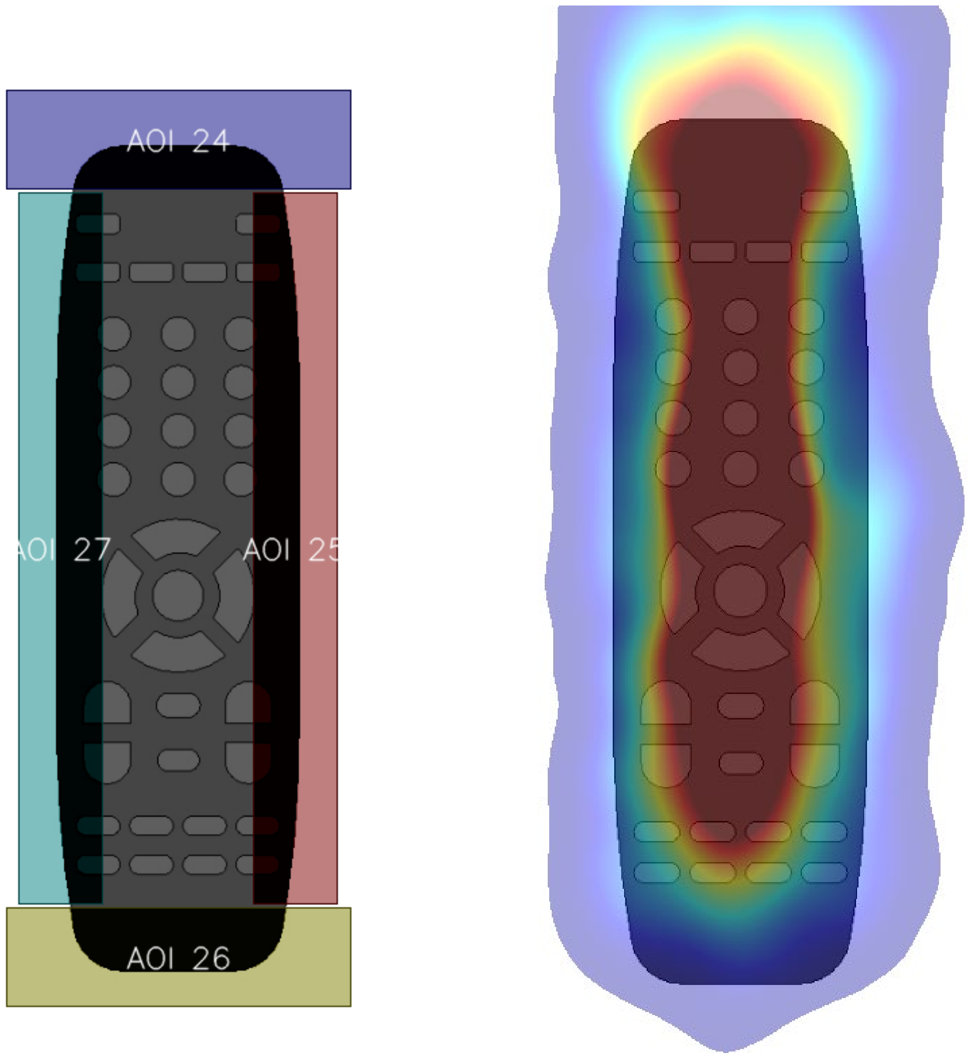
	Number of fixations prior to first fixation of any AOI (#)		Time to first fixation of an AOI (sec)				Number of fixations on an AOI (#)				Dwell time of first fixation on an AOI (sec)			
			AOI				AOI				AOI			
	#	AOI	20	21	22	23	20	21	22	23	20	21	22	23
Median	1.00	20	2.27	3.69	5.46	4.88	9.00	7.00	3.00	5.00	0.42	0.30	0.46	0.33
	4.00	21												
	1.00	22												
	2.00	23												
Median Rank			1	2	4	3	1	2	4	3	2	4	1	3

Table 2.14 (continued)

	Total dwell time on an AOI (sec)				Percentage of time spent on an AOI (%)			
	AOI				AOI			
	20	21	22	23	20	21	22	23
Median	2.42	1.58	0.73	1.10	8.07	5.28	0.73	3.65
Median Rank	1	2	4	3	1	2	4	3

From Table 2.10, AOI 20 and AOI 22 contained the least number of fixations prior to first fixation (*Mdn* = 1.00); AOI 21 had the most number of fixations before first fixation (*Mdn* = 4.00). The least amount of time was spent before fixating on AOI 20 (*Mdn* = 2.27). AOI 20 had the most number of fixations compared to all other AOIs (*Mdn* = 9.00). Dwell time of the first fixation was highest for AOI 22 (*Mdn* = 0.46); second highest dwell time of the first fixation was for AOI 20 (*Mdn* = 0.42). Total dwell time on AOI 20 was highest (*Mdn* = 2.42); total dwell time on AOI 22 was lowest (*Mdn* = 0.73). Most time was spent fixated on AOI 20 (*Mdn* = 8.07%) in comparison to all AOIs.

2.6.8 Rectangular Stout



(a) **(b)**

Figure 2.10 Paired example of Rectangular Stout design. (a) AOI Definition. (b) Heat map.

Figure 2.10a shows the AOI definition for the Rectangular Stout remote design. Figure 2.10b shows the absolute gaze duration heatmap. Participants spent most time fixated on the button design. In comparison to all AOIs, most time was spent on AOI 24 and the least amount of time was spent on AOI 26.

Table 2.15 Eye tracking metrics for Rectangular Stout design.

	Number of fixations prior to first fixation of any AOI (#)		Time to first fixation of an AOI (sec)				Number of fixations on an AOI (#)				Dwell time of first fixation on an AOI (sec)			
			AOI				AOI				AOI			
	#	**AOI**	**24**	**25**	**26**	**27**	**24**	**25**	**26**	**27**	**24**	**25**	**26**	**27**
Median	2.00	**24**	4.40	4.90	10.11	6.82	10.00	10.00	1.00	7.50	0.40	0.33	0.43	0.28
	9.50	**25**												
	-	**26**												
	1.00	**27**												
Median Rank			1	2	4	3	1	1	4	3	2	3	1	4

Table 2.15 (continued)

	Total dwell time on an AOI (sec)				Percentage of time spent on an AOI (%)			
	AOI				AOI			
	24	**25**	**26**	**27**	**24**	**25**	**26**	**27**
Median	2.77	2.75	0.26	1.86	9.24	9.15	0.88	6.21
Median Rank	1	2	4	3	1	2	4	3

From Table 2.11, AOI 27 had the least number of fixations prior to first fixation on an AOI (*Mdn* = 1.00), participants did not have their first fixation on AOI 26. The least amount of time was spent before fixating on AOI 24 (*Mdn* = 4.40). AOI 24 and AOI 25 had equally the same number of total fixations (*Mdn* = 10.00). Dwell time of the first fixation was highest for AOI 26 (*Mdn* = 0.43). Total dwell time on AOI 24 was highest (*Mdn* = 2.77); total dwell time on AOI 26 was lowest (*Mdn* = 0.26). In general, participants spent a majority of their time fixated on AOI 24 (*Mdn* = 9.24) compared to all other AOIs.

2.7 Eye Tracking Results by Demographics and Remote Control Design

2.7.1 Gender

Performing Mann Whitney tests to look for differences between gender and remote control design yielded sparse results. For the rectangular with rounded corners design, dwell times to the first fixation on an AOI for AOI 0 were higher for females than males (U=72.000, $p < 0.05$).

For the rectangular stout design, dwell time to the first fixation of AOI 27 was higher for males than females (U=18.500, $p < 0.05$). The total dwell time of AOI 27 was higher for males than females (U=16.000, $p < 0.05$). The percentage of time spent on AOI 27 was higher for males than female (U=16.000, $p < 0.05$).

2.7.2 Age

Applying Mann Whitney tests to look for differences between age and remote control design demonstrated some differences for specific AOIs. For the hourglass round design, the number of fixations on AOI 18 were higher for those participants that were 40 years and older (U=72.500, $p < 0.05$). The total dwell time of AOI 18 was higher for the group of people 40 and above (U=70.000, $p < 0.05$). The percentage of time spent on AOI 18 was higher for people 40 and above (U=70.000, $p < 0.05$).

For the trapezoidal remote control design, the percentage of time spent on AOI 20 was higher for people 40 and above (U=74.000, $p < 0.05$).

For the rectangular stout design, the time to first fixation on AOI 24 was higher for people 40 and older (U=75.000, $p < 0.05$). The number of fixations on AOI 24 was higher for people between the ages of 18 and 39 years (U=15.500, $p < 0.05$). The total dwell time of AOI was higher for participants between 18 and 39 years of age

(U=16.500, $p < 0.05$). The percentage of time spent on AOI 24 was higher for people between 18 and 39 years (U=16.000, $p < 0.05$).

2.7.3 Design Experience

For the rectangular with rounded corners design, the Mann Whitney test results for the time to first fixation on AOI 0 was higher for those participants with design experience (U=57.000, $p < 0.05$).

For the rectangular subjacent design, the number of fixations on AOI 11 was higher for people with design experience (U=12.000, $p < 0.05$).

For the hourglass subjacent remote design, the number of fixations on AOI 13 was higher for people that did not have design experience (U=58.500, $p < 0.05$).

For the hourglass round design, the number of fixations on AOI 16 was higher for those participants without design experience (U=58.500, $p < 0.05$). The total dwell time on AOI 16 was higher for participants without design experience (U=60.000, $p < 0.05$). The percentage of time spent on AOI 16 was higher for participants without design experience (U=60.000, $p < 0.05$).

For the rectangular stout design, the time to first fixation of AOI 27 was higher for people without design experience (U=59.000, $p < 0.05$).

2.8 Discussion

Median values for eye metrics were chosen to represent the central tendency of aesthetic value for each remote control design. Values originally thought to represent saliency were highlighted in comparison to all other AOIs for each metric for each design. After comparing median values of all eye tracking metrics for similarly defined

AOIs across the different remote control designs, there was no statistical difference in the values measured for all eye tracking metrics. Participants did not look at similarly defined AOIs differently across remote control designs; the design of the remote control did not have a statistical influence on eye movements. Aesthetic saliency of remote control design elements was not determined.

In analyzing the percentage of time participants spent throughout looking at each remote design, 75-85% of the participants' visual attention was spent focused on the button layout. With the button layout receiving most of the participants' visual attention, this may have contributed to the inability of determining design element saliency. Most of the participants' visual attention on the buttons could also suggest that the usability of the buttons may be at the forefront of their attentional span ahead of those items related to appearance.

Little time was spent fixated on the defined AOIs as compared to the button layout; the button layout was not defined as an AOI. Since the button layout received most of the visual attention, it could be argued that removing the button layout altogether and conducting the experiment again would force participants to focus more on the geometrically varied design elements. It is unclear what the result would be if a participant is asked to evaluate a remote control, without buttons, since functional buttons are a key feature that defines a remote control.

From the heatmaps, there are similarities in the fixation areas across all designs. Towards the top of all remotes, this is where most time was spent in comparison to all AOIs. No inferences could be made about why the top side AOIs received the most attention, from all other AOIs, based on open-ended responses. With how most remotes area designed today, the top side areas usually contain the ON / OFF buttons. The top side area of most remotes are usually pointed at the device of interest when inputting a command which determines the orientation of the remote when it is held; this determined orientation highlights the functional area of the remote where electrical commands are sent from the remote to the device. This functional area could explain the resultant fixation area. There is a characteristic narrowing of the fixation area around the cluster of buttons presumed to be the numeric keys; the narrowing could be attributed to how participants do not have much interest in the presumed numeric keys or how the numeric keys are located away from the middle of the remote where you would naturally hold the device. Towards the middle of the remote, there is a bulging of the fixation area as you move southward from the presumed numeric keys. From discussions, this could be attributed to the way participants envisioned holding the remote, towards the middle, and interacting with the adjacent keys. Some participants commented that for the hourglass designs, holding the remote in the middle was intuitive. As you move southward from the middle of the remote, there generally is a consistent fixation area around the presumed channel and volume keys. Some participants did mention they envisioned interacting with the presumed channel and volume keys. Out of all the presumed keys, the presumed channel and volume keys were the most mentioned from discussions which may be how this sample of participants typically interact with their personal remote controls.

The task of having participants evaluate different remote controls for its appealing design features is an open-ended problem that can have many different answers, solutions, or scan paths. According to Bojko (2013), “More specific tasks are better suited for eye tracking analysis than open-ended tasks because eye tracking data analysis is only possible if the researcher knows what the participant is trying to accomplish at each step" (p. 262). There are many ways in which a participant could approach the task of looking at a remote control to determine which features are most attractive. The open-ended nature of the experimental task may have contributed to the lack of significant differences of eye movements between remote designs.

The task of having participants evaluate remotes on design features that make its appearance most attractive as stated in Figure 2.1 is a top-down cognitive process. In general terms, the word 'saliency' refers to something that grabs your attention; this is inherently a bottom-up cognitive process. Some items that determine saliency are colors and motion. Since the button layout was receiving most attention, it could be shown that the buttons were the most salient objects and not the geometrically varied design elements unique to each remote; this was an unintended consequence of the study because the button design remained constant throughout the entire eye tracking experiment.

When analyzing participant's eye tracking results, it was observed that some participants did not fixate on certain AOIs. It was assumed that no fixation on an AOI represented a non-salient AOI. Based on the analysis from comparing similarly defined AOIs across different remotes, this is not necessarily the case. A participant who did not fixate on an AOI could also be related to the task being an open-ended problem.

For all remote control designs, there was a first AOI fixation on the top or right side AOIs. The rectangular with rounded corners design did not receive a first fixation on the bottom or left side AOIs; AOI 2 and AOI 3 respectively. The hourglass round design did not receive a first fixation on the bottom side AOI 18. The rectangular stout design did not receive a first fixation on the bottom side AOI 26. The minimal amount of time, prior to the first fixation, was spent on all topside AOIs except for the hourglass subjacent design where minimal time was spent prior to the first fixation on the right side AOI 13. The topside AOIs had the most number of fixations for all remotes except for the hourglass subjacent and hourglass round designs where the most number of fixations were located on the right side AOIs; AOI 13 and AOI 17 respectively. For all remote designs, the topside AOI received the highest dwell time except for the hourglass round design where the highest dwell time was recorded on the right side AOI 17. An observation from this analysis is that the hourglass subjacent or hourglass round designs did not follow typical correlations like most of remote controls designs. Although these remote control designs did not follow typical trends, it is still insufficient to claim that these remote designs, with the previously highlighted AOIs, contained salient design elements for reasons stated earlier about the open-ended nature of the scan task.

From discussions with participants after the study, some did verbally elaborate that they thought that some remote designs were more appealing than others, but a general consensus from the informal conversations could not be established. Some participants elaborated how the pinched-waist feature for the different hourglass-based designs was appealing; some elaborated how they considered the tapered sides of the trapezoidal design to be appealing. Based on discussions, some participants expressed which features they thought were attractive, but the eye tracking study could not make that distinction. One participant mentioned that he evaluates a consumer product as a whole instead of individual elements for determining aesthetic value. Another participant mentioned that he evaluates products using peripheral vision; peripheral vision cannot be captured by an eye tracker.

From comments received by 2 participants, it was mentioned that they evaluate products as a whole including using their peripheral vision in the evaluation. With the eye tracker used in this study, peripheral vision was not measured; foveal vision is only measured. It is unclear how many how many participants evaluated the remotes with peripheral vision and to what degree.

2.9 Conclusion

2.9.1 Summary

It was expected that images of differently designed remote controls would elicit differences in eye movements when judging aesthetics, particularly to those design elements which make the remote control design unique. When a participant looked at a remote design that is aesthetically pleasing, it was anticipated that a unique set of appealing design elements could be determined based on their eye tracking results.

When analyzing participants' eye tracking results, no significant differences were found between eye movements and similarly defined AOIs across each remote design. Using eye tracking data to determine design element saliency of a remote control was unsuccessful. From discussions with some participants, there was mention of certain design elements that were attractive to them, but these attractive design elements did not transfer to significant differences in eye movements. There were observed differences in relationships for the hourglass subjacent and hourglass rounds designs, for some of the of the eye measures, that did not follow the same relationships of the other remote designs, but little can be inferred from this information.

2.9.2 Limitations

The eye tracker software does have limitations when defining AOIs related to this study. The design elements of interest within each remote control can be defined by a set of curves, splines, and radii. The software cannot define an AOI to follow these elements; the software can only defined AOIs by rectilinear shapes. This disparity in AOI definition could erroneous measurements. It is unclear if the spatial accuracy of the eye tracker could lead to erroneous measurements.

When reviewing visual replays of participant's fixations, 1 participant's results showed sporadic movements in their eye behavior which did not follow a smooth motion through each part of the designs that was observed. According to Gazepoint, there are 3-5% of people they tested where remote eye tracking does not work due to physiological incompatibility attributed to pupil shape or size; this percentage agrees with the percentage observed during this study.

2.9.3 Future Work

Future changes to the study could include showing participants only those design elements of interest rather than the entire remote control design, then having them choose which design elements are more attractive. This change would eliminate the open-ended nature of the current study while being more specific about the task.

The study findings provide future researchers insight into the shortcomings of determining aesthetic features using an eye tracker. An open-ended search environment for determining aesthetic features did not yield successful results, rather a close-ended target search analysis environment might provide better results.

The setup of evaluating single remote control designs at a time was part of the open-ended search framework of this study. Future studies could include changing this evaluation method to a close-ended task by asking participants to choose between a set of salient elements by fixating on those elements they find most attractive. The method for evaluating remotes in this study was to evaluate each remote control individually in alternation. When evaluating a group of remote controls for salient design features, it could be easier evaluating the remotes in pairs or groups rather than individually; this gives the framework for having participants compare between design features and choosing what is more appealing.

A majority of the time that participants spent during the evaluation process was spent fixated on the remote control buttons. Although the evaluation of the remote control buttons was not part of this study, it should be noted that this area of the design should be reconsidered. Reconsidering the button design could force participants to fixate on other areas of interest throughout the design and simplify the evaluation process. In discussion with some participants, it was mentioned that they envisioned themselves holding and utilizing the buttons during the evaluation task; this was one reason why they fixated on the button layout. Although the evaluation was to determine those features that make each remote aesthetically appealing, some participants mentioned they evaluated the functional use of the buttons since this is a primary feature of any remote control; button functionality impacted how participants evaluated geometric form of a remote control.

Looking at different views, aside from the front view containing the buttons, is another area of future work for understanding aesthetics and usability. Giving participants different viewing perspectives to visualize a remote design adds another dimension for measuring eye movements. Other viewpoints could allow participants to focus more on geometrical design elements and spend less time focusing on the functional button layout. The way participants envision their interaction with a remote could change with different viewing perspectives which could result in a more desirable effect in evaluating design elements.

CHAPTER III

UNDERSTANDING PARTICIPANTS' ATTITUDES TOWARDS AESTHETICS AND SUBJECTIVE USABILITY FOR GEOMETRICALLY VARIED REMOTE CONTROL DESIGNS USING VISUAL QUESTIONNAIRES

3.1 Introduction

The role of aesthetics has been widely documented including the appearance, shape, and form of a product in order to provide the most immediate product data for the user (Maquet, 1988; McDonagh, Bruseberg, & Haslam, 2002). Product functionality includes the emotional needs and other intangible, qualitative aspects that affect the relationship of the user with the product (McDonagh, Bruseberg, & Haslam, 2002). The relationship between the user and the product has high importance in industry and there is currently a lot of investment in this area (McDonagh, Bruseberg, & Haslam, 2002). The emotional relationship between the user and the product is largely determined by the symbolic dimension of the product (McDonagh, Bruseberg, & Haslam, 2002). The symbolic meaning of an object relies on a shared understanding between individuals (McDonagh, Bruseberg, & Haslam, 2002). Consumers use product symbolism to define themselves and their relationship with others (Solomon, 1983). Manufacturers are aware of the requirement to satisfy user needs beyond functional aspects (McDonagh, Bruseberg, & Haslam, 2002).

3.2 Background

From Vermeeren, et al., (2010), questionnaires and scales are one of the most versatile forms of research for collecting UX (user experience) data.

Usability is defined in terms of five attributes: learnability, efficiency, memorability, errors, and satisfaction (Nielsen, 1993). Nielsen (1993) states that the evaluation of system usability requires the measurement of these five attributes during or after people have used the system. The use of certain inspection methods is required to establish a certain degree of usability even though designers might rely on principles and guidelines to design usable systems (Nielsen, 1993).

Researchers have demonstrated the effective use of multiple methods to explore usability. The following sections summarize the advantages and disadvantages of the various methods as reported by Holmqvist, et al., (2011)

3.2.1 Questionnaires

Questionnaires are used to elicit information from the participant where conscious responses are given to highly structured questions. The structure of a questionnaire can be more or less rigid where one extreme would be to force participants to provide responses to questions with few alternatives and another extreme would be to have participants answer open-ended questions. An advantage of having a rigid questionnaire structure is that all the answers are confined within an easily analyzed answer space. A disadvantage of a rigid questionnaire is the risk of low validity due to wrong constructs or misinterpreted questions; participants may not understand what you are asking about or may be forced to provide a response to a question they believe is not applicable. Likert scales are often used since they can be easily analyzed. It also allows the ability to ask a certain question with different wording to reduce the effect of incorrect phrasing.

3.2.2 Eye Movement

Eye movement is influenced by bottom-up (i.e. stimulus-driven) or top-down (i.e. goal-oriented) cognitive processes. Bottom-up attention refers to the involuntary allocation of attention to objects that contrast with their surroundings in some way (Bojko, 2013). For example, bright colors, movement, items that are new and unexpected in a familiar environment can grab your attention. Top-down attention refers to the voluntary allocation of attention to certain features, objects, or regions in space (Pinto, van der Leij, Sligte, Lamme, & Scholte, 2013). Salient stimuli can attract attention, even though the subject had no intentions to attend to these stimuli ((Schreij, Owens, & Theeuwes, 2008). The similarity in top-down and bottom-up attention is that the effects are largely the same although the reason for attentional deployment is different. In both cases, this leads to an increased neural response, which has functional consequences such as better memory storage (Buschman & Miller, 2007). Eye movements are task dependent; this means that a person will look at the same object differently if given a different task.

Although eye tracking is a non-invasive method for gathering information about participants' responses to different remote control designs, it does have its disadvantages when collecting data. A participant does not have to stare directly at an item in order to see it. The participant can also stare directly at an item but be devoting cognitive resources to those items in peripheral view. Since this research depends on the accuracy of data regarding eye movement, erroneous eye movement needs to be separated from legitimate eye movement. The positive properties from eye tracking can be further increased by additional data collection methods. Eye tracking data only provides info about where on a stimulus a cognitive process operated and possibly its duration, but does not provide information about which cognitive process was involved. Methodological triangulation refers to the use of more than one method in investigating a research question to enhance confidence in the ensuing findings (Denzin, 1970).

3.2.3 Reaction Time Measures

Latency measures are a way to quantify the time of a cognitive process. Eye tracking provides many different metrics for measuring latency: saccadic latency, smooth pursuit latency, latency of the reflex blink, pupil dilation latency, eye fixation related potential, entry time, threshold entry time, proportion of participants over time, eye-voice latency, eye-hand span, and eye-eye span.

Traditional non-eye-tracking latency is measured from the onset of a task until the participant presses one of two or more buttons to mark a decision. The latency of the decision is treated as a dependent variable and used as an approximation of the ease of processing for a specific stimuli. Participants are faster where the cognitive processing leading up to a decision is easy unlike when the decision is hard which leads to longer latencies.

3.2.4 Galvanic Skin Response

Galvanic skin response (GSR) measures the electrical conductivity of the skin. The variation in GSR signal relates to the automatic nerve response as a parameter of the sweat gland function. The motivation for using eye tracking along with GSR is to investigate cognitive load and emotional reactions in usability tasks and social anxiety research (Westerman, Sutherland, Robinson, Powell, & Tuck, 2007; Wieser, Pauli, Alpers, & Mühlberger, 2009).

GSR reactions appear 1-2 seconds after a stimulus has been presented. This latency could mean that the eyes have left the part of the stimulus that cause the GSR effect long before the effect was recorded. This latency is difficult to take into account and could be one reason why there are so few combined studies.

3.2.5 Motion Tracking

Motion trackers are used to measure the movement of all external body parts except for the eyes. Motion trackers can be magnetic or optic. Magnetic motion trackers can be optional parts of head-mounted eye trackers. Optical motion trackers use infrared cameras and reflections just like eye tracking. This method gives the same type of sample data stream as eye tracking with comparable sampling frequency and precision, in 3D, for a selected set of points across the participant's body or objects manipulated by the participant. The benefit to using motion trackers is to measure synchronized movements of the eye, body, and objects.

3.2.6 Electroencephalography (EEG)

EEG measures the surface of the brain where there is high variance in the thickness of the skull and scalp between individuals. High amplification is needed for weak signals. It is possible that many trials are needed for each participant because noise levels are high. Artifacts from EEG measures come from alternating current, eye blinks, saccadic movements, and micro saccadic movements; these artifacts may be removed with filters. When EEG is added to eye tracking, analysis focuses on signal amplitude, direction, and the latency of a signal with a particular scalp distribution as a response to external stimulus events or internal cognitive processing.

3.2.7 Functional Magnetic Resonance Imaging (fMRI)

Functional magnetic resonance imaging (fMRI) measures activity throughout the entire area of the brain. The temporal resolution differs between fMRI and eye tracking. Temporal resolution for eye tracking is 0.5-1ms. In contrast, the temporal resolution of fMRI involves measuring over 1000ms time spans. The difference in temporal resolution between the two methods makes it difficult to co-analyze fMRI and eye tracking. The output from an fMRI measurement is a visualization of the blood oxygenation level-dependent signal. Researchers who analyze eye tracking data usually only detect saccades, and to ensure the eye is not moving.

3.2.8 Verbal Data

Verbal data is the totality of data resulting from recordings of verbalizations in the form of audio or transcribed data. Eye tracking data and verbal data are made in several research areas including applied usability projects. There are three main purposes for recording eye tracking data in conjunction with verbal data:

1. To investigate the relationship between vision and speech over time (Holsanova, 2008).
2. To investigate working memory processes directly in addition to perceptual / attentional processes as shown by eye tracking data (Jarodzka, Scheiter, Gerjets, & Van Gog, 2010; Altmann & Kamide, 2007).

3. Eye tracking data are recorded to help participants to elicit verbal data by a method known as cued retrospective recording (Hansen, 1991; Van Gog, Paas, Van Merriënboer, & Witte, 2005).

From Ericsson (2006), the central assumption behind the think-aloud process is that "it is possible to instruct participants to verbalize their thoughts in a manner that does not alter the sequence and content of thoughts mediating the completion of a task and therefore should reflect immediately available information during thinking" Ericsson (pp. 223-241).

3.3 Research Objectives

The objective of this study is to determine attitudes towards appearance and usability of the 7 different remote control designs with the participants from the in-person study. The study will also determine which design elements participants find attractive when asked to choose between a paired set of remote controls. It is expected that there will be a correlation of the Likert survey results to the results from the pairwise comparison survey

3.4 Methods

3.4.1 Participants

The study included the same participants from the first study. Participants were at least 18 years of age with adequate literacy and fluency in English. Each participant was a current user of a remote control device. Preferential selection was made to those participants with experience in designing consumer products.

3.4.2 Experimental Design

After completing the previous eye tracking study, participants were given a series of questionnaires in three parts. For the first part of the questionnaire, participants provided responses to each remote control device separately for all 7 remote control designs regarding its appearance as in Figure 3.1. They were asked to rate their aesthetic attitudes and preferences of each remote control for the following qualities: proportion, shape, and configuration. Participants were asked open-ended questions regarding items they liked and disliked about each design's appearance.

For the second part of the questionnaire, participants provided responses to each remote control separately for all 7 remote control designs regarding its usability as in Figure 3.2. They were asked to rate their usability attitudes and preferences of each remote control for the following qualities: proportion, shape, and configuration. Participants were asked open-ended questions regarding items they liked and disliked about each product's ease of use.

For the third part of the questionnaire, participants were presented with 10 sets of paired remote control designs. Within each pair, a specific set of design elements were compared against each other while all other design elements remained similar. Participants were forced to choose which remote control design they favored based on appearance. Figure 3.3 shows an example of a paired set of remote control designs and their contrasting design elements. All questionnaires were distributed using the SurveyMonkey website.

3.5 Data Analysis

For analyzing Likert data, the following descriptive statistics were calculated: frequency distributions, median values, and percentages. The Mann Whitney test was used to help determine if a difference existed between the following independent groups: remote control design and gender, remote control design and age, and remote control design and design experience. For analyzing pairwise comparison results, frequency distributions and percentages were calculated.

For the appearance and usability questionnaires, exclusion criteria was implemented in rejecting participant's responses if simple arithmetic questions were answered incorrectly. For the pairwise comparison survey, exclusion criteria consisted of presenting a duplicate paired set of remote control designs; inconsistency in the responses of the duplicated paired set would result in rejection of the participant's responses.

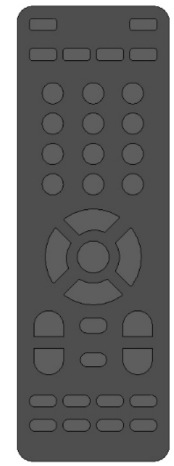
Regarding the **appearance** of this remote, what do you think	VERY POOR 1	POOR 2	OK 3	GOOD 4	VERY GOOD 5	
a) of its overall **shape**						
b) of its overall **size**						
c) of the **shape** of its outline						
What do you **like** about the **appearance** of the product?						
What do you **dislike** about the **appearance** of the product?						

Figure 3.1 Example appearance questionnaire for rectangular with rounded corners design.

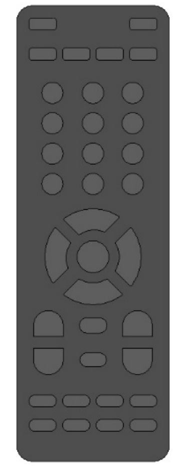
Regarding the **usability** of this remote, what do you think	VERY POOR 1	POOR 2	OK 3	GOOD 4	VERY GOOD 5	
a) of its overall **shape**						
b) of its overall **size**						
c) of the **shape** of its outline						
What do you **like** about the **usability** of the product?						
What do you **dislike** about the **usability** of the product?						

Figure 3.2 Example usability questionnaire for rectangular with rounded corners design.

Please select the remote control design which is most **appealing** to you.

Figure 3.3 Example pairwise comparison; pinched waist versus flat sides.

The following pairwise comparisons are included: flat bottom v. narrow rounded bottom, flat top and bottom v. rounded top and bottom, pinched waist v. rounded sides, rounded top v. flat top, flat sides v. rounded sides, flat bottom v. wide rounded bottom, flat sides v. tapered sides, and rounded sides v. tapered sides.

3.6 Results Summary

3.6.1 Likert Results by Proportion

Table 3.1 and Table 3.2 show Likert appearance and usability survey results for the attributes of proportion, shape, and configuration. For appearance, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 3.58) and hourglass round (*Mdn* = 4, *M* = 3.68) proportion over all other designs. For usability, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 3.84) and hourglass round (*Mdn* = 4, *M* = 4.00) proportion over all other designs. For appearance, participants least preferred the trapezoidal design's proportion (*Mdn* = 3, *M* = 2.95). For usability, participants least preferred the rectangular with rounded corners design's proportion (*Mdn* = 3, *M* = 2.79). Figure 3.4 and Figure 3.5 illustrate the frequency distributions for appearance and usability respectively for all remote control designs concerning the attribute of proportion.

3.6.2 Likert Results by Shape

For appearance of a remote control, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 3.90) and hourglass round (*Mdn* = 4, *M* = 3.74) shape over all other designs. For usability of a remote control, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 4.00) and hourglass round (*Mdn* = 4, *M* = 4.05) shape over all designs. Regarding appearance, the least preferred design for the attribute of shape was hourglass flat (*Mdn* = 2, *M* = 2.53). For usability, the least preferred design for the attribute of shape was rectangular with rounded corners (*Mdn* = 3, *M* = 2.74). Figure 3.6 and Figure

3.7 show the frequency distributions for the qualities of appearance and usability for all remote designs for the attribute of shape.

3.6.3 Likert Results by Configuration

For appearance of a remote control, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 3.84) and hourglass round (*Mdn* = 3, *M* = 3.47) configuration in comparison to all other designs. For usability of a remote control, hourglass subjacent (*Mdn* = 4, *M* = 4.00) and hourglass round (*Mdn* = 4, *M* = 4.00) configuration over all designs. Regarding appearance, the least preferred design for the attribute of configuration was the hourglass flat design (*Mdn* = 2, *M* = 2.47). For usability, participants least preferred the designs of rectangular with rounded corners and trapezoidal for the attribute of configuration which were rated equally the same (*Mdn* = 3, *M* = 2.89). Figure 3.8 and Figure 3.9 show the frequency distribution for appearance and usability for the attribute of configuration for all remote control designs.

Table 3.1 Likert in-person appearance survey results for proportion, shape, and configuration categories of remote designs.

	Proportion		Shape		Configuration	
	Median	**Mean**	**Median**	**Mean**	**Median**	**Mean**
Rectangular w/ Rounded Corners	3	3.32	3	3.00	3	3.16
Hourglass Flat	3	3.11	2	2.53	2	2.47
Rectangular Subjacent	3	3.21	3	2.95	3	3.00
Hourglass Subjacent	4	3.58	4	3.90	4	3.84
Hourglass Round	4	3.68	4	3.74	3	3.47
Trapezoidal	3	2.95	3	2.74	3	2.95
Rectangular Stout	3	3.21	3	2.95	3	2.95

Table 3.2 Likert in-person usability survey results for proportion, shape, and configuration categories.

	Proportion		Shape		Configuration	
	Median	**Mean**	**Median**	**Mean**	**Median**	**Mean**
Rectangular w/ Rounded Corners	3	2.79	3	2.74	3	2.89
Hourglass Flat	3	3.21	3	3.30	3	3.16
Rectangular Subjacent	3	3.21	3	3.00	3	3.21
Hourglass Subjacent	4	3.84	4	4.00	4	4.00
Hourglass Round	4	4.00	4	4.05	4	4.00
Trapezoidal	3	3.11	3	3.05	3	2.89
Rectangular Stout	3	3.21	3	3.16	3	3.11

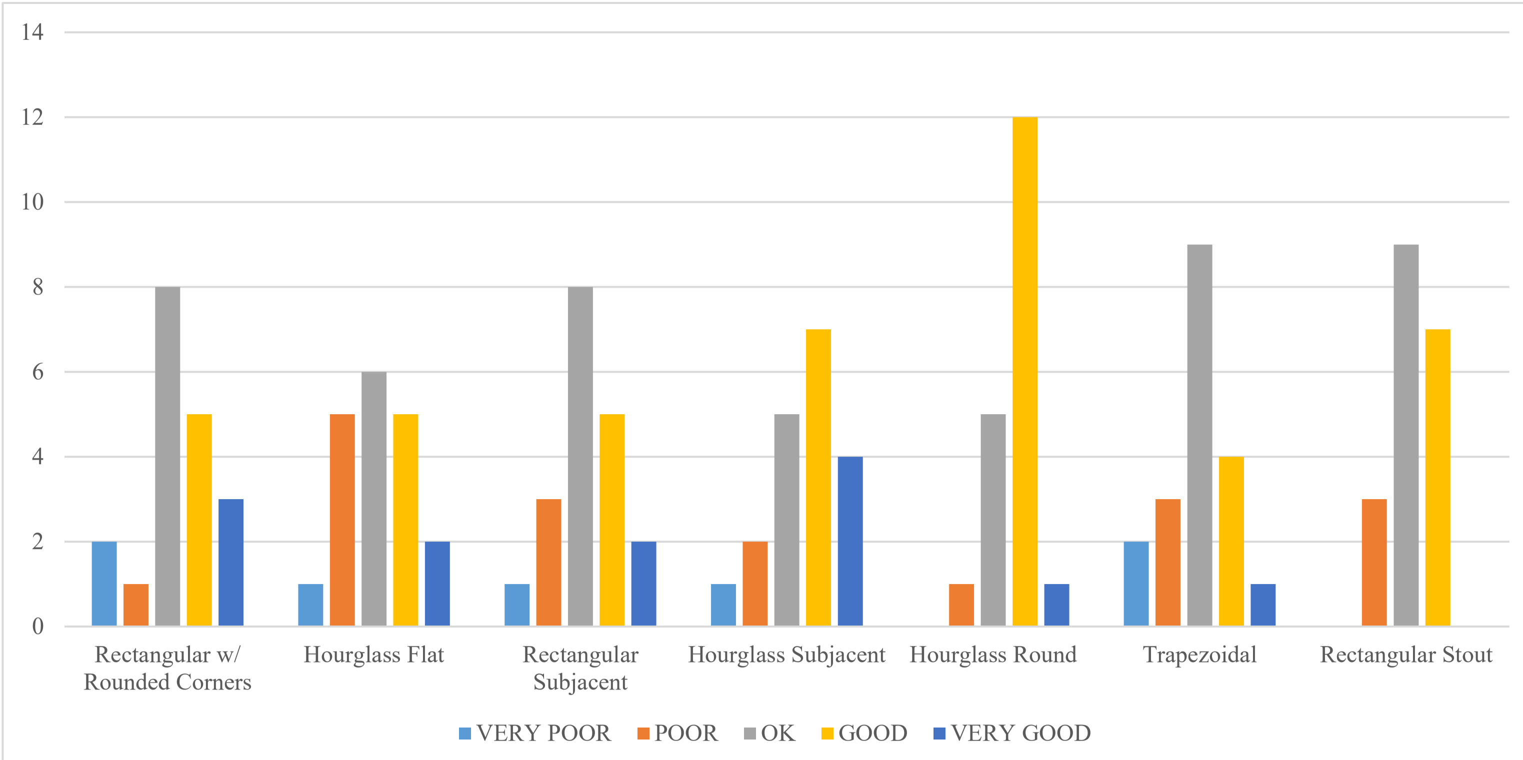


Figure 3.4 Frequency distribution of in-person Likert appearance survey results for proportion of remote control designs.

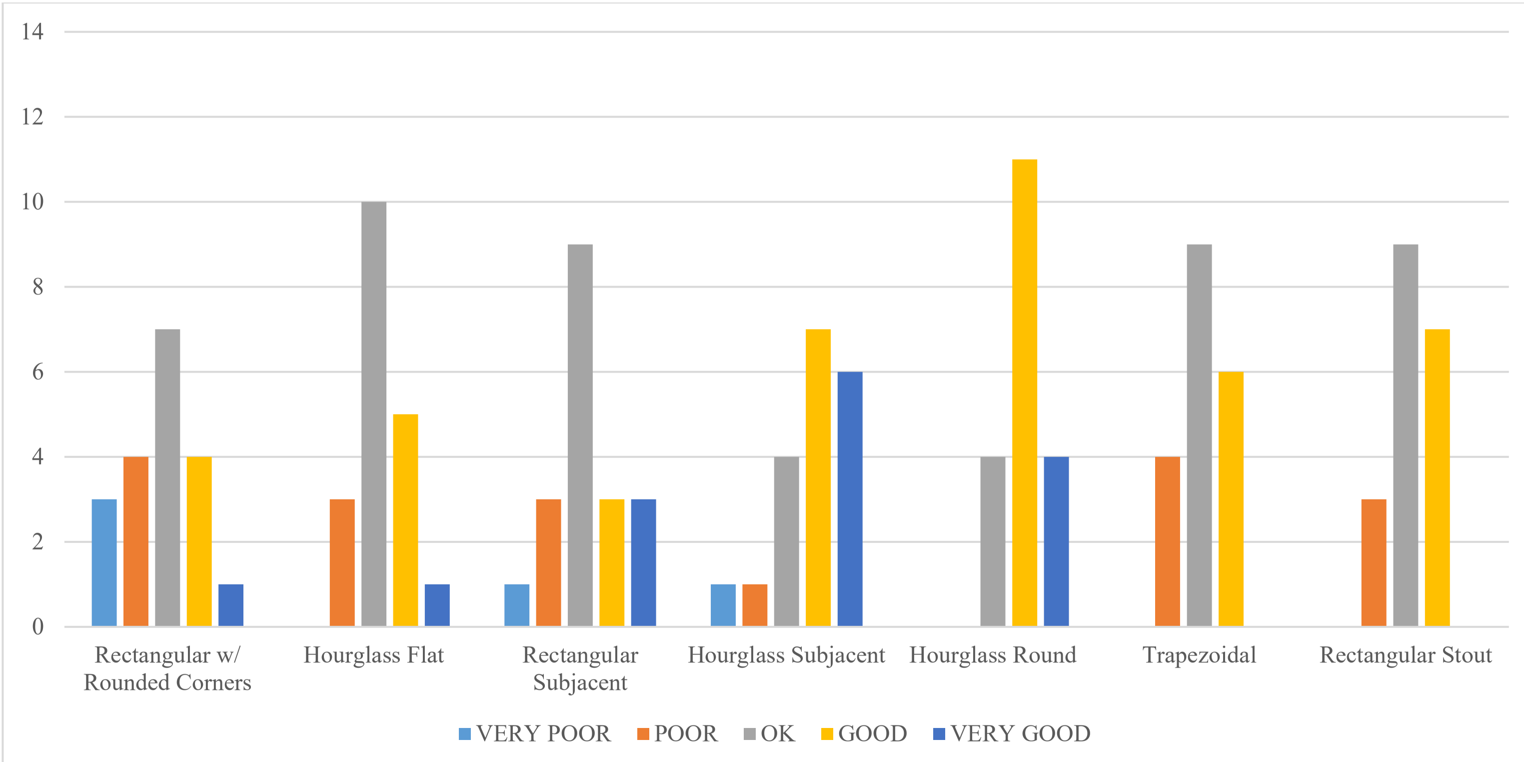


Figure 3.5 Frequency distribution of in-person Likert usability survey results for proportion of remote control designs.

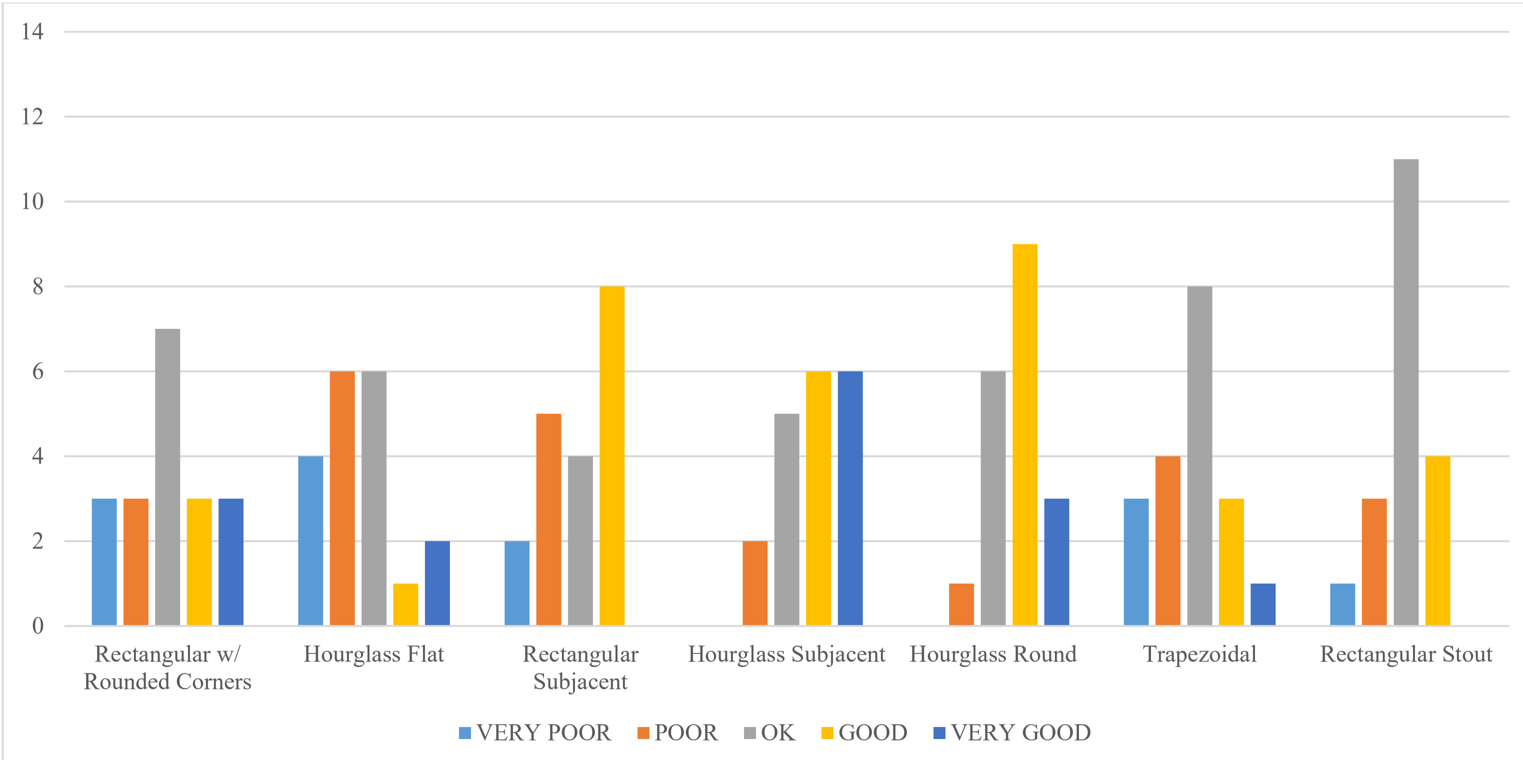


Figure 3.6 Frequency distribution of in-person Likert appearance survey results for shape of remote control designs.

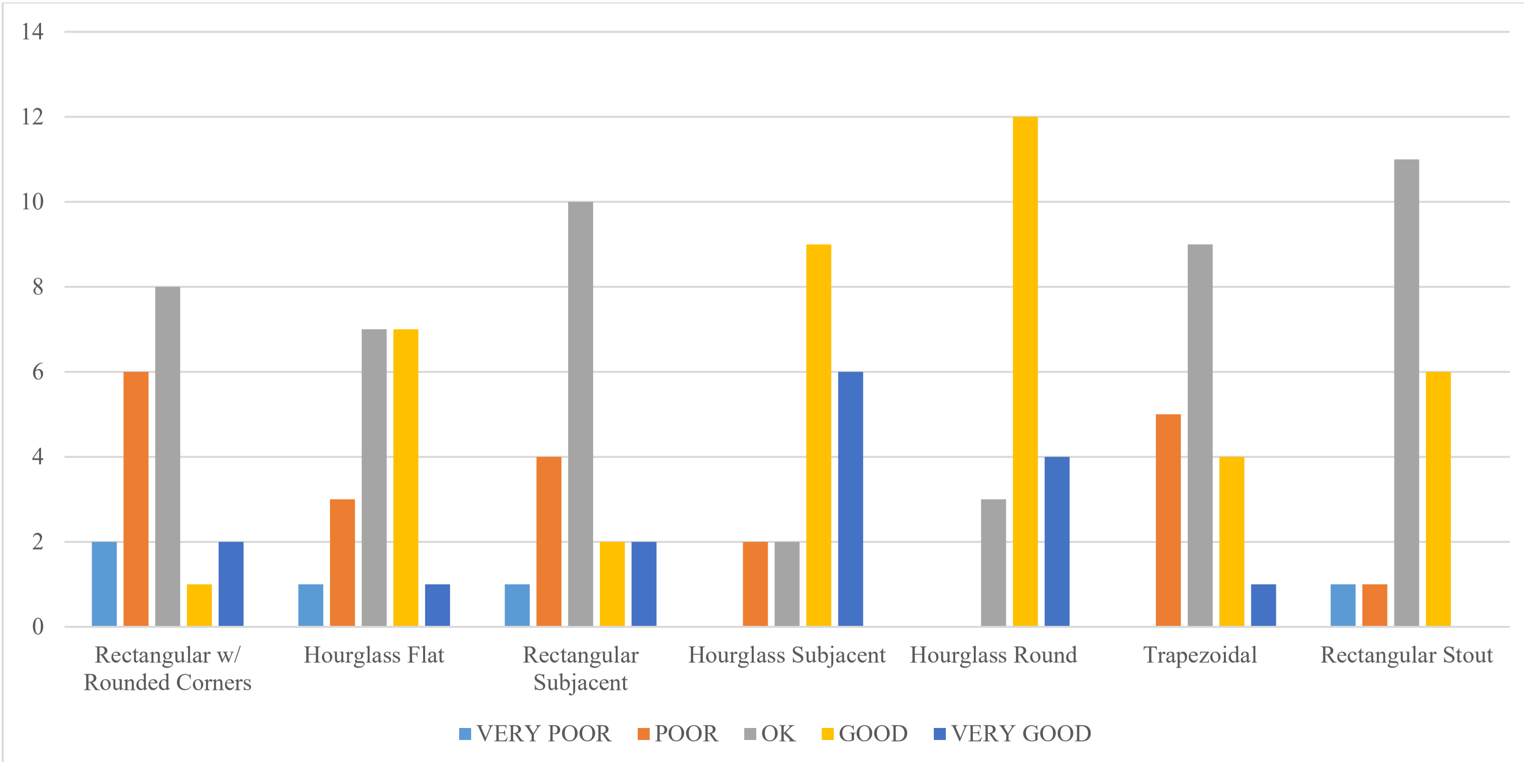


Figure 3.7 Frequency distribution of in-person Likert usability survey results for shape of remote control designs.

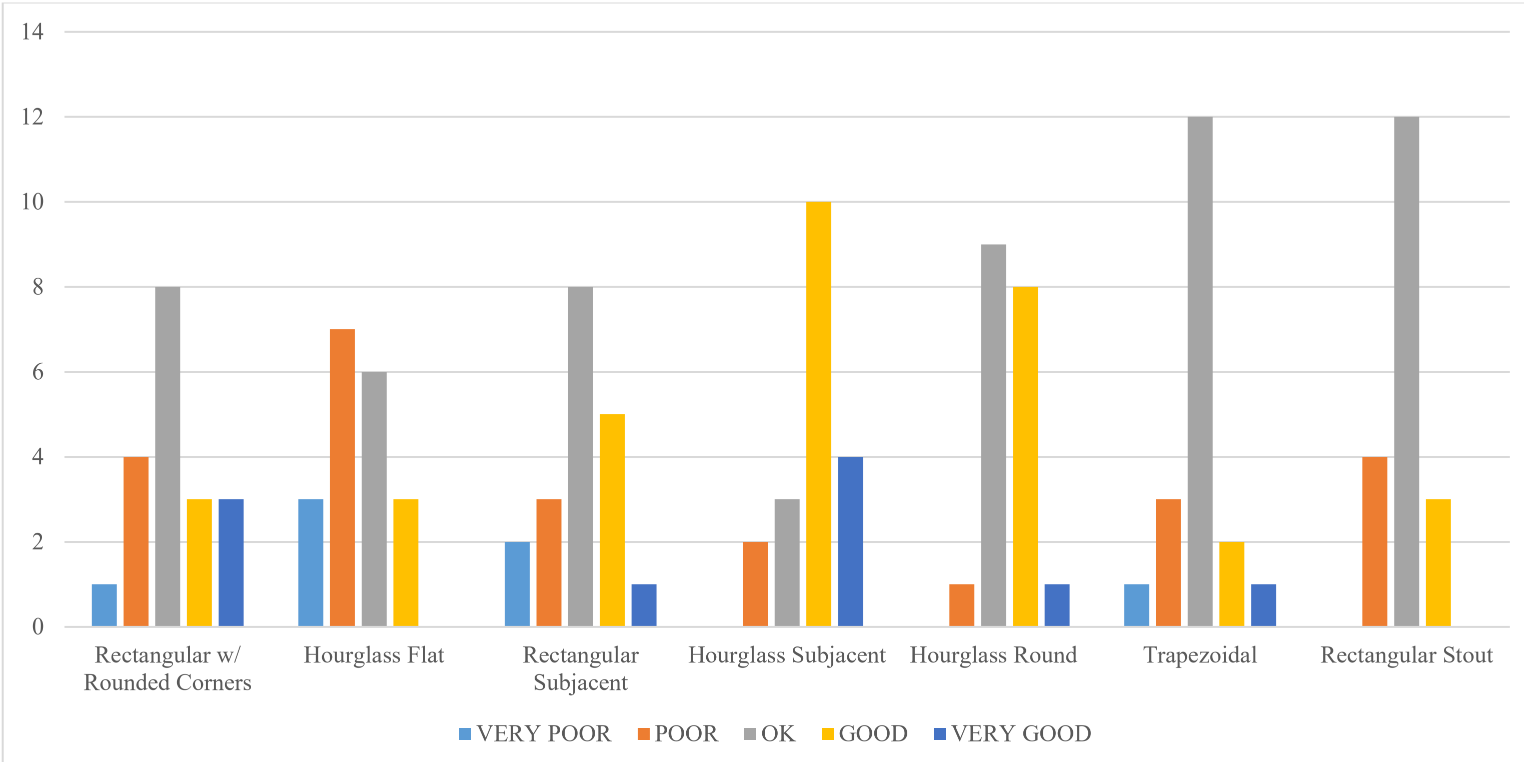


Figure 3.8 Frequency distribution of in-person Likert appearance survey results for configuration of remote control designs.

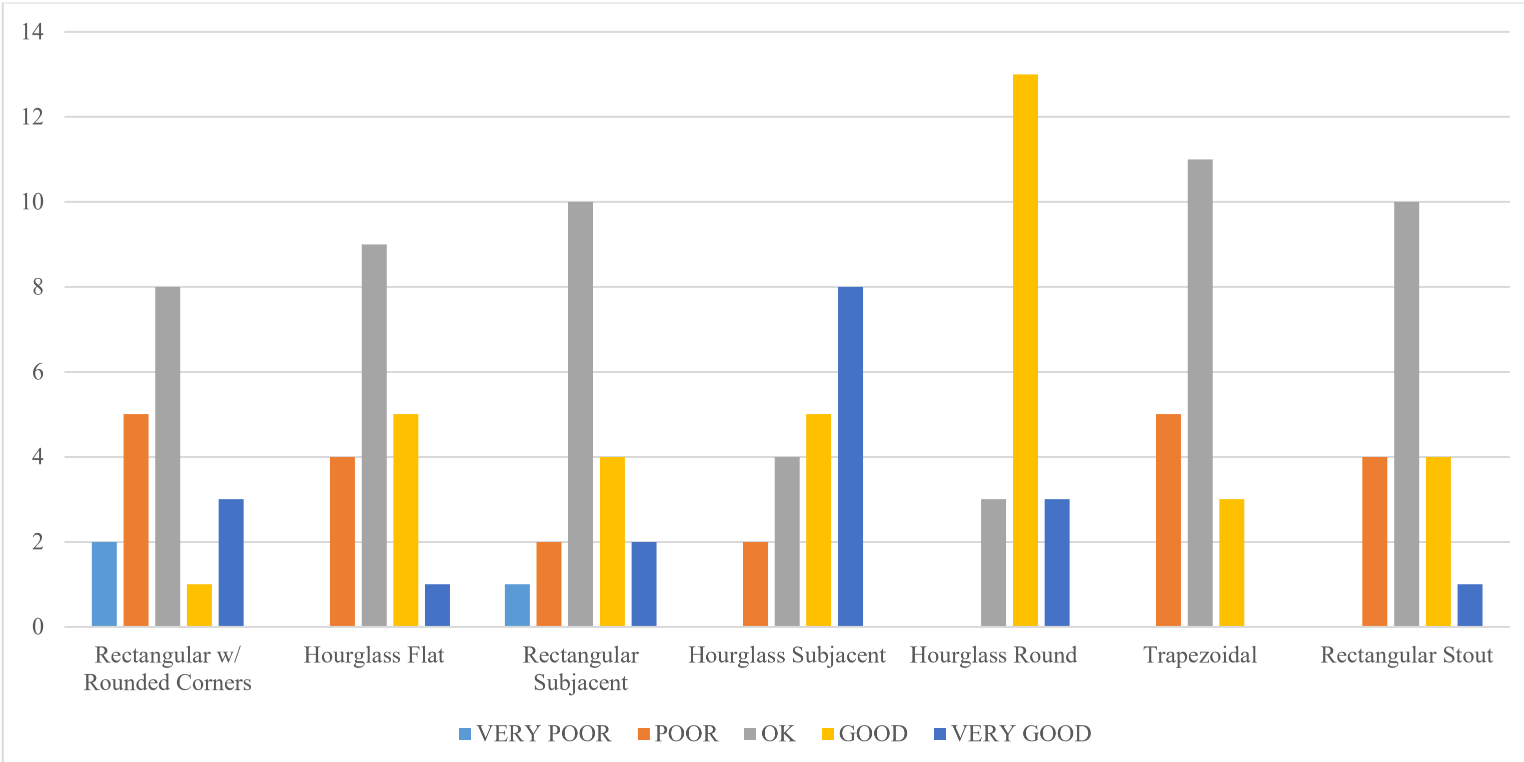


Figure 3.9 Frequency distribution of in-person Likert usability survey results for configuration of remote control designs.

3.6.4 Likert Results of Pairwise Comparison Survey

In Figure 3.10, 10 participants preferred the hourglass flat design while 9 participants chose the rectangular with rounded corners design.

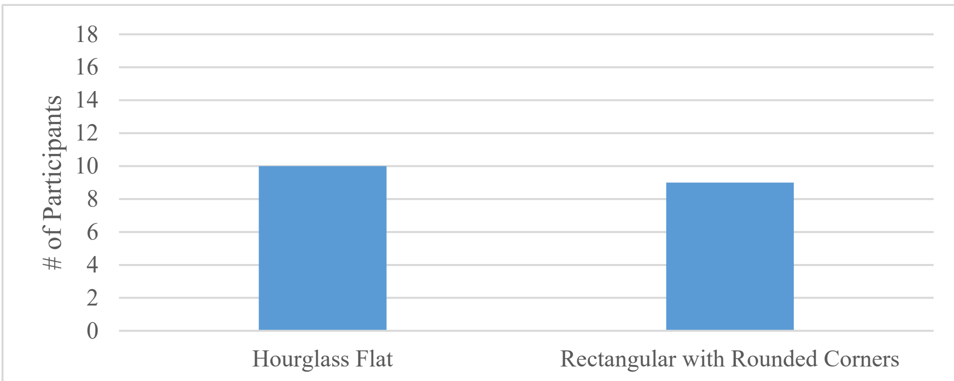


Figure 3.10 Pairwise comparison for in-person participants between Hourglass Flat and Rectangular with Rounded Corners designs.

In Figure 3.11, 15 participants chose the hourglass subjacent design over the 4 participants that chose the hourglass flat design.

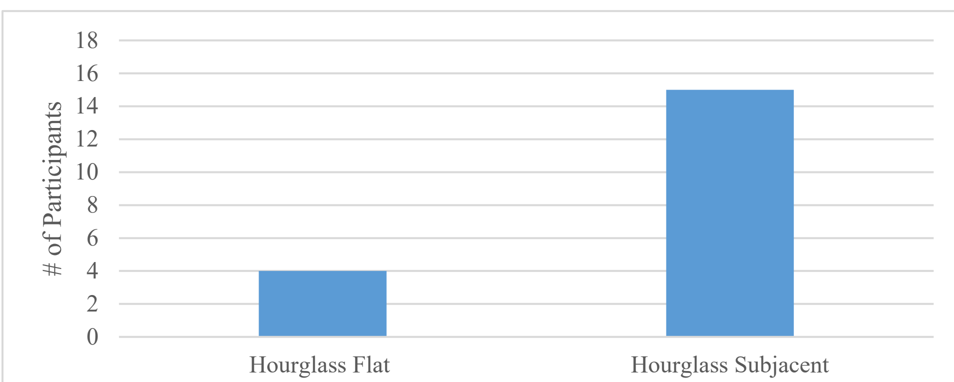


Figure 3.11 Pairwise comparison for in-person participants between Hourglass Flat and Hourglass Subjacent designs.

In Figure 3.12, 16 participants selected the hourglass round design over the 3 participants that chose the hourglass flat design.

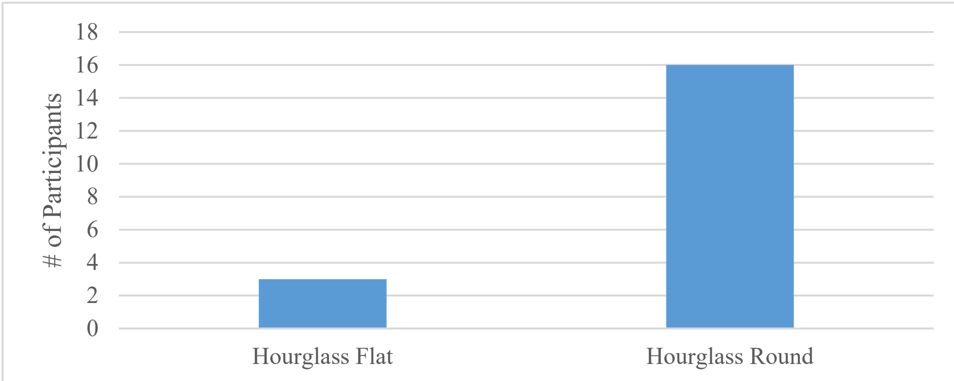


Figure 3.12 Pairwise comparison for in-person participants between Hourglass Flat and Hourglass Round designs.

In Figure 3.13, 14 participants chose the rectangular stout design versus the 5 participants that chose the hourglass flat design.

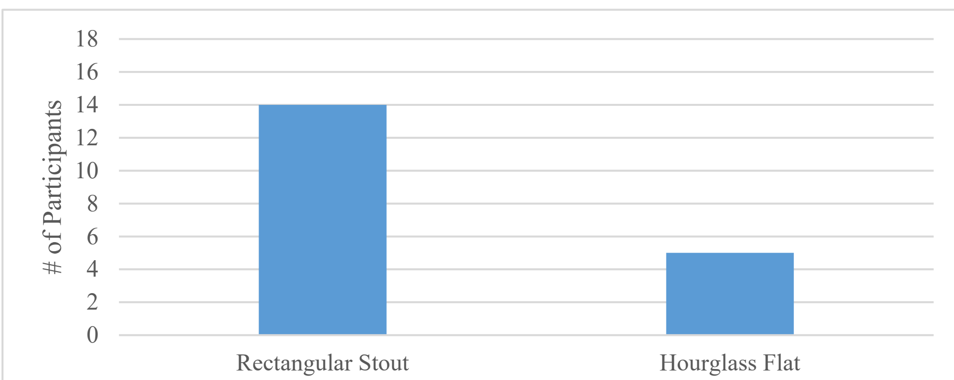


Figure 3.13 Pairwise comparison for in-person participants between Rectangular Stout and Hourglass Flat designs.

In Figure 3.14, 13 participants chose the hourglass round design over the 6 participants that chose the hourglass subjacent remote design.

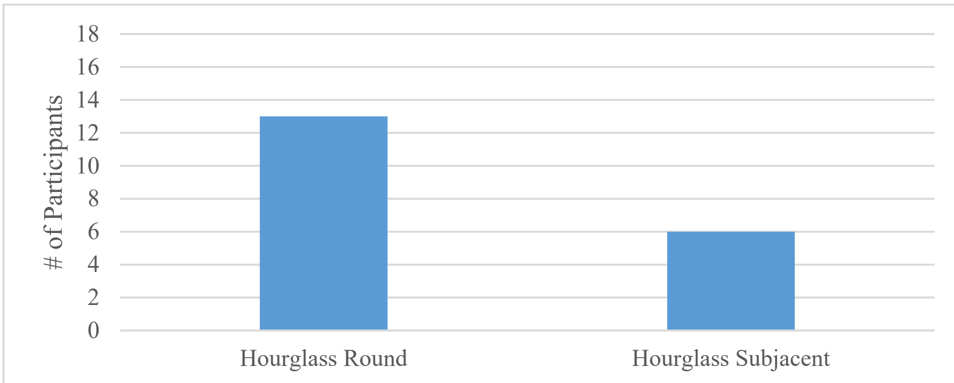


Figure 3.14 Pairwise comparison for in-person participants between Hourglass Round and Hourglass Subjacent designs.

In Figure 3.15, 11 participants chose the rectangular stout design versus the 8 participants that chose the rectangular with rounded corners design.

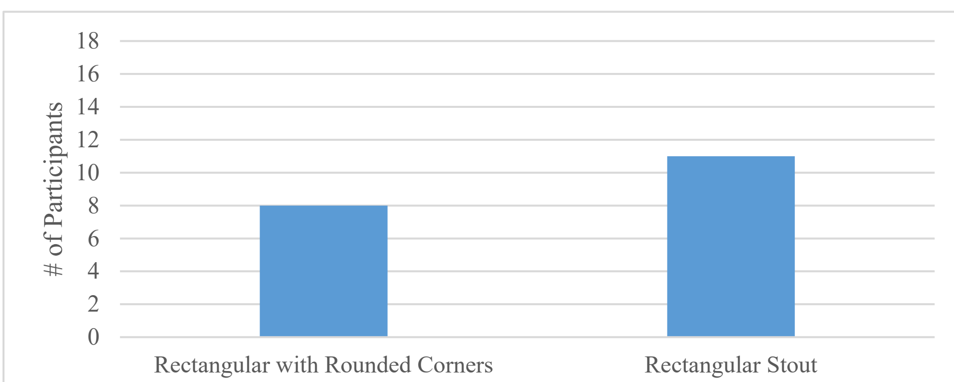


Figure 3.15 Pairwise comparison for in-person participants between Rectangular w/ Rounded Corners and Rectangular Stout designs.

In Figure 3.16, 10 participants chose the rectangular subjacent design over the 9 participants that selected the rectangular with rounded corners remote design.

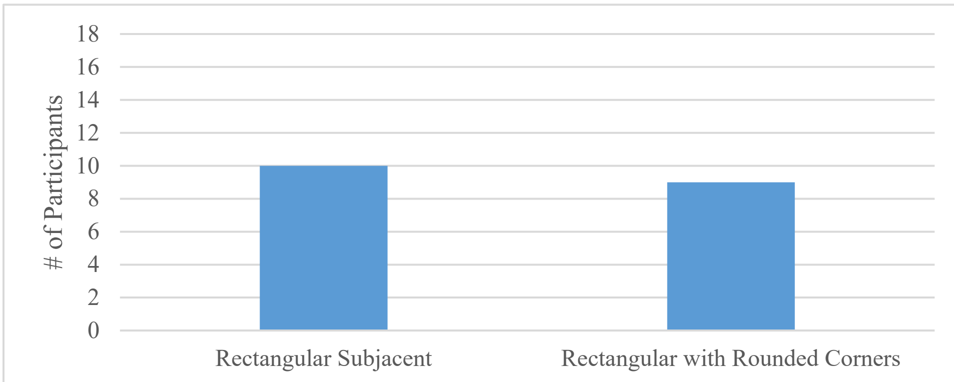


Figure 3.16 Pairwise comparison for in-person participants between Rectangular Subjacent and Rectangular w/ Rounded Corners designs.

In Figure 3.17, 10 participants chose the trapezoidal remote design over the 9 participants who chose the rectangular with rounded corners design.

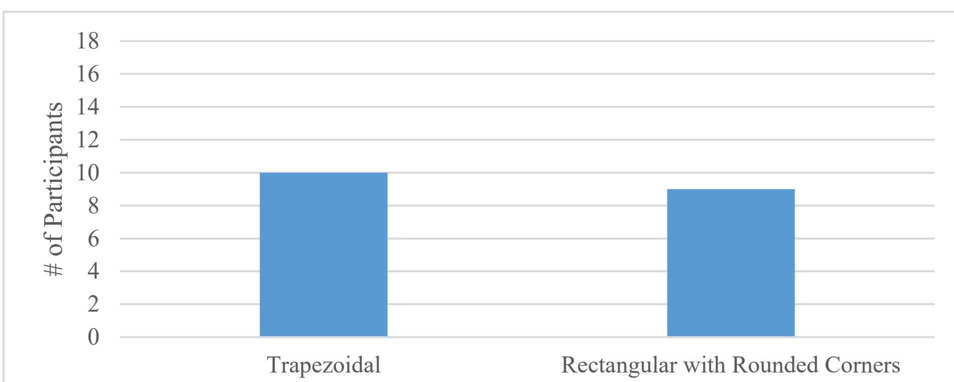


Figure 3.17 Pairwise comparison for in-person participants between Trapezoidal and Rectangular w/ Rounded Corners designs.

In Figure 3.18, 10 people chose the trapezoidal remote design over the 9 people that chose the rectangular stout design.

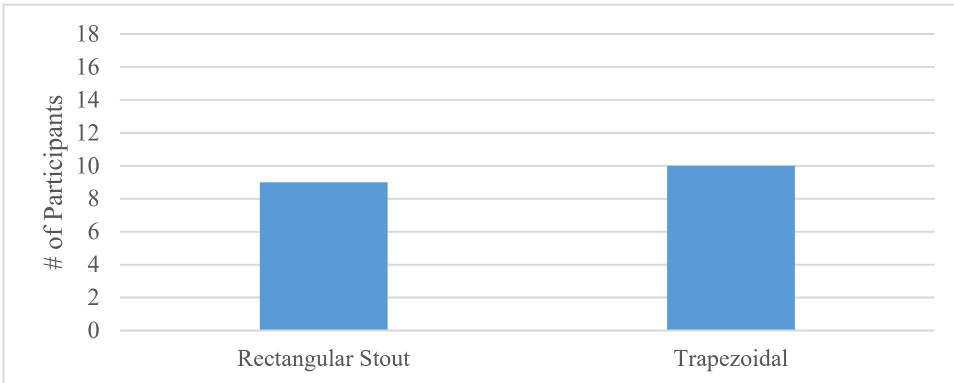


Figure 3.18 Pairwise comparison for in-person participants between Rectangular Stout and Trapezoidal designs.

In Table 3.3, hourglass round and rectangular stout were the top 1 and 2 remote designs that were most preferred from the set of pairwise comparisons based on the percentage value of how many times those designs were chosen, relative to its paired comparison, to the number of times it was possible to choose that design. The max values varied based on the number of possible times the respective remote design could have been chosen in the pairwise set.

Table 3.3 Pairwise ranking of in-person participants for remote control designs.

Remote Control Design	Max Value	Actual Value	Percentage	Rank
Hourglass Round	38	29	76%	1
Rectangular Stout	57	34	60%	2
Hourglass Subjacent	38	21	55%	3
Rectangular Subjacent	19	10	53%	4
Trapezoidal	38	20	53%	4
Rectangular w/ Rounded Corners	95	44	46%	6
Hourglass Flat	95	32	34%	7

n=19 participants. The Max Value represent the total number of times all 19 participants could have chosen the respective remote control design. The Actual Value represents how many times the respective remote control design was chosen from the 19 total participants.

From the results of the pairwise comparisons, the consequent design elements could be inferred. Table 3.4 shows the results of the most preferred design element for each pairwise comparison. For comparison #1, 53% of participants chose the pinched waist element over flat sides. 79% of participants preferred the narrow-rounded bottom design feature versus the flat bottom for comparison #2. 84% of participants selected the rounded top and bottom design elements over the flat top and bottom features for comparison #3. For comparison #4, 74% preferred rounded sides rather than the pinched waist feature. 68% of people chose the rounded top feature over the flat top feature for comparison #5. For comparison #6, 58% of participants chose rounded sides over flat sides. For comparison #7, 53% of participants preferred the wide-rounded bottom feature over the flat bottom feature. 53% chose tapered sides over flat sides for comparison #8.

53% of people chose tapered sides over rounded sides for pairwise comparison #9.

Table 3.4 Consequent design elements that were chosen from the selected set of paired comparisons for in-person participants.

Pairwise Comparison #1 Hourglass Flat v. Rectangular w/ Rounded Corners	**Pinched Waist** 53%	**Flat Sides** 47%
Pairwise Comparison #2 Hourglass Flat v. Hourglass Subjacent	**Flat Bottom** 21%	**Narrow Rounded Bottom** 79**%**
Pairwise Comparison #3 Hourglass Flat v. Hourglass Round	**Flat Top and Bottom** 16%	**Rounded Top and Bottom** 84%
Pairwise Comparison #4 Hourglass Flat v. Rectangular Stout	**Pinched Waist** 26%	**Rounded Sides** 74%
Pairwise Comparison #5 Hourglass Round v. Hourglass Subjacent	**Rounded Top** 68%	**Flat Top** 32%
Pairwise Comparison #6 Rectangular w/ Rounded Corners v. Rectangular Stout	**Flat Sides** 42%	**Rounded Sides** 58%
Pairwise Comparison #7 Rectangular w/ Rounded Corners v. Rectangular Subjacent	**Flat Bottom** 47%	**Wide Rounded Bottom** 53%
Pairwise Comparison #8 Rectangular w/ Rounded Corners v. Trapezoidal	**Flat Sides** 47%	**Tapered Sides** 53%
Pairwise Comparison #9 Rectangular Stout v. Trapezoidal	**Rounded Sides** 47%	**Tapered Sides** 53%

3.7 Mann Whitney Test Results by Demographics

3.7.1 Gender

For the quality of appearance, there was no significant differences in Likert responses between gender and the attributes of proportion, shape, and configuration. For the quality of usability, a difference was found between gender and the rectangular stout design for the attribute of configuration ($U = 17.500$, $p < 0.05$).

3.7.2 Age

For the qualities of appearance and usability, no differences were found between age and the remote designs that were chosen for all attributes of proportion, shape, and configuration.

3.7.3 Design Experience

For the qualities of appearance and usability, no differences were found between those participants with design experience and the remote designs that were chosen for all attributes of proportion, shape, and configuration.

3.8 Discussion

From the Likert responses, the hourglass subjacent and hourglass round designs were rated the highest for appearance and usability. Both designs share the pinched-waist and rounded bottom features; the main difference is that the hourglass round has a rounded top instead of a flat top like the hourglass subjacent design. The qualities of appearance and usability seem to go together; when one design was most preferred for appearance, it was also most preferred for usability or vice versa. This observation suggests that it can be difficult to separate these two qualities apart when a design has been identified to be the highest rated across the attributes of proportion, shape, and configuration.

Some remote designs were not equally preferred for the qualities of aesthetics and usability for specific attributes. For example, for the rectangular with rounded corners designs, people preferred the appearance of its proportion more than the usability of its proportion. For the rectangular stout design, participants preferred the usability of its shape more than the appearance of its shape. Depending on the remote design and its representative geometric form, participants could favor one quality over the other; certain participants prefer appearance over usability or vice versa for a given design. Applying this contrast could be useful if the intent is to design a remote control that emphasizes one quality over another to address a specific need.

The pairwise comparison ranking shows that the hourglass round design ranked highest versus all other designs. From Table 3.4 comparison #5, 68% of the participants preferred the rounded top compared to 32% of the participants who preferred the flat top. Of the 9 pairwise comparisons, 7 of those comparisons were a contrast between rectilinear and round design features. From the 7 comparisons of rectilinear versus round design features, most participants preferred the designs with the contrasting round features in 6 of those comparisons.

Recent studies have researched to see if the human brain finds certain shapes more appealing than others. Clive Bell, a British art critic, has postulated that there is a significant form, comprised of lines and shapes, that qualifies a given work as art (Gambino, 2013). He goes on to mention that these aesthetic qualities trigger a pleasing response in the viewer, and that the response is universal no matter where and when that viewer lives (Gambino, 2013).

An art exhibition, Beauty and the Brain Revealed, was conducted at the AAAS Art Gallery in Washington D.C. was trying to answer the question 'Why do we find some works of art so appealing?'. The exhibition wanted to examine how the brain perceives abstract sculpture. Scientists involved with this study ultimately found that visitors like shapes with gentle curves as opposed to sharp point (Gambino, 2013). The article written by Gambino (2013) goes on to mention that shallow convex surface curvature is a characteristic feature of living organisms. Gambino (2013) further mentions in her article that the brain may have evolved to process information, such as smoothly rounded shapes, in order to guide survival behaviors such as eating, mating, and predator evasion. The brain devotes less processing to high curvature jagged forms which tend to be inorganic and less important (Gambino, 2013). From a participant's open-ended response from the Likert survey about the hourglass round design, it was mentioned that rounded edges are visually appealing.

A study conducted in 2013 looked to understand how architecture impacts behavior, specifically the contour of architectural spaces. The variable of contour was chosen because of number of previous studies have shown that it affects aesthetic judgments (Vartanian, et al., 2018). Test subjects were shown 200 images of architectural spaces; half of the images were of spaces designated by rectilinear objects and the other half of curvilinear objects. Functional magnetic resonance imaging (fMRI) scans were performed while participants evaluated the images. When contemplating beauty, curvilinear contour activated the anterior cingulate cortex exclusively; a region of the brain strongly responsive to the reward properties and emotional salience of objects (Vartanian, et al., 2018). As expected, the study found that participants were more likely to judge spaces as beautiful if they were curvilinear than rectilinear (Vartanian, et al., 2018).

For comparison #4, it is unclear why rounded sides were preferred over the pinched-waist feature. Since this pairwise set compares different types of round features, the previously mentioned studies do not elaborate on preferences when it comes to comparing round features alike. The article from Gambino (2013) could provide a possible explanation for this result. It mentions that the brain processes information concerning smoothly rounded shapes; the brain devotes less processing to high curvature jagged forms (Gambino, 2013). This provides insight that the degree of curvature could explain why the rectangular stout design is preferred over the hourglass flat design. In terms of curve depth, the rectangular stout design has a shallower curvature than the hourglass flat design. It is unknown how the length of curvature between these two designs affects judgement.

For comparison #9, no clear explanation can be provided for why tapered sides are preferred over rounded sides. Previously mentioned studies show curvilinear shapes are preferred over rectilinear ones, but this does not apply for this comparison. When analyzing the Likert results, the rectangular stout design was rated higher than the trapezoidal except when comparing the quality of appearance for the attribute of configuration where they were rated equally the same. When analyzing open-ended responses from the Likert survey, many comments were made with respect to the use of the remote buttons and the respective remote shape. It is unknown what impact the functionality of the remote buttons has on judging aesthetics between these two remotes. In the article by Khalighy S. , Green, Scheepers, & Whittey (2015), they created a selection task in their study, similar to the pairwise comparison between remote controls, that involved images with simple geometric figures with no indication of any functionality. From Khalighy S. , Green, Scheepers, & Whittey (2015), in the absence of function, only beauty exists and consequently the judgement of preference is only based on beauty. In addition to the lack of explanation why tapered sides were preferred over rounded sides, only 19 participants were surveyed. Increasing the number of participants could provide more clout to the recorded values causing the results to sway more favorably towards one direction.

This study was able to provide insight for design elements that could be salient in the context of paired comparisons. In Table 3.4, some of the comparisons were too close to delineate which design feature was preferred from the sample of participants. Some comparisons, namely comparisons 2 – 5, showed more strength to be swayed more favorably in one direction over the other.

3.9 Conclusion

3.9.1 Summary

It was hypothesized that participants' attitudes towards appearance and usability of the 7 different remote control designs would be determined from the Likert survey. From participant's attitudes, preferred and non-preferred remote control designs from the sample of participants could be determined. From the pairwise comparison survey, salient design elements could be determined with reference to another remote control design of similar design elements.

A distinction was made between the two most preferred designs, hourglass round and hourglass subjacent, based on the pairwise comparison survey. Both designs share the pinched waist and rounded bottom design elements, with the main difference being that the hourglass round has a rounded top instead of a flat top like the hourglass subjacent design. 68% of participants voted in favor of the hourglass round design being more appealing to the 32% of participants that voted in favor of the hourglass subjacent design; the contrasting design element between the two designs was the rounded top. From the 9 paired comparisons, 7 comparisons were a comparison between flat and round design elements. Out of the 7 comparisons with contrasting flat or round design elements, participants chose round features in 6 of those comparisons.

A study conducted at the AAAS Art Gallery in Washington D.C. found that visitors preferred shapes with gentle curves as opposed to a sharp point. A separate study conducted by Vartanian, et al. (2018) on the architectural impacts to behavior showed that participants were more likely to judge spaces as aesthetically pleasing if they were curvilinear instead of rectilinear. From these two studies, a similar relationship was observed in the preferred choices from participants of round versus flat design elements for 6 of the 7 relevant pairwise comparisons.

3.9.2 Limitations

The methods described in this study provide insight for salient design elements when using a paired comparison approach, but this does not necessarily provide a procedure for identifying globally accepted salient design elements. The set of paired comparions chosen did not include a full combinatorial set of comparions; from the 7 remote designs, a full combinatorial set would include 21 paired comparisons. The set of paired comparisons chosen were based on remotes that shared similar design elements with the exception of 1 set of contrasting design elements. Making additional paired comparisons, from those that were already chosen, would result in the inability to single-out individual consequent elements because there would be more than 1 set of contrasting design elements to choose from.

This study gave insight to preferred design elements in the context of paired comparisons, but a statistically appropriate sample size would be needed to determine preferred design elements with confidence. Only 19 participants were chosen for this study, and the results could be questioned due to its statistical signifcance.

Two conducted studies mentioned in the discussion section showed that curvilinear shapes were preferred to rectilinear ones in their respective contexts, but neither study goes to examine the effects that function has on the judgement of aesthetics. Both previously mentioned studies were primarily based on shapes, while the determination of salient design elements using a remote control involves the use of functional buttons when judging aesthetics. It is unclear what impact the functional buttons had in the Likert and pairwise comparison surveys.

3.9.3 Future Work

Future studies could consider making the pairwise comparison survey evaluate more paired sets of remote controls from the entire set of remote designs. The pairwise survey in this study only compared 2 remote control designs at a time using remotes that shared similar design elements except 1 contrasting design element. An ideal pairwise comparison survey would allow all remote control designs to be compared with all other designs; this could allow a ranking system of preferred design elements to be established.

Increasing the number of remote control designs that are compared against each other could also be another area of future study. It is typical in a real-world setting that many different remote controls are displayed on shelves for customers to compare against. This pairwise comparison study could be extended to include more than 2 remotes at a time for comparison.

CHAPTER IV

ADMINISTERING VISUAL QUESTIONNAIRES OF AESTHETICS AND SUBJECTIVE USABILITY TO ONLINE PARTICIPANTS

4.1 Introduction

The internet is a resourceful tool that has contributed to many scientific forms of study. More notably, the internet has provided methods for conducting surveys through electronic mail and the world-wide web (Schonlau, Fricker Jr., & Elliott, 2002). Using the questionnaires developed in Chapter 3, participants will be solicited from Amazon's Mechanical Turk (MTurk) crowdsourcing internet marketplace to administer the same questionnaires for the purposes of generalizing results due to limited response rates from conducting in-person surveys. The administering of the online surveys will not include gathering eye tracking data since participants will be at remote locations. It is expected that there will be a correlation between the Likert survey results to the results from the pairwise comparison survey.

4.2 Background

Extension professionals and survey researchers are interested in generalizing findings due to low response rates obtained from surveys (Radhakrishna & Doamekpor, 2008). In their review of Research in Brief articles published in the Journal of Extension, Lindner & Wingenbach (2002) found that non-response error was a threat to external validity of 82% of articles. Generalizing is related to external validity which is the degree that conclusions in a study would hold for other persons in other places and at other times (Trochim, 2006). According to Trochim (2006), there are two approaches for providing evidence for a generalization.

- In a sampling model, a population is identified to generalize to. A sample is drawn from the identified population. Since the sample represents the population, the results can be generalized back to the population.
- In a proximal similarity model, generalizability contexts are chosen that are more and less similar than the study of interest. A gradient of similarity is created when different generalizable contexts are placed in terms of their relative similarities.

With the emergence of the World Wide Web and electronic mail, the internet has opened many areas for surveying (Fricker Jr. & Schonlau, 2002). Internet-based surveying offers unique capabilities as an alternative to conventional survey modes (Fricker Jr. & Schonlau, 2002). Internet surveys have become popular because of four popular assumptions: they are less time consuming, they are just as good or better than more traditional surveys, they are cheaper to conduct, and they are easier to execute (Schonlau, Fricker Jr., & Elliott, 2002).

There are several advantages of online survey research that has made this method of surveying popular among researchers in a variety of disciplines. An advantage of online survey research is the ability of the internet to provide access to groups who would be difficult to reach through other channels (Garton, Haythornthwaite, & Wellman, 1997; Wellman, 1997). A second advantage of online survey-research is the ability of a researcher to reach thousands of people with common characteristics in a short amount of time even when separated by great distances (Bachmann & Elfrink, 1996; Garton, Haythornthwaite, & Wellman, 1997; Taylor, 2000; Yun & Trumbo, 2000). A third advantage of online survey-research is that it can save money from moving to an electric medium from a paper format (Bachmann & Elfrink, 1996; Couper, 2000; Llieva, Baron, & Healey, 2002; Yun & Trumbo, 2000).

4.2.1 Mechanical Turk Validity

Mechanical Turk (MTurk), run by Amazon.com, provides an online workforce that lets people complete work in return for compensation (Goodman, Cryder, & Cheema, 2013). Researchers have found that at least 16 of the top 30 universities use MTurk, but it is not yet widely accepted as a participant source at this time (Goodman, Cryder, & Cheema, 2013). Goodman, Cryder, & Cheema (2013) have mentioned that research of MTurk has not identified significant differences between MTurk participants and traditional samples with the exception of one study involving MTurk participants and non-MTurk participants (Paolacci, Chandler, & Ipeirotis, 2010) in the Asian Disease problem (Tversky & Kahneman, 1981).

With MTurk growing as a valuable research for behavioral research, some concerns still remain. Researchers are concerned that MTurk participants do not pay enough attention to study materials, the use of international participants may provide language or cultural differences, and the workers who participate in studies for low monetary compensation may be peculiar in their attitudes about money and time which are variables of interest to decision-making researchers (Goodman, Cryder, & Cheema, 2013). To overcome some of these concerns, questionnaires including those administered through MTurk will have screening questions that will be easily recognizable to ensure participants are paying attention to study materials; any participants that incorrectly answer screening questions will be disregarded from the study. MTurk participants will be screened for English fluency and selected within the US. Compensation for participants will depend on the available budget to conduct this study; past studies conducted by the ISE department at Mississippi State that used MTurk for research purposes will be examined for appropriate compensation amounts that would avoid unusual responses to behavioral questions.

4.3 Research Objectives

The objective of this study it to determine attitudes towards appearance and usability of the 7 remote control designs with online participants. The study will determine which design elements online participants find attractive when asked to choose between a paired set of remote control designs. It is anticipated that there will be a correlation between the Likert survey results to the results from the pairwise comparison survey.

4.4 Methods

4.4.1 Participants

The study included 300 male and female participants found using the MTurk online marketplace. Participants were at least 18 years of age with adequate literacy and fluency in English. All selected participants lived in the U.S. Each participant was a current user of a remote control device.

4.4.2 Experimental Design

Online participants were given a series of questionnaires in three parts. For the first part of the questionnaire, participants provided responses to each remote control device separately for all 7 remote control designs regarding its appearance as in Figure 3.1. They were asked to rate their aesthetic attitudes and preferences of each remote control for the following: proportion, shape, and configuration. Participants were asked open-ended questions regarding items they liked and disliked bout each design's appearance.

For the second part of the questionnaire, participants provided responses to each remote control separately for all 7 remote control designs regarding its usability as in Figure 3.2. They were asked to rate their usability attitudes and preferences of each remote control for the following: proportion, shape, and configuration. Participants were asked open-ended questions regarding items they liked and disliked about each product's ease of use.

For the third part of the questionnaire, participants were presented with 10 sets of paired remote control designs. Within each pair, a specific set of design elements were compared against each other while all other design elements remained similar. Participants were forced to choose which remote control design they favored based on appearance. Figure 3.3 shows an example of a paired set of remote control designs and their contrasting design elements.

4.5 Data Analysis

For analyzing Likert data, the following description statistics were calculated: frequency distribution, median values, and percentages. The Mann Whitney test was used to detect differences between the following independent groups: remote control design and gender, remote control design and age, and remote control design and design experience. For analyzing results from the pairwise comparison study, frequency distributions and percentages were calculated.

4.6 Results Summary

4.6.1 Likert Results by Proportion

Table 4.1 and Table 4.2 show results from the Likert appearance and usability surveys for the attributes of proportion, shape, and configuration. For appearance, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 3.52) and hourglass round (*Mdn* = 4, *M* = 3.59) proportion versus all other designs. For usability, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 3.62) and hourglass round (*Mdn* = 4, *M* = 3.51) proportion over all other designs. For appearance, participants least preferred the hourglass flat's proportion (*Mdn* = 3, *M* = 3.01). For usability, the trapezoidal design's proportion was least preferred (*Mdn* = 3, *M* = 2.98). Figure 4.1 and Figure 4.2 show the frequency distribution for appearance and usability respectively for all remote designs that concern the attribute of proportion.

4.6.2 Likert Results by Shape

For appearance of a remote control, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 3.59) and hourglass round (*Mdn* = 4, *M* = 3.65) shape over all remote designs. For usability of a remote control, participants chose the hourglass subjacent (*Mdn* = 4, *M* = 3.63) and hourglass round (*Mdn* = 4, *M* = 3.62) shape over all designs. For appearance, the hourglass flat design was least preferred for the attribute of shape

(*Mdn* = 3, *M* = 2.90). For usability, the least preferred design for the attribute of shape was the trapezoidal design (*Mdn* = 3, *M* = 2.88). Figure 4.3 and Figure 4.4 show the frequency distribution for the qualities of appearance and usability for all remote design for the attribute of shape.

4.6.3 Likert Results by Configuration

For appearance of a remote control, participants preferred the hourglass subjacent (*Mdn* = 4, *M* = 3.52) and hourglass round (*Mdn* = 4, *M* = 3.63) configuration over all other designs. For usability, the hourglass subjacent (*Mdn* = 4, *M* = 3.57) and hourglass round (*Mdn* = 4, *M* = 3.55) configuration was preferred over all designs. Regarding appearance, the least preferred design for the attribute of configuration was the hourglass flat design (*Mdn* = 3, *M* = 3.06). For usability, participants least preferred the trapezoidal design's configuration (*Mdn* = 3, *M* = 3.02). Figures 4.5 and 4.6 show the frequency distribution for appearance and usability for the attribute of configuration across all remote controls.

Table 4.1 Likert online appearance survey results for proportion, shape, and configuration categories.

	Proportion		Shape		Configuration	
	Median	**Mean**	**Median**	**Mean**	**Median**	**Mean**
Rectangular w/ Rounded Corners	3	3.12	3	2.94	3	3.12
Hourglass Flat	3	3.01	3	2.90	3	3.06
Rectangular Subjacent	3	3.28	3	3.22	3	3.31
Hourglass Subjacent	4	3.52	4	3.59	4	3.52
Hourglass Round	4	3.59	4	3.65	4	3.63
Trapezoidal	3	3.03	3	2.91	3	3.14
Rectangular Stout	3	3.26	3	3.10	3	3.30

Table 4.2 Likert online usability survey results for proportion, shape, and configuration categories.

	Proportion		Shape		Configuration	
	Median	**Mean**	**Median**	**Mean**	**Median**	**Mean**
Rectangular w/ Rounded Corners	3	3.04	3	2.98	3	3.08
Hourglass Flat	3	3.00	3	2.96	3	3.07
Rectangular Subjacent	3	3.12	3	3.10	3	3.18
Hourglass Subjacent	4	3.62	4	3.63	4	3.57
Hourglass Round	4	3.51	4	3.62	4	3.55
Trapezoidal	3	2.98	3	2.88	3	3.02
Rectangular Stout	3	3.11	3	3.08	3	3.13

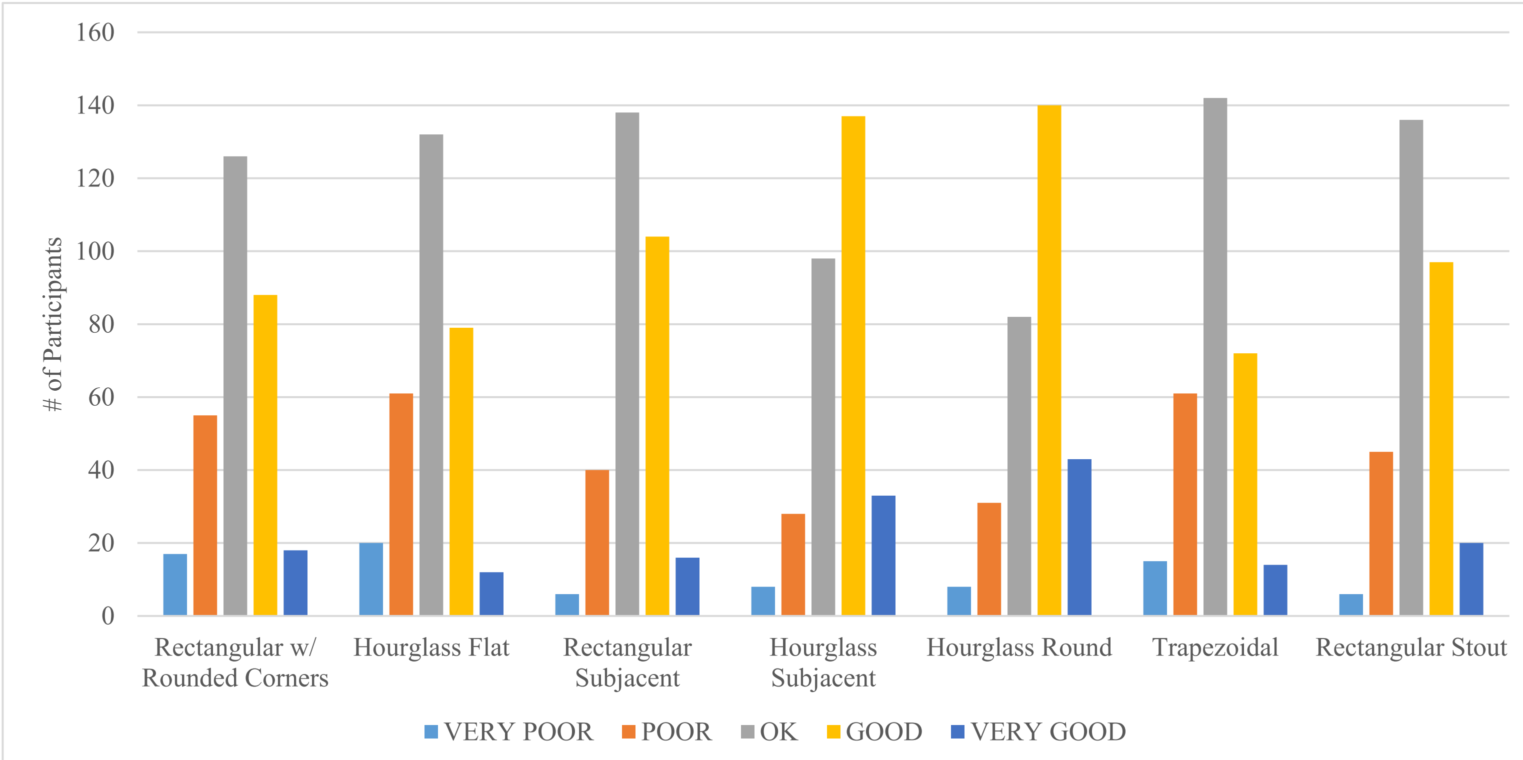


Figure 4.1 Frequency distribution for online Likert appearance survey regarding proportion of remote control designs.

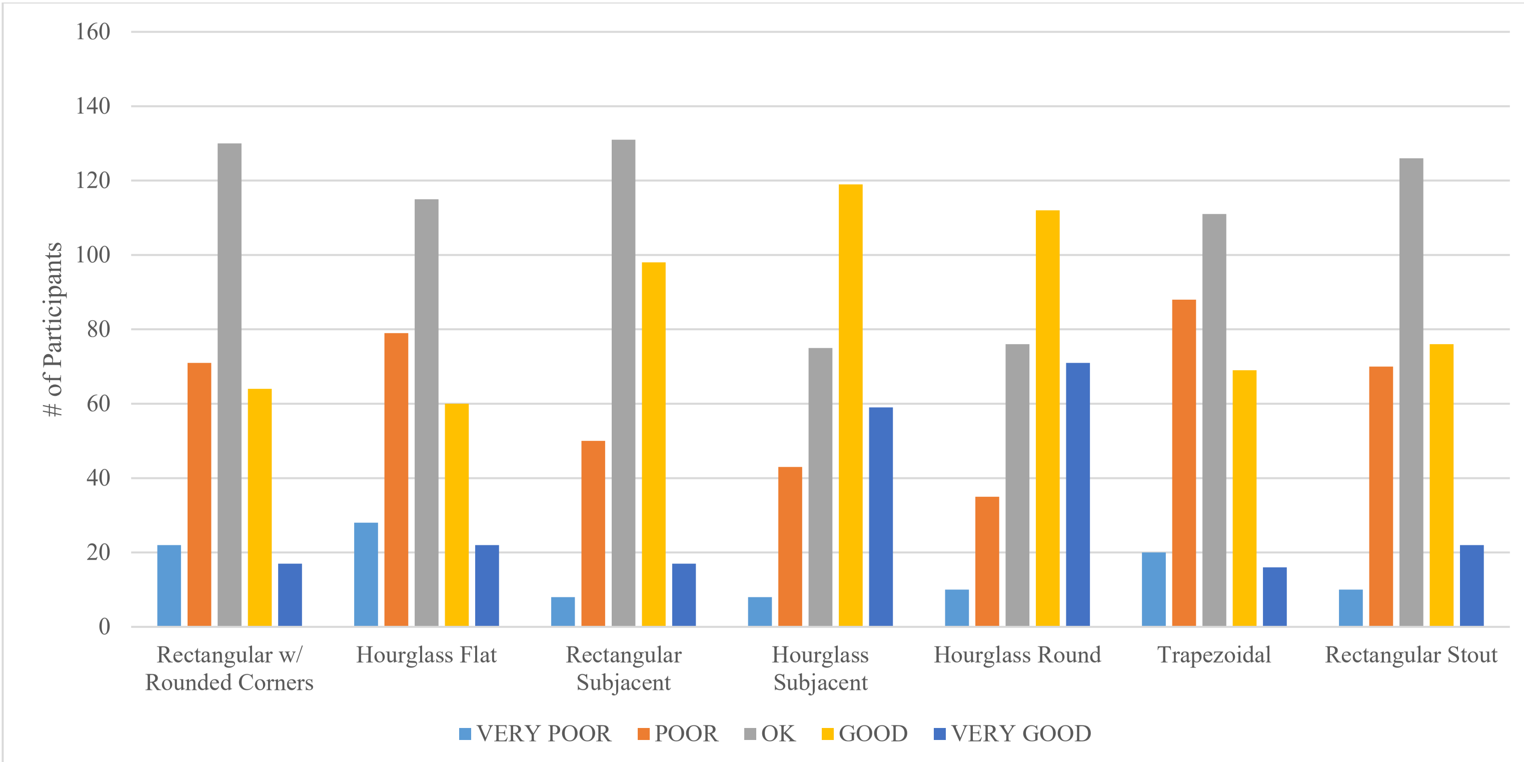


Figure 4.2 Frequency distribution for online Likert appearance survey regarding shape of remote control designs.

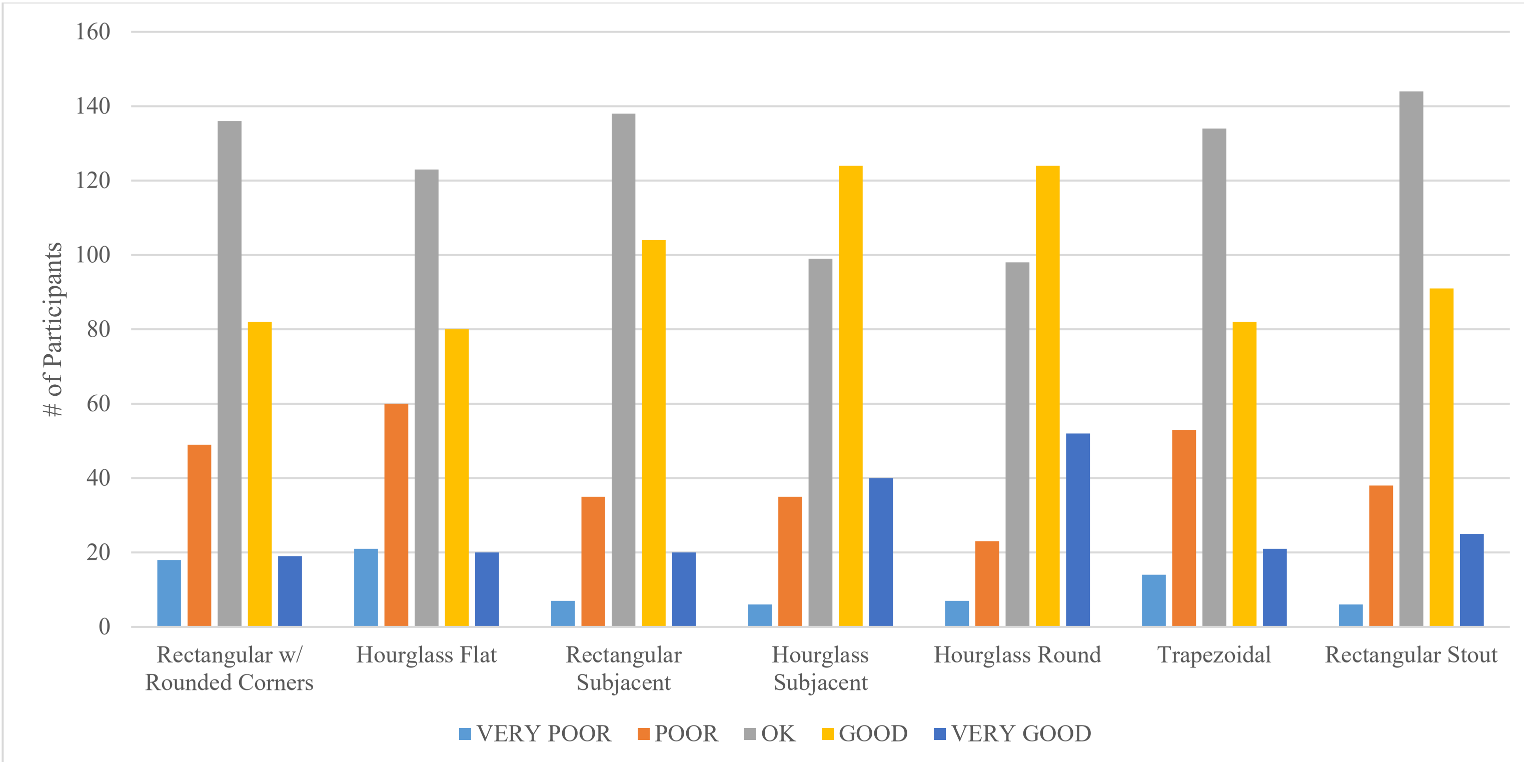


Figure 4.3 Frequency distribution for online Likert appearance survey regarding configuration of remote control designs.

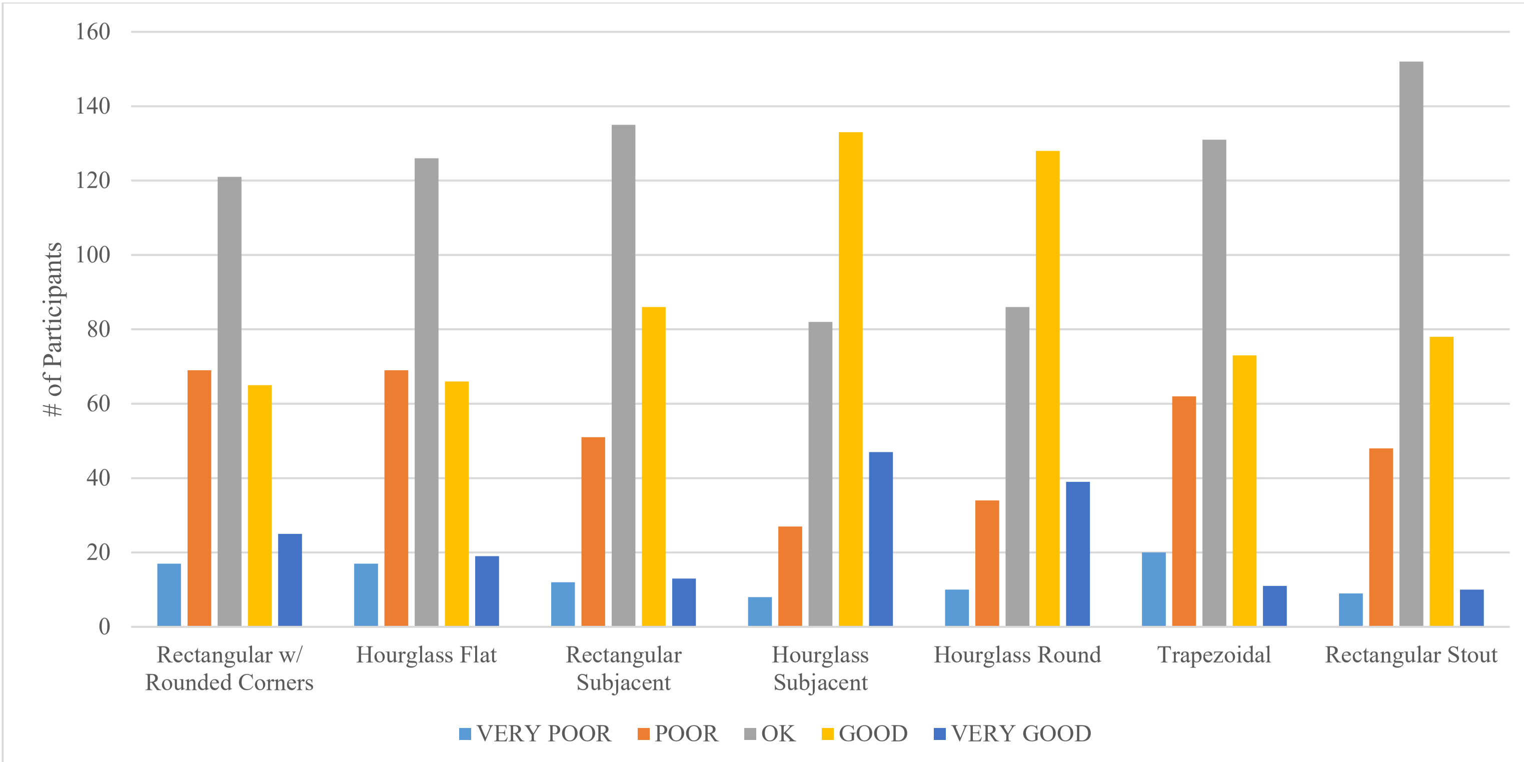


Figure 4.4 Frequency distribution for online Likert usability survey regarding proportion of remote control designs.

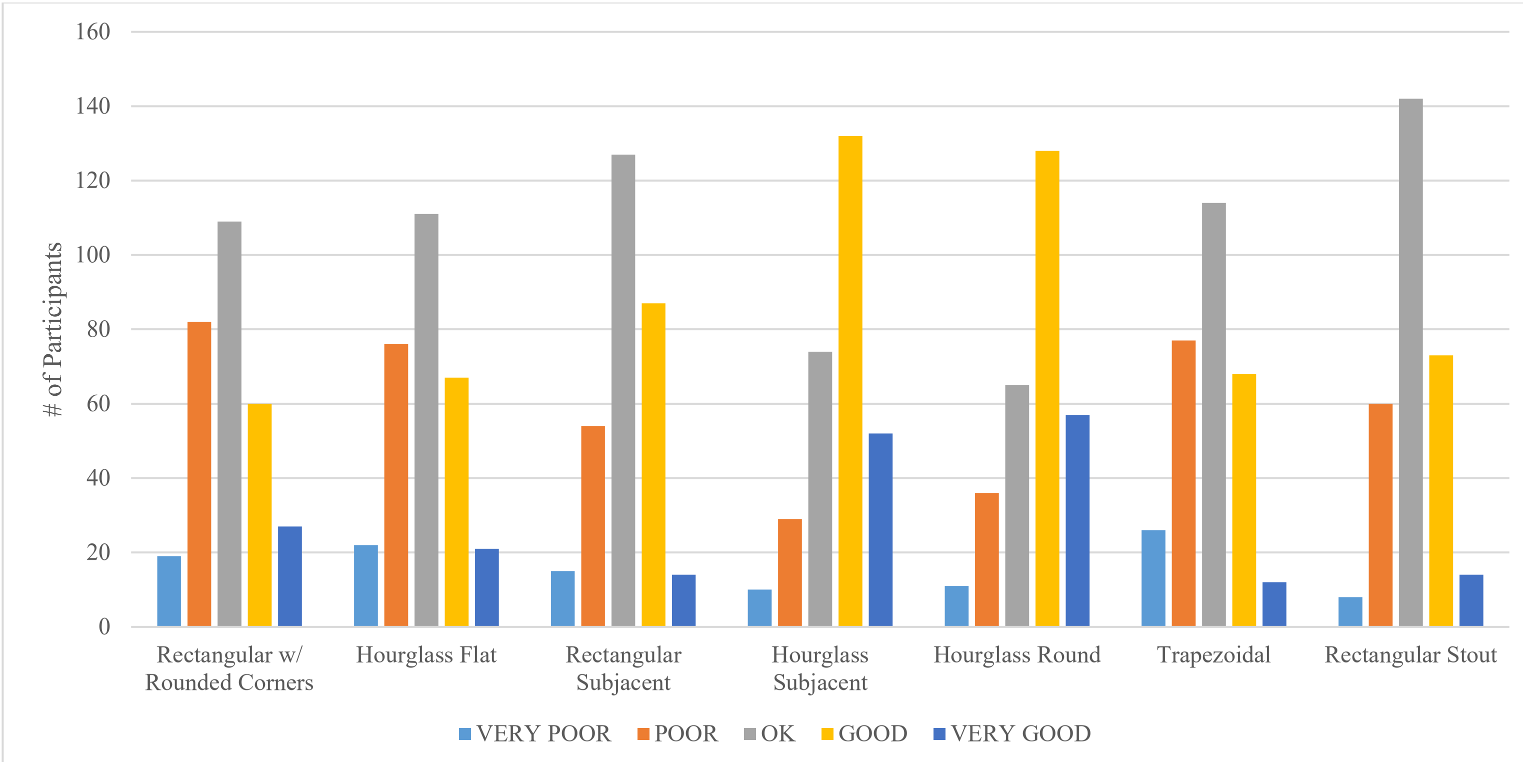


Figure 4.5 Frequency distribution for online Likert usability survey regarding shape of remote control designs.

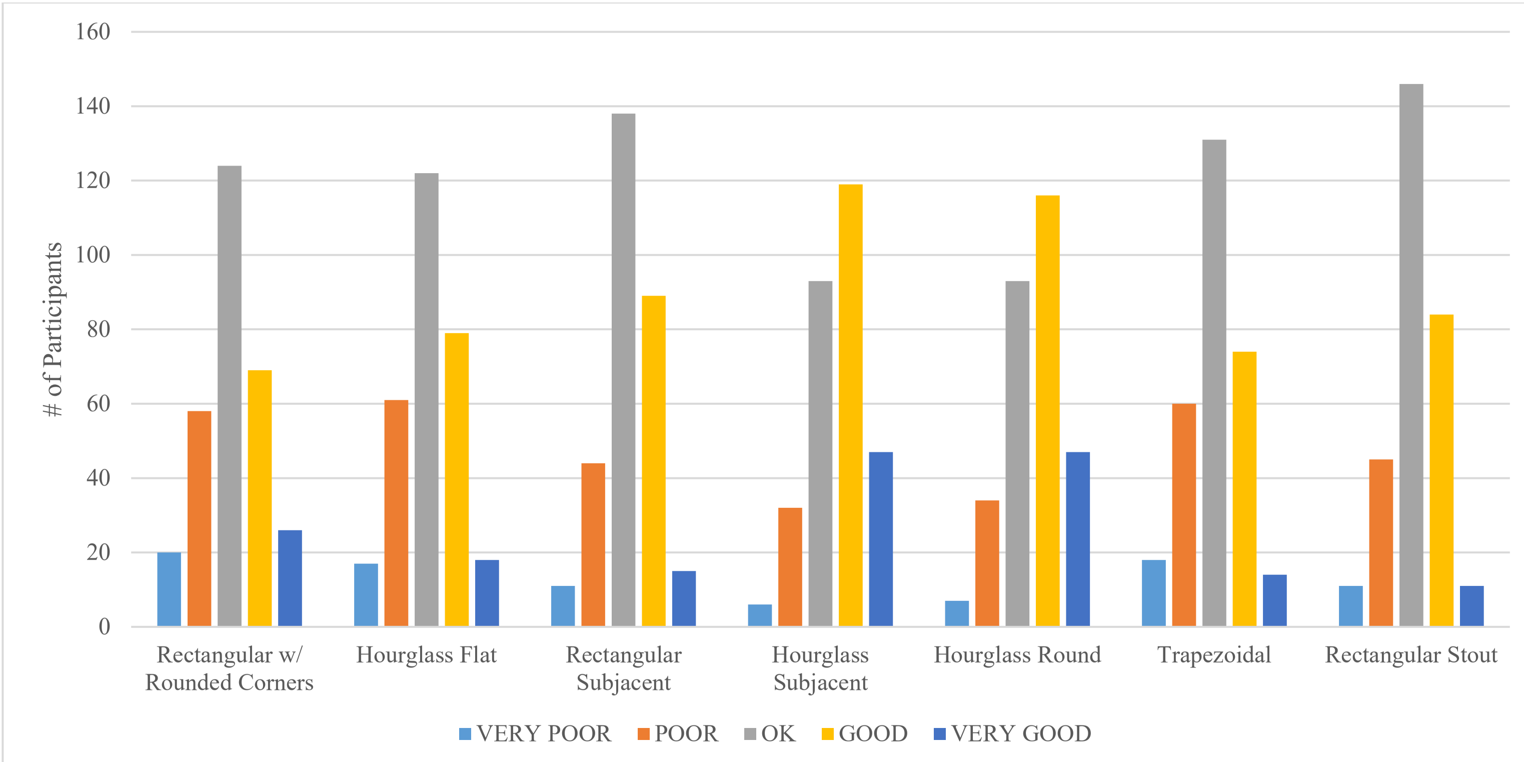


Figure 4.6 Frequency distribution for online Likert usability survey regarding configuration of remote control designs.

4.6.4 Likert Results of Pairwise Comparison Survey

In Figure 4.7, 159 participants preferred the hourglass flat design while 91 participants chose the rectangular with rounded corners design.

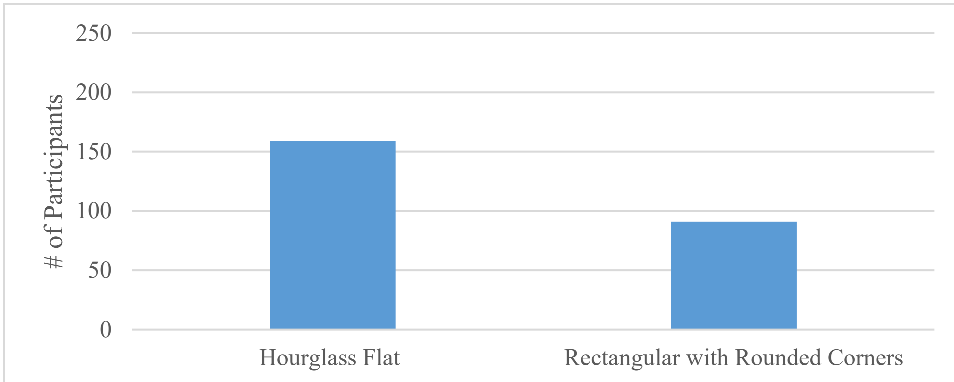


Figure 4.7 Pairwise comparison for online participants between Hourglass Flat and Rectangular w/ Rounded corners designs.

In Figure 4.8, 200 participants preferred the hourglass subjacent design while 50 participants preferred the hourglass flat design.

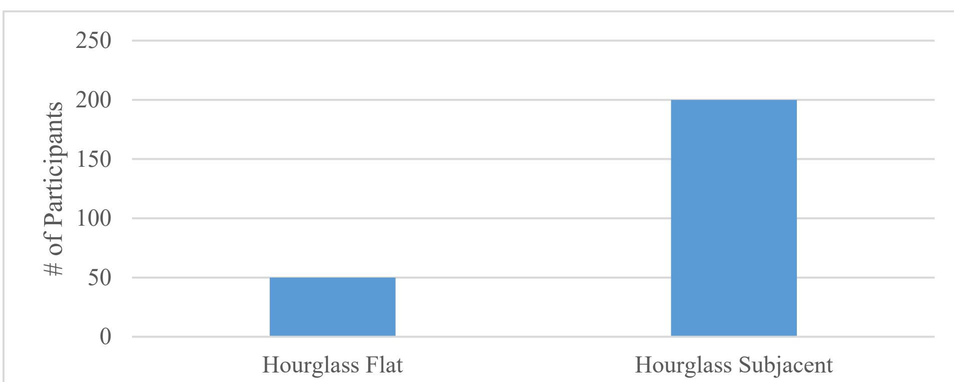


Figure 4.8 Pairwise comparison for online participants between Hourglass Flat and Hourglass Subjacent designs.

In Figure 4.9, 195 participants selected the hourglass round design versus the 55 participants that chose the hourglass flat design.

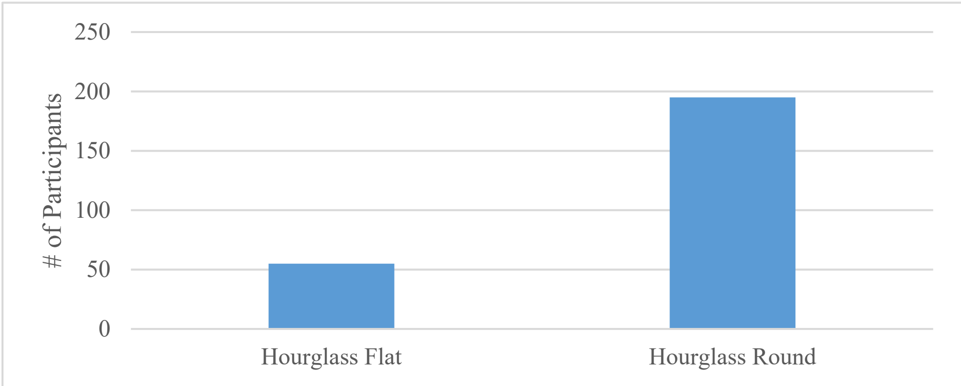


Figure 4.9 Pairwise comparison of Hourglass Flat and Hourglass Round designs.

In Figure 4.10, an equal number of participants chose between the rectangular stout and hourglass flat designs.

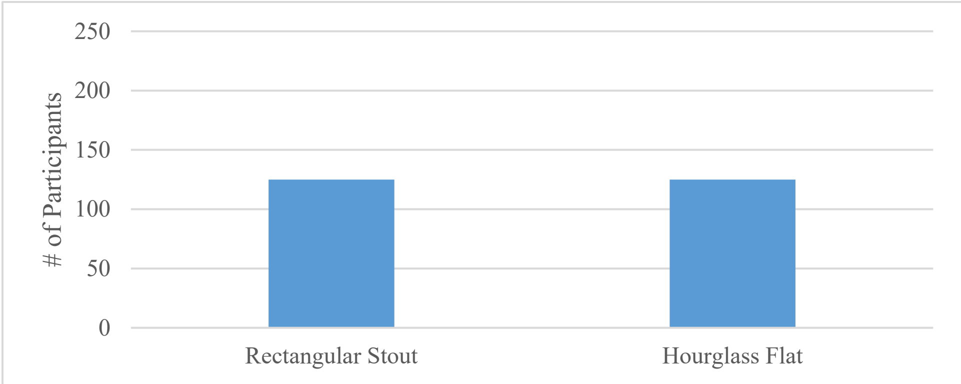


Figure 4.10 Pairwise comparison of Rectangular Stout and Hourglass Flat designs.

In Figure 4.11, 160 participants selected the hourglass round design over the 90 participants that selected the hourglass subjacent design.

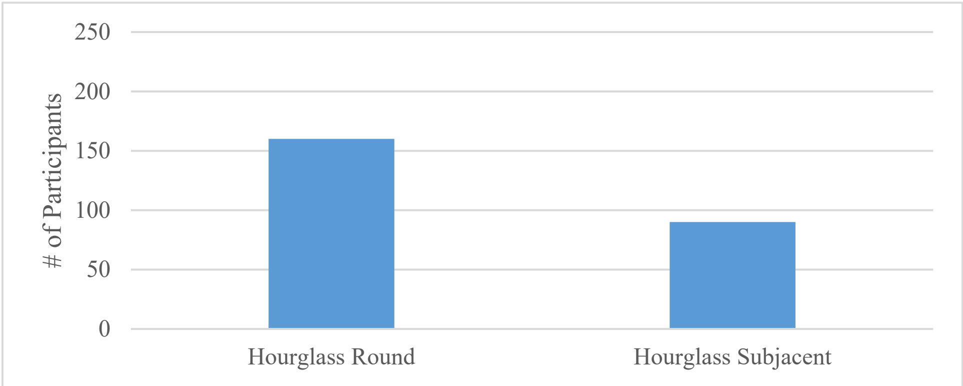


Figure 4.11 Pairwise comparison between Hourglass Round and Hourglass Subjacent designs.

In Figure 4.12, 173 participants chose the rectangular stout design over the 77 participants that selected the rectangular with rounded corners design.

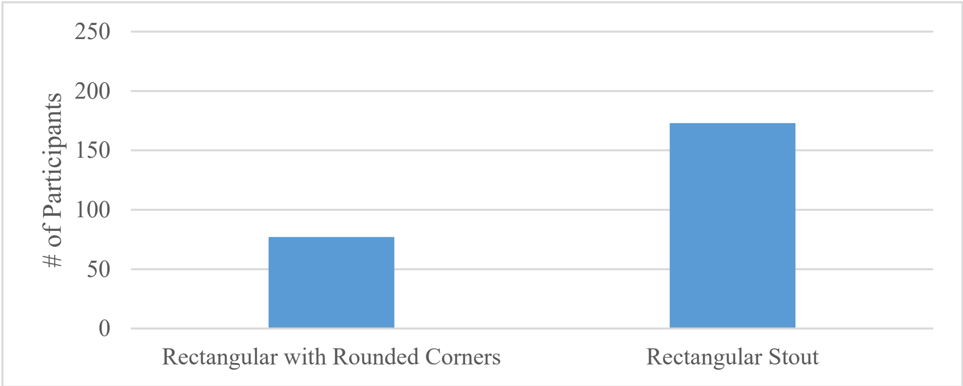


Figure 4.12 Pairwise comparison between Rectangular w/ Rounded Corners and Rectangular Stout designs.

In Figure 4.13, 172 people preferred the rectangular subjacent design over the 78 participants that preferred the rectangular with rounded corners design.

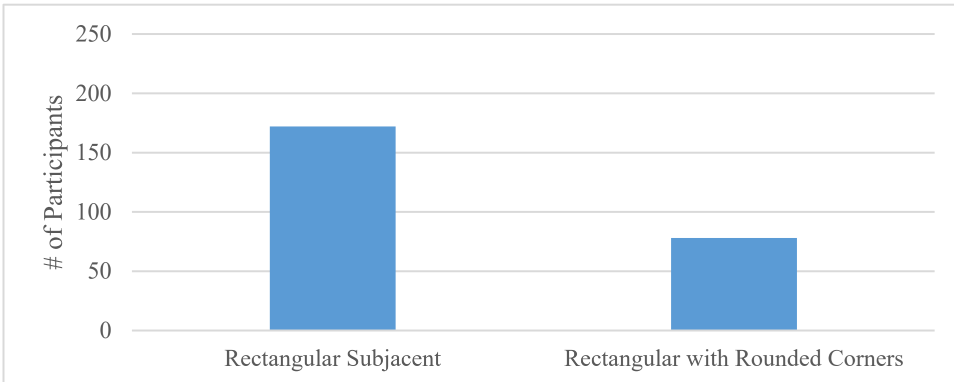


Figure 4.13 Pairwise comparison between Rectangular Subjacent and Rectangular w/ Rounded Corners designs.

In Figure 4.14, 134 participants preferred the trapezoidal design over the 116 participants that preferred the rectangular with rounded corners design.

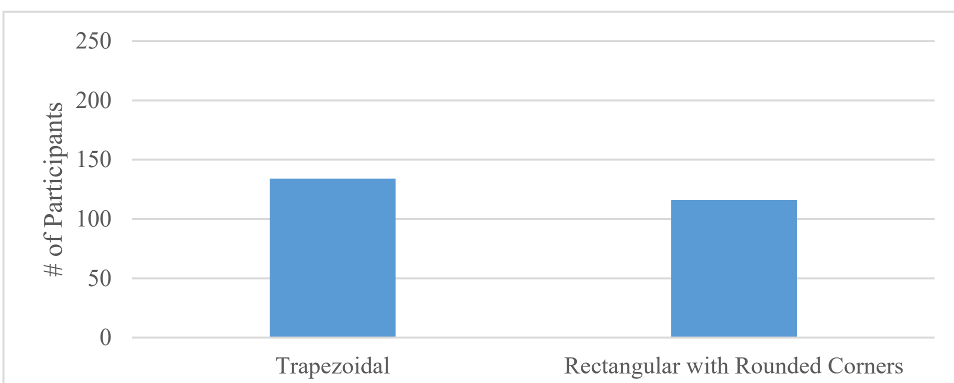


Figure 4.14 Pairwise comparison between Trapezoidal and Rectangular w/ Rounded Corners designs.

In Figure 4.15, 180 participants preferred the rectangular stout design over the 70 participants that preferred the trapezoidal design.

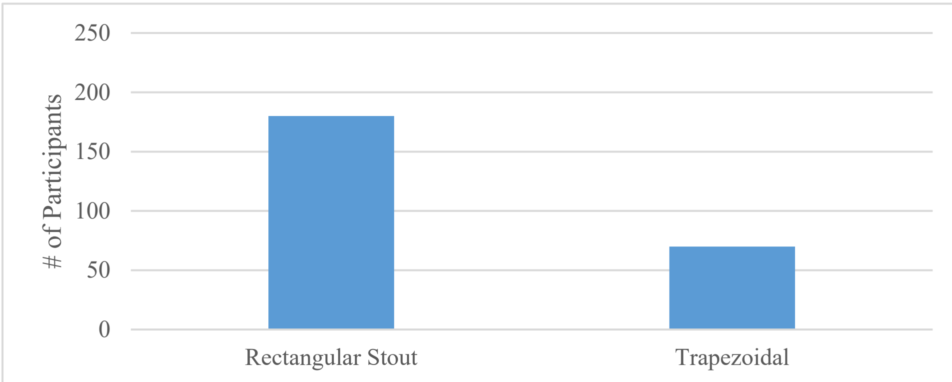


Figure 4.15 Pairwise comparison between Rectangular Stout and Trapezoidal designs.

In Table 4.3, the hourglass round and hourglass subjacent design were the top 1 and 2 preferred designs from the set of pairwise comparisons based on the percentage value of how many times those designs were chosen, relative to its paired comparison, to the number of times it was possible to choose that design. The max values varied based on the number of possible times the respective remote design could have been chosen in the pairwise set.

Table 4.3 Pairwise ranking of online participants for remote control designs.

Remote Control Design	Max Value	Actual Value	Percentage	Rank
Hourglass Round	500	355	71%	1
Rectangular Subjacent	250	172	69%	2
Rectangular Stout	750	478	64%	3
Hourglass Subjacent	500	290	58%	4
Hourglass Flat	1250	548	44%	5
Trapezoidal	500	204	41%	6
Rectangular w/ Rounded Corners	1250	453	36%	7

n=250 participants. The Max Value represents the total number of times all 250 participants could have chosen the respective remote control design. The Actual Value represents how many times the respective remote control design was chosen from the 250 total participants.

From the pairwise comparisons, the consequent design elements could be determined from the participants' results. Table 4.4 shows the preferred design elements for each comparison. From pairwise comparison #1, 64% of participants preferred the pinched waist feature over the 36% of participants the preferred flat sides. For comparison #2, 80% of participants preferred the narrow rounded bottom feature to the 20% that preferred the flat bottom. For comparison #3, 78% of people preferred the rounded top and bottom features to the 22% that preferred the flat top and bottom features. For pairwise comparison #4, the design element preference was split between the pinched waist and rounded sides features. For comparison #5, 64% of participants preferred the rounded top design element over the 36% of participants that preferred the flat top. For comparison #6, 69% of participants preferred rounded sides to the 31% that preferred flat sides. For comparison #7, 69% of participants preferred the wide rounded bottom to the 31% that preferred the flat bottom. For comparison #8, 54% of people chose tapered sides to the 46% of people that chose flat sides. For comparison #9, 72% of participants chose rounded sides over the 28% that chose tapered sides.

Table 4.4 Consequent design elements that were chosen from the selected set of paired comparisons for online participants.

Pairwise Comparison #1 Hourglass Flat v. Rectangular w/ Rounded Corners	**Pinched Waist** 64%	**Flat Sides** 36%
Pairwise Comparison #2 Hourglass Flat v. Hourglass Subjacent	**Flat Bottom** 20%	**Narrow Rounded Bottom** 80%
Pairwise Comparison #3 Hourglass Flat v. Hourglass Round	**Flat Top and Bottom** 22%	**Rounded Top and Bottom** 78%
Pairwise Comparison #4 Hourglass Flat v. Rectangular Stout	**Pinched Waist** 50%	**Rounded Sides** 50%
Pairwise Comparison #5 Hourglass Round v. Hourglass Subjacent	**Rounded Top** 64%	**Flat Top** 36%
Pairwise Comparison #6 Rectangular w/ Rounded Corners v. Rectangular Stout	**Flat Sides** 31%	**Rounded Sides** 69%
Pairwise Comparison #7 Rectangular w/ Rounded Corners v. Rectangular Subjacent	**Flat Bottom** 31%	**Wide Rounded Bottom** 69%
Pairwise Comparison #8 Rectangular w/ Rounded Corners v. Trapezoidal	**Flat Sides** 46%	**Tapered Sides** 54%
Pairwise Comparison #9 Rectangular Stout v. Trapezoidal	**Rounded Sides** 72%	**Tapered Sides** 28%

4.6.6 Open-ended responses from Likert surveys

From Table 4.5, 65% of the responses for the hourglass flat design were characterized as negative from the appearance survey. 61% of the responses for the rectangular with rounded corners design were also characterized as negative. For the hourglass round and hourglass subjacent designs, 61% and 63% of participants positively characterized those designs respectively.

Table 4.5 Percentage of participants that provided negative and positive open-ended responses for the appearance survey

Design	Type of Comment	
	Negative	Positive
Hourglass Flat	65%	41%
Hourglass Round	35%	61%
Hourglass Subjacent	44%	63%
Rectangular Stout	55%	48%
Rectangular Subjacent	49%	50%
Rectangular w /Rounded Corners	61%	40%
Trapezoidal	57%	40%

304 total participants

From Table 4.6, 52% of respondents negatively commented about the hourglass flat and rectangular with rounded corners design. 61% of respondents characterized the hourglass round design using positive comments. 66% of respondents also characterized the hourglass subjacent design using positive comments.

Table 4.6 Percentage of participants that provided negative and positive open-ended responses for the usability survey.

Design	Type of Comment	
	Negative	Positive
Hourglass Flat	52%	46%
Hourglass Round	30%	61%
Hourglass Subjacent	28%	66%
Rectangular Stout	43%	49%
Rectangular Subjacent	40%	52%
Rectangular w /Rounded Corners	52%	42%
Trapezoidal	51%	37%

297 total participants

4.7 Mann Whitney Test Results by Demographics

4.7.1 Gender

For the quality of appearance, there was no significant differences in Likert responses between gender and the attributes of proportion, shape, and configuration. For the quality of usability, there was no significant differences in Likert responses between gender and the attributes of proportion, shape, and configuration.

4.7.2 Age

For the quality of appearance, differences were found between age and the rectangular stout design for the attributes of proportion (U = 10185.500, $p < 0.05$), shape (U = 10988.500, $p < 0.05$), and configuration (U = 10961.000, $p < 0.05$). For the quality of usability, there were no significant differences in Likert responses between age and the attributes of proportion, shape, and configuration.

4.7.3 Design Experience

For the quality of appearance, no significant differences were observed in Likert responses between design experience and the attributes of proportion, shape, and configuration. For the attribute of usability, a difference was found between design experience and the hourglass subjacent design for the attribute of shape ($U = 5608.000$, $p < 0.05$).

4.8 Discussion

Likert results show that the hourglass subjacent and hourglass rounds designs were most preferred for the qualities of aesthetics and usability for all attributes of proportion, shape, and configuration. The qualities of appearance and usability seem to go together; when one design was most preferred for appearance, it was also most preferred for usability or vice versa. This observation suggests that it can be difficult to separate these two qualities apart when a design has been identified to be the highest rated across the attributes of proportion, shape, and configuration. Some remotes were not equally preferred for the qualities of appearance and usability for specific attributes. For the rectangular stout design, people preferred the appearance of its proportion more than the usability of its proportion. For the rectangular subjacent design, people preferred the appearance of its configuration more than the usability of its configuration. Depending on the design, participants prefer appearance over usability or usability over appearance.

The pairwise comparison ranking shows that the hourglass round design ranked highest out of all other designs. From Table 4.4, for all pairwise comparisons where there was a contrast between a round or rectilinear feature, a round feature was preferred for all relevant comparisons.

Curved shapes tend to be described as more beautiful and pleasant (Bertamini, Palumbo, Gheorghes, & Galatsidas, 2016). From Bertamini, Palumbo, Gheorghes, & Galatsidas (2016), people have a preference for curved versions of objects or abstract shapes. From Chapter 3, curvilinear objects are preferred over rectilinear ones. In the comparisons where participants were forced to choose between curvilinear or rectilinear design elements, not all comparisons were convincingly one-sided; some participants favored rectilinear-shaped remote controls. With designs that are primarily rectilinear, such as the rectangular with rounded corners and trapezoidal designs, 40% of participants' comments for each design was positive. Review of positive open-ended responses for these two remotes show that some participants evaluated the functoinality of the buttons in their judgement about the quality of appearance. Some participants openly responded about both remote designs as being simple and easy to use in their judgement about appearance; these type of responses concern the functionality of the remote control and not aesthetics. Although curvilinear objects were preferred based on previously presented literature, these studies did not include a component of user functionality in their research. User functionaltiy is playing a role in participants' attitudes toward the remote controls. It is unclear how much of an impact user functionality contributes to participants' judgements towards aesthetics.

With the hourglass round and hourglass subjacent designs being preferred by most respondents based on Likert results, there were still a significant amount of respondents that commented negatively about these remote designs. From open-ended responses of the appearance survey, some participants commented negatively about button functionality. Even when asking participants to judge a remote control design strictly on appearance, some participants made comments about its functionality. Button functionality could have swayed participants to comment negatively about the hourglass round and hourglass subjacent designs.

The type of design elements used impacted how some users envisoined using the remote controls. For some participants, the pinched waist design feature was a positive key feature for where the remote control could be held when used. For some participants, the pinched waist feature drew negative attention. Curvilinear features were commented both negatiely and positively in relation to the type of remote design those featurres were used on. For some particpants, the presence or absence of curved features determined if the comment was either positive or negative with no consistency in responses. Based on this inconsistency, participants' preferences played a role in their attitudes. It is unclear how these preferences are developed. Design elements, when implemented on an object of functionality, impacted the particpants' attitudes toward that remote design.

4.9 Conclusion

4.9.1 Summary

The aim of this study was to determine the attitudes of online participants towards appearance and usability of the 7 remote designs. It was hypothesized that attractive design elements could be determined between a paired set of remote control designs. It was expected that a relationship between Likert and pairwise comparison results could be established.

Likert survey results showed that most participants preferred the hourglass round and hourglass subjacent designs. From the pairwise comparison survey, participants preferred curvilinear features to rectilinear ones. Previously conducted studies have shown that round features are preferred, but this did not lead to a majority of online participants to choose the remote design, with predominantly round features, over the remote design with predominantly flat features. Review of participants' open-ended responses showed some participants were factoring remote functionality into their judgement about appearance.

Participants' attitudes were determined towards appearance and usability, but it is unclear how much impact remote functionality played in their responses. Attractive design elements were determined in the context of paired remote comparisons, but this was reported as a percentage of participants that preferred a particular remote design over its paired counterpart; a global set of design elements was not determined.

4.9.2 Limitations

7 remote designs were chosen as part of the Likert and pairwise comparison surveys. The set of paired comparisons, using these 7 remote designs, did not form a full combinatorial set of comparisons. Paired comparisons, in this study, were selected based on remote designs sharing similar design elements except 1 contrasting design element.

The impact of functionality was unknown in the Likert and pairwise comparisons surveys. The button design was the same across all remote designs, but based on open-ended responses from the Likert surveys, participants envisioned how they would use the buttons relative to the shape of the remote. Button functionality and remote outline are two variables that need reconsideration.

4.9.3 Future Work

Future work at determining salient design elements of remote controls should evaluate the impact that button functionality has to the judgement of aesthetics. It observed that button functionality did contribute to judgement of aesthetics. Changing the button design, to minimize the judgement of aesthetics, should be considered. If one were to consider removing the button design all together, then the study would be one primarily about the judgement of shapes; previously conducted studies show that round objects would be preferred in this scenario.

Other consumer devices should be considered if conducting a similar study. Mobile phones, tablets, or laptops can be classified as consumer electronics. If these types of devices are used, functional components of these devices need to be considered.

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APPENDIX A

MANN-WHITNEY TEST RESULTS FOR DIFFERENCES BETWEEN EYE MOVEMENTS AND DEMOGRAPHICS

Table A.1 Mann-Whitney U test results for differences between eye movements and gender for rectangular with rounded corners remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 0	Time to first fixation of an AOI (sec)	47.000	0.423	0.673
AOI 1	Time to first fixation of an AOI (sec)	37.000	-0.423	0.672
AOI 2	Time to first fixation of an AOI (sec)	31.000	-1.127	0.260
AOI 3	Time to first fixation of an AOI (sec)	23.000	-1.698	0.090
AOI 0	Number of fixations on an AOI (#)	43.500	0.127	0.899
AOI 1	Number of fixations on an AOI (#)	43.500	0.128	0.898
AOI 2	Number of fixations on an AOI (#)	34.000	-0.755	0.450
AOI 3	Number of fixations on an AOI (#)	28.000	-1.197	0.231
AOI 0	Dwell time of first fixation on an AOI (sec)	72.000	2.535	< 0.05
AOI 1	Dwell time of first fixation on an AOI (sec)	30.000	-1.016	0.310
AOI 2	Dwell time of first fixation on an AOI (sec)	29.000	-1.333	0.183
AOI 3	Dwell time of first fixation on an AOI (sec)	30.000	-1.073	0.283
AOI 0	Total dwell time on an AOI (sec)	37.000	-0.423	0.673
AOI 1	Total dwell time on an AOI (sec)	38.000	-0.338	0.735
AOI 2	Total dwell time on an AOI (sec)	30.000	-1.172	0.241
AOI 3	Total dwell time on an AOI (sec)	21.500	-1.740	0.082
AOI 0	Percentage of time spent on an AOI (%)	37.000	-0.423	0.673
AOI 1	Percentage of time spent on an AOI (%)	38.000	-0.338	0.735
AOI 2	Percentage of time spent on an AOI (%)	30.000	-1.172	0.241
AOI 3	Percentage of time spent on an AOI (%)	21.500	-1.740	0.082

Table A.2 Mann-Whitney U test results for differences between eye movements and gender for hourglass flat remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 4	Time to first fixation of an AOI (sec)	37.000	-0.423	0.673
AOI 5	Time to first fixation of an AOI (sec)	58.500	1.401	0.161
AOI 6	Time to first fixation of an AOI (sec)	56.000	1.659	0.097
AOI 7	Time to first fixation of an AOI (sec)	45.000	0.256	0.798
AOI 4	Number of fixations on an AOI (#)	45.000	0.255	0.799
AOI 5	Number of fixations on an AOI (#)	45.500	0.298	0.766
AOI 6	Number of fixations on an AOI (#)	52.500	1.077	0.281
AOI 7	Number of fixations on an AOI (#)	31.000	-0.939	0.348
AOI 4	Dwell time of first fixation on an AOI (sec)	41.000	-0.085	0.933
AOI 5	Dwell time of first fixation on an AOI (sec)	36.500	-0.467	0.641
AOI 6	Dwell time of first fixation on an AOI (sec)	58.000	1.896	0.058
AOI 7	Dwell time of first fixation on an AOI (sec)	39.000	-0.256	0.798
AOI 4	Total dwell time on an AOI (sec)	43.000	0.085	0.933
AOI 5	Total dwell time on an AOI (sec)	42.000	0.000	1.000
AOI 6	Total dwell time on an AOI (sec)	54.000	1.229	0.219
AOI 7	Total dwell time on an AOI (sec)	30.000	-1.014	0.310
AOI 4	Percentage of time spent on an AOI (%)	43.000	0.085	0.933
AOI 5	Percentage of time spent on an AOI (%)	42.000	0.000	1.000
AOI 6	Percentage of time spent on an AOI (%)	54.000	1.229	0.219
AOI 7	Percentage of time spent on an AOI (%)	30.000	-1.014	0.310

Table A.3 Mann-Whitney U test results for differences between eye movements and gender for rectangular subjacent remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 8	Time to first fixation of an AOI (sec)	28.000	-1.183	0.237
AOI 9	Time to first fixation of an AOI (sec)	40.500	-0.132	0.895
AOI 10	Time to first fixation of an AOI (sec)	52.000	1.024	0.306
AOI 11	Time to first fixation of an AOI (sec)	36.000	-0.527	0.598
AOI 8	Number of fixations on an AOI (#)	46.000	0.341	0.733
AOI 9	Number of fixations on an AOI (#)	49.000	0.602	0.547
AOI 10	Number of fixations on an AOI (#)	42.000	0.000	1.000
AOI 11	Number of fixations on an AOI (#)	21.000	-1.811	0.070
AOI 8	Dwell time of first fixation on an AOI (sec)	40.000	-0.169	0.866
AOI 9	Dwell time of first fixation on an AOI (sec)	39.500	-0.220	0.826
AOI 10	Dwell time of first fixation on an AOI (sec)	48.000	0.615	0.539
AOI 11	Dwell time of first fixation on an AOI (sec)	38.000	-0.351	0.725
AOI 8	Total dwell time on an AOI (sec)	45.000	0.254	0.800
AOI 9	Total dwell time on an AOI (sec)	49.000	0.601	0.548
AOI 10	Total dwell time on an AOI (sec)	49.000	0.601	0.548
AOI 11	Total dwell time on an AOI (sec)	27.000	-1.270	0.204
AOI 8	Percentage of time spent on an AOI (%)	45.000	0.254	0.800
AOI 9	Percentage of time spent on an AOI (%)	49.000	0.601	0.548
AOI 10	Percentage of time spent on an AOI (%)	41.000	-0.087	0.931
AOI 11	Percentage of time spent on an AOI (%)	27.000	-1.270	0.204

Table A.4 Mann-Whitney U test results for differences between eye movements and gender for hourglass subjacent remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 12	Time to first fixation of an AOI (sec)	52.000	0.845	0.398
AOI 13	Time to first fixation of an AOI (sec)	44.000	0.169	0.866
AOI 14	Time to first fixation of an AOI (sec)	50.500	1.131	0.258
AOI 15	Time to first fixation of an AOI (sec)	50.000	0.679	0.497
AOI 12	Number of fixations on an AOI (#)	33.500	-0.723	0.470
AOI 13	Number of fixations on an AOI (#)	45.500	0.298	0.766
AOI 14	Number of fixations on an AOI (#)	48.000	0.576	0.565
AOI 15	Number of fixations on an AOI (#)	31.500	-0.897	0.370
AOI 12	Dwell time of first fixation on an AOI (sec)	64.000	1.859	0.063
AOI 13	Dwell time of first fixation on an AOI (sec)	50.000	0.679	0.497
AOI 14	Dwell time of first fixation on an AOI (sec)	50.500	1.131	0.258
AOI 15	Dwell time of first fixation on an AOI (sec)	32.500	-0.807	0.420
AOI 12	Total dwell time on an AOI (sec)	28.000	-1.183	0.237
AOI 13	Total dwell time on an AOI (sec)	45.500	0.296	0.767
AOI 14	Total dwell time on an AOI (sec)	55.000	1.270	0.204
AOI 15	Total dwell time on an AOI (sec)	32.000	-0.846	0.398
AOI 12	Percentage of time spent on an AOI (%)	28.000	-1.183	0.237
AOI 13	Percentage of time spent on an AOI (%)	45.500	0.296	0.767
AOI 14	Percentage of time spent on an AOI (%)	55.000	1.270	0.204
AOI 15	Percentage of time spent on an AOI (%)	32.000	-0.845	0.398

Table A.5 Mann-Whitney U test results for differences between eye movements and gender for hourglass round remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 16	Time to first fixation of an AOI (sec)	36.000	-0.507	0.612
AOI 17	Time to first fixation of an AOI (sec)	45.500	0.297	0.766
AOI 18	Time to first fixation of an AOI (sec)	32.000	-0.941	0.347
AOI 19	Time to first fixation of an AOI (sec)	49.000	0.593	0.553
AOI 16	Number of fixations on an AOI (#)	46.500	0.382	0.703
AOI 17	Number of fixations on an AOI (#)	36.000	-0.508	0.611
AOI 18	Number of fixations on an AOI (#)	29.500	-1.149	0.250
AOI 19	Number of fixations on an AOI (#)	46.000	0.339	0.734
AOI 16	Dwell time of first fixation on an AOI (sec)	47.000	0.423	0.673
AOI 17	Dwell time of first fixation on an AOI (sec)	38.500	-0.297	0.766
AOI 18	Dwell time of first fixation on an AOI (sec)	38.500	-0.329	0.742
AOI 19	Dwell time of first fixation on an AOI (sec)	38.000	-0.339	0.735
AOI 16	Total dwell time on an AOI (sec)	49.000	0.592	0.554
AOI 17	Total dwell time on an AOI (sec)	40.500	-0.127	0.899
AOI 18	Total dwell time on an AOI (sec)	35.500	-0.594	0.553
AOI 19	Total dwell time on an AOI (sec)	43.500	0.127	0.899
AOI 16	Percentage of time spent on an AOI (%)	49.000	0.592	0.554
AOI 17	Percentage of time spent on an AOI (%)	40.500	-0.127	0.899
AOI 18	Percentage of time spent on an AOI (%)	35.500	-0.594	0.553
AOI 19	Percentage of time spent on an AOI (%)	43.500	0.127	0.899

Table A.6 Mann-Whitney U test results for differences between eye movements and gender for trapezoidal remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 20	Time to first fixation of an AOI (sec)	42.000	0.000	1.000
AOI 21	Time to first fixation of an AOI (sec)	35.000	-0.597	0.550
AOI 22	Time to first fixation of an AOI (sec)	46.000	0.474	0.636
AOI 23	Time to first fixation of an AOI (sec)	57.500	1.316	0.188
AOI 20	Number of fixations on an AOI (#)	57.500	1.329	0.184
AOI 21	Number of fixations on an AOI (#)	37.000	-0.428	0.669
AOI 22	Number of fixations on an AOI (#)	52.000	1.025	0.305
AOI 23	Number of fixations on an AOI (#)	37.000	-0.425	0.671
AOI 20	Dwell time of first fixation on an AOI (sec)	42.000	0.000	1.000
AOI 21	Dwell time of first fixation on an AOI (sec)	28.000	-1.194	0.233
AOI 22	Dwell time of first fixation on an AOI (sec)	45.000	0.355	0.722
AOI 23	Dwell time of first fixation on an AOI (sec)	40.000	-0.170	0.865
AOI 20	Total dwell time on an AOI (sec)	44.000	0.169	0.866
AOI 21	Total dwell time on an AOI (sec)	34.000	-0.679	0.497
AOI 22	Total dwell time on an AOI (sec)	48.000	0.615	0.539
AOI 23	Total dwell time on an AOI (sec)	35.000	-0.592	0.554
AOI 20	Percentage of time spent on an AOI (%)	44.000	0.169	0.866
AOI 21	Percentage of time spent on an AOI (%)	34.000	-0.679	0.497
AOI 22	Percentage of time spent on an AOI (%)	48.000	0.615	0.539
AOI 23	Percentage of time spent on an AOI (%)	35.000	-0.592	0.554

Table A.7 Mann-Whitney U test results for differences between eye movements and gender for rectangular stout remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 24	Time to first fixation of an AOI (sec)	39.000	-0.254	0.800
AOI 25	Time to first fixation of an AOI (sec)	50.000	0.682	0.495
AOI 26	Time to first fixation of an AOI (sec)	32.000	-1.090	0.276
AOI 27	Time to first fixation of an AOI (sec)	50.000	0.676	0.499
AOI 24	Number of fixations on an AOI (#)	51.000	0.767	0.443
AOI 25	Number of fixations on an AOI (#)	25.500	-1.399	0.162
AOI 26	Number of fixations on an AOI (#)	25.500	-1.524	0.127
AOI 27	Number of fixations on an AOI (#)	18.500	-1.993	< 0.050
AOI 24	Dwell time of first fixation on an AOI (sec)	34.000	-0.676	0.499
AOI 25	Dwell time of first fixation on an AOI (sec)	36.000	-0.512	0.609
AOI 26	Dwell time of first fixation on an AOI (sec)	34.000	-0.872	0.383
AOI 27	Dwell time of first fixation on an AOI (sec)	19.000	-1.944	0.052
AOI 24	Total dwell time on an AOI (sec)	43.000	0.085	0.933
AOI 25	Total dwell time on an AOI (sec)	32.000	-0.845	0.398
AOI 26	Total dwell time on an AOI (sec)	32.500	-0.868	0.385
AOI 27	Total dwell time on an AOI (sec)	16.000	-2.197	< 0.050
AOI 24	Percentage of time spent on an AOI (%)	43.000	0.085	0.933
AOI 25	Percentage of time spent on an AOI (%)	32.000	-0.845	0.398
AOI 26	Percentage of time spent on an AOI (%)	32.500	-0.868	0.385
AOI 27	Percentage of time spent on an AOI (%)	16.000	-2.197	< 0.050

Table A.8 Mann-Whitney U test results for differences between eye movements and age for rectangular with rounded corners remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 0	Time to first fixation of an AOI (sec)	53.000	0.743	0.457
AOI 1	Time to first fixation of an AOI (sec)	32.000	-0.993	0.321
AOI 2	Time to first fixation of an AOI (sec)	50.000	0.600	0.548
AOI 3	Time to first fixation of an AOI (sec)	40.000	-0.349	0.727
AOI 0	Number of fixations on an AOI (#)	21.000	-1.908	0.056
AOI 1	Number of fixations on an AOI (#)	41.000	-0.249	0.803
AOI 2	Number of fixations on an AOI (#)	49.500	0.507	0.612
AOI 3	Number of fixations on an AOI (#)	49.500	0.460	0.646
AOI 0	Dwell time of first fixation on an AOI (sec)	41.000	-0.248	0.804
AOI 1	Dwell time of first fixation on an AOI (sec)	50.000	0.496	0.620
AOI 2	Dwell time of first fixation on an AOI (sec)	48.500	0.451	0.652
AOI 3	Dwell time of first fixation on an AOI (sec)	46.500	0.218	0.827
AOI 0	Total dwell time on an AOI (sec)	37.000	-0.578	0.563
AOI 1	Total dwell time on an AOI (sec)	49.000	0.413	0.680
AOI 2	Total dwell time on an AOI (sec)	51.000	0.668	0.504
AOI 3	Total dwell time on an AOI (sec)	48.500	0.373	0.709
AOI 0	Percentage of time spent on an AOI (%)	37.000	-0.578	0.563
AOI 1	Percentage of time spent on an AOI (%)	49.000	0.413	0.680
AOI 2	Percentage of time spent on an AOI (%)	51.000	0.668	0.504
AOI 3	Percentage of time spent on an AOI (%)	48.500	0.373	0.709

Table A.9 Mann-Whitney U test results for differences between eye movements and age for hourglass flat remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 4	Time to first fixation of an AOI (sec)	57.000	1.073	0.283
AOI 5	Time to first fixation of an AOI (sec)	46.500	0.207	0.836
AOI 6	Time to first fixation of an AOI (sec)	57.000	1.505	0.132
AOI 7	Time to first fixation of an AOI (sec)	43.000	-0.083	0.934
AOI 4	Number of fixations on an AOI (#)	26.500	-1.453	0.146
AOI 5	Number of fixations on an AOI (#)	52.500	0.706	0.480
AOI 6	Number of fixations on an AOI (#)	60.000	1.603	0.109
AOI 7	Number of fixations on an AOI (#)	37.500	-0.542	0.588
AOI 4	Dwell time of first fixation on an AOI (sec)	45.000	0.083	0.934
AOI 5	Dwell time of first fixation on an AOI (sec)	64.500	1.700	0.089
AOI 6	Dwell time of first fixation on an AOI (sec)	55.000	1.273	0.203
AOI 7	Dwell time of first fixation on an AOI (sec)	41.000	-0.250	0.803
AOI 4	Total dwell time on an AOI (sec)	31.000	-1.073	0.283
AOI 5	Total dwell time on an AOI (sec)	53.000	0.744	0.457
AOI 6	Total dwell time on an AOI (sec)	57.000	1.301	0.193
AOI 7	Total dwell time on an AOI (sec)	37.000	-0.578	0.563
AOI 4	Percentage of time spent on an AOI (%)	31.000	-1.073	0.283
AOI 5	Percentage of time spent on an AOI (%)	53.000	0.744	0.457
AOI 6	Percentage of time spent on an AOI (%)	57.000	1.301	0.193
AOI 7	Percentage of time spent on an AOI (%)	37.000	-0.578	0.563

Table A.10 Mann-Whitney U test results for differences between eye movements and age for rectangular subjacent remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 8	Time to first fixation of an AOI (sec)	67.000	1.899	0.058
AOI 9	Time to first fixation of an AOI (sec)	35.500	-0.729	0.466
AOI 10	Time to first fixation of an AOI (sec)	39.000	-0.500	0.617
AOI 11	Time to first fixation of an AOI (sec)	47.000	0.257	0.797
AOI 8	Number of fixations on an AOI (#)	48.500	0.374	0.708
AOI 9	Number of fixations on an AOI (#)	46.000	0.168	0.866
AOI 10	Number of fixations on an AOI (#)	58.500	1.237	0.216
AOI 11	Number of fixations on an AOI (#)	55.000	0.927	0.354
AOI 8	Dwell time of first fixation on an AOI (sec)	58.000	1.156	0.248
AOI 9	Dwell time of first fixation on an AOI (sec)	53.500	0.815	0.415
AOI 10	Dwell time of first fixation on an AOI (sec)	35.000	-0.901	0.368
AOI 11	Dwell time of first fixation on an AOI (sec)	47.000	0.257	0.797
AOI 8	Total dwell time on an AOI (sec)	47.000	0.248	0.804
AOI 9	Total dwell time on an AOI (sec)	49.000	0.419	0.675
AOI 10	Total dwell time on an AOI (sec)	50.000	0.508	0.611
AOI 11	Total dwell time on an AOI (sec)	56.000	0.993	0.321
AOI 8	Percentage of time spent on an AOI (%)	47.000	0.248	0.804
AOI 9	Percentage of time spent on an AOI (%)	49.000	0.419	0.675
AOI 10	Percentage of time spent on an AOI (%)	50.000	0.508	0.611
AOI 11	Percentage of time spent on an AOI (%)	56.000	0.993	0.321

Table A.11 Mann-Whitney U test results for differences between eye movements and age for hourglass subjacent remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 12	Time to first fixation of an AOI (sec)	51.000	0.578	0.563
AOI 13	Time to first fixation of an AOI (sec)	60.000	1.323	0.186
AOI 14	Time to first fixation of an AOI (sec)	40.500	-0.455	0.649
AOI 15	Time to first fixation of an AOI (sec)	58.000	1.161	0.246
AOI 12	Number of fixations on an AOI (#)	38.000	-0.499	0.618
AOI 13	Number of fixations on an AOI (#)	39.500	-0.374	0.709
AOI 14	Number of fixations on an AOI (#)	46.000	0.188	0.851
AOI 15	Number of fixations on an AOI (#)	58.000	1.168	0.243
AOI 12	Dwell time of first fixation on an AOI (sec)	48.000	0.330	0.741
AOI 13	Dwell time of first fixation on an AOI (sec)	41.500	-0.207	0.836
AOI 14	Dwell time of first fixation on an AOI (sec)	40.500	-0.455	0.649
AOI 15	Dwell time of first fixation on an AOI (sec)	56.000	0.996	0.319
AOI 12	Total dwell time on an AOI (sec)	33.000	-0.908	0.364
AOI 13	Total dwell time on an AOI (sec)	44.500	0.041	0.967
AOI 14	Total dwell time on an AOI (sec)	40.000	-0.382	0.703
AOI 15	Total dwell time on an AOI (sec)	49.500	0.454	0.650
AOI 12	Percentage of time spent on an AOI (%)	33.000	-0.908	0.364
AOI 13	Percentage of time spent on an AOI (%)	44.500	0.041	0.967
AOI 14	Percentage of time spent on an AOI (%)	40.000	-0.382	0.703
AOI 15	Percentage of time spent on an AOI (%)	49.000	0.413	0.680

Table A.12 Mann-Whitney U test results for differences between eye movements and age for hourglass round remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 16	Time to first fixation of an AOI (sec)	39.000	-0.413	0.680
AOI 17	Time to first fixation of an AOI (sec)	33.000	-0.912	0.362
AOI 18	Time to first fixation of an AOI (sec)	54.000	0.919	0.358
AOI 19	Time to first fixation of an AOI (sec)	41.000	-0.248	0.804
AOI 16	Number of fixations on an AOI (#)	35.500	-0.705	0.481
AOI 17	Number of fixations on an AOI (#)	63.000	1.572	0.116
AOI 18	Number of fixations on an AOI (#)	72.500	2.560	< 0.050
AOI 19	Number of fixations on an AOI (#)	51.500	0.622	0.534
AOI 16	Dwell time of first fixation on an AOI (sec)	27.000	-1.404	0.160
AOI 17	Dwell time of first fixation on an AOI (sec)	39.000	-0.415	0.678
AOI 18	Dwell time of first fixation on an AOI (sec)	62.000	1.655	0.098
AOI 19	Dwell time of first fixation on an AOI (sec)	36.000	-0.662	0.508
AOI 16	Total dwell time on an AOI (sec)	33.000	-0.908	0.364
AOI 17	Total dwell time on an AOI (sec)	55.500	0.950	0.342
AOI 18	Total dwell time on an AOI (sec)	70.000	2.321	< 0.050
AOI 19	Total dwell time on an AOI (sec)	51.000	0.578	0.563
AOI 16	Percentage of time spent on an AOI (%)	33.000	-0.908	0.364
AOI 17	Percentage of time spent on an AOI (%)	55.500	0.950	0.342
AOI 18	Percentage of time spent on an AOI (%)	70.000	2.321	< 0.050
AOI 19	Percentage of time spent on an AOI (%)	51.000	0.578	0.563

Table A.13 Mann-Whitney U test results for differences between eye movements and age for trapezoidal remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 20	Time to first fixation of an AOI (sec)	56.000	0.991	0.322
AOI 21	Time to first fixation of an AOI (sec)	58.000	1.167	0.243
AOI 22	Time to first fixation of an AOI (sec)	55.000	1.273	0.203
AOI 23	Time to first fixation of an AOI (sec)	54.500	0.871	0.384
AOI 20	Number of fixations on an AOI (#)	58.500	1.215	0.224
AOI 21	Number of fixations on an AOI (#)	56.500	1.045	0.296
AOI 22	Number of fixations on an AOI (#)	52.500	0.851	0.395
AOI 23	Number of fixations on an AOI (#)	44.500	0.042	0.967
AOI 20	Dwell time of first fixation on an AOI (sec)	43.000	-0.083	0.934
AOI 21	Dwell time of first fixation on an AOI (sec)	39.000	-0.417	0.677
AOI 22	Dwell time of first fixation on an AOI (sec)	55.000	1.273	0.203
AOI 23	Dwell time of first fixation on an AOI (sec)	41.000	-0.249	0.803
AOI 20	Total dwell time on an AOI (sec)	74.000	2.477	0.013
AOI 21	Total dwell time on an AOI (sec)	55.500	0.954	0.340
AOI 22	Total dwell time on an AOI (sec)	51.000	0.701	0.484
AOI 23	Total dwell time on an AOI (sec)	50.000	0.496	0.620
AOI 20	Percentage of time spent on an AOI (%)	74.000	2.477	< 0.050
AOI 21	Percentage of time spent on an AOI (%)	55.500	0.954	0.340
AOI 22	Percentage of time spent on an AOI (%)	51.000	0.701	0.484
AOI 23	Percentage of time spent on an AOI (%)	49.000	0.413	0.680

Table A.14 Mann-Whitney U test results for differences between eye movements and age for rectangular stout remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 24	Time to first fixation of an AOI (sec)	75.000	2.560	< 0.050
AOI 25	Time to first fixation of an AOI (sec)	31.000	-1.083	0.279
AOI 26	Time to first fixation of an AOI (sec)	50.500	0.692	0.489
AOI 27	Time to first fixation of an AOI (sec)	21.000	-1.899	0.058
AOI 24	Number of fixations on an AOI (#)	15.500	-2.374	< 0.050
AOI 25	Number of fixations on an AOI (#)	52.500	0.704	0.481
AOI 26	Number of fixations on an AOI (#)	45.500	0.135	0.892
AOI 27	Number of fixations on an AOI (#)	40.000	-0.331	0.740
AOI 24	Dwell time of first fixation on an AOI (sec)	39.000	-0.413	0.680
AOI 25	Dwell time of first fixation on an AOI (sec)	53.000	0.750	0.453
AOI 26	Dwell time of first fixation on an AOI (sec)	52.500	0.905	0.365
AOI 27	Dwell time of first fixation on an AOI (sec)	47.000	0.248	0.804
AOI 24	Total dwell time on an AOI (sec)	16.500	-2.272	< 0.050
AOI 25	Total dwell time on an AOI (sec)	47.000	0.248	0.804
AOI 26	Total dwell time on an AOI (sec)	41.000	-0.268	0.789
AOI 27	Total dwell time on an AOI (sec)	40.000	-0.330	0.741
AOI 24	Percentage of time spent on an AOI (%)	16.000	-2.312	< 0.050
AOI 25	Percentage of time spent on an AOI (%)	47.000	0.248	0.804
AOI 26	Percentage of time spent on an AOI (%)	41.000	-0.268	0.789
AOI 27	Percentage of time spent on an AOI (%)	40.000	-0.330	0.741

Table A.15 Mann-Whitney U test results for differences between eye movements and design experience for rectangular with rounded corners remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 0	Time to first fixation of an AOI (sec)	57.000	2.037	< 0.05
AOI 1	Time to first fixation of an AOI (sec)	53.000	1.669	0.095
AOI 2	Time to first fixation of an AOI (sec)	40.000	0.561	0.575
AOI 3	Time to first fixation of an AOI (sec)	34.000	-0.098	0.922
AOI 0	Number of fixations on an AOI (#)	45.500	0.977	0.329
AOI 1	Number of fixations on an AOI (#)	50.000	1.399	0.162
AOI 2	Number of fixations on an AOI (#)	37.500	0.258	0.796
AOI 3	Number of fixations on an AOI (#)	19.000	-1.499	0.134
AOI 0	Dwell time of first fixation on an AOI (sec)	33.000	-0.185	0.853
AOI 1	Dwell time of first fixation on an AOI (sec)	29.000	-0.556	0.578
AOI 2	Dwell time of first fixation on an AOI (sec)	39.000	0.449	0.653
AOI 3	Dwell time of first fixation on an AOI (sec)	30.000	-0.490	0.624
AOI 0	Total dwell time on an AOI (sec)	20.000	-1.389	0.165
AOI 1	Total dwell time on an AOI (sec)	37.000	0.185	0.853
AOI 2	Total dwell time on an AOI (sec)	38.500	0.374	0.708
AOI 3	Total dwell time on an AOI (sec)	17.500	-1.627	0.104
AOI 0	Percentage of time spent on an AOI (%)	20.000	-1.389	0.165
AOI 1	Percentage of time spent on an AOI (%)	37.000	0.185	0.853
AOI 2	Percentage of time spent on an AOI (%)	38.500	0.374	0.708
AOI 3	Percentage of time spent on an AOI (%)	17.500	-1.627	0.104

Table A.16 Mann-Whitney U test results for differences between eye movements and design experience for hourglass flat remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 4	Time to first fixation of an AOI (sec)	29.000	-0.555	0.579
AOI 5	Time to first fixation of an AOI (sec)	34.500	-0.046	0.963
AOI 6	Time to first fixation of an AOI (sec)	25.000	-1.298	0.194
AOI 7	Time to first fixation of an AOI (sec)	24.000	-1.027	0.304
AOI 4	Number of fixations on an AOI (#)	50.000	1.396	0.163
AOI 5	Number of fixations on an AOI (#)	31.500	-0.326	0.744
AOI 6	Number of fixations on an AOI (#)	28.500	-0.730	0.465
AOI 7	Number of fixations on an AOI (#)	23.500	-1.075	0.282
AOI 4	Dwell time of first fixation on an AOI (sec)	37.000	0.185	0.853
AOI 5	Dwell time of first fixation on an AOI (sec)	21.500	-1.255	0.209
AOI 6	Dwell time of first fixation on an AOI (sec)	25.000	-1.298	0.194
AOI 7	Dwell time of first fixation on an AOI (sec)	17.000	-1.681	0.093
AOI 4	Total dwell time on an AOI (sec)	49.000	1.296	0.195
AOI 5	Total dwell time on an AOI (sec)	27.000	-0.742	0.458
AOI 6	Total dwell time on an AOI (sec)	29.000	-0.673	0.501
AOI 7	Total dwell time on an AOI (sec)	25.000	-0.926	0.355
AOI 4	Percentage of time spent on an AOI (%)	49.000	1.296	0.195
AOI 5	Percentage of time spent on an AOI (%)	27.000	-0.742	0.458
AOI 6	Percentage of time spent on an AOI (%)	29.000	-0.673	0.501
AOI 7	Percentage of time spent on an AOI (%)	25.000	-0.926	0.355

Table A.17 Mann-Whitney U test results for differences between eye movements and design experience for rectangular subjacent remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 8	Time to first fixation of an AOI (sec)	31.000	-0.370	0.711
AOI 9	Time to first fixation of an AOI (sec)	40.000	0.481	0.631
AOI 10	Time to first fixation of an AOI (sec)	39.000	0.449	0.654
AOI 11	Time to first fixation of an AOI (sec)	33.500	-0.144	0.885
AOI 8	Number of fixations on an AOI (#)	34.000	-0.093	0.926
AOI 9	Number of fixations on an AOI (#)	40.000	0.471	0.637
AOI 10	Number of fixations on an AOI (#)	32.000	-0.287	0.774
AOI 11	Number of fixations on an AOI (#)	12.000	-2.173	< 0.050
AOI 8	Dwell time of first fixation on an AOI (sec)	23.000	-1.111	0.267
AOI 9	Dwell time of first fixation on an AOI (sec)	25.000	-0.962	0.336
AOI 10	Dwell time of first fixation on an AOI (sec)	39.000	0.449	0.654
AOI 11	Dwell time of first fixation on an AOI (sec)	33.500	-0.144	0.885
AOI 8	Total dwell time on an AOI (sec)	23.000	-1.111	0.267
AOI 9	Total dwell time on an AOI (sec)	32.500	-0.235	0.814
AOI 10	Total dwell time on an AOI (sec)	30.000	-0.475	0.635
AOI 11	Total dwell time on an AOI (sec)	17.000	-1.669	0.095
AOI 8	Percentage of time spent on an AOI (%)	23.000	-1.111	0.267
AOI 9	Percentage of time spent on an AOI (%)	32.500	-0.235	0.814
AOI 10	Percentage of time spent on an AOI (%)	30.000	-0.475	0.635
AOI 11	Percentage of time spent on an AOI (%)	17.000	-1.669	0.095

Table A.18 Mann-Whitney U test results for differences between eye movements and design experience for hourglass subjacent remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 12	Time to first fixation of an AOI (sec)	34.000	-0.093	0.926
AOI 13	Time to first fixation of an AOI (sec)	31.000	-0.371	0.711
AOI 14	Time to first fixation of an AOI (sec)	27.500	-1.093	0.274
AOI 15	Time to first fixation of an AOI (sec)	23.000	-1.116	0.264
AOI 12	Number of fixations on an AOI (#)	35.000	0.000	1.000
AOI 13	Number of fixations on an AOI (#)	58.500	2.188	< 0.05
AOI 14	Number of fixations on an AOI (#)	36.000	0.105	0.916
AOI 15	Number of fixations on an AOI (#)	27.500	-0.702	0.483
AOI 12	Dwell time of first fixation on an AOI (sec)	21.000	-1.296	0.195
AOI 13	Dwell time of first fixation on an AOI (sec)	54.000	1.767	0.077
AOI 14	Dwell time of first fixation on an AOI (sec)	27.500	-1.093	0.274
AOI 15	Dwell time of first fixation on an AOI (sec)	37.000	0.186	0.852
AOI 12	Total dwell time on an AOI (sec)	32.000	-0.278	0.781
AOI 13	Total dwell time on an AOI (sec)	51.000	1.482	0.138
AOI 14	Total dwell time on an AOI (sec)	36.000	0.107	0.915
AOI 15	Total dwell time on an AOI (sec)	27.000	-0.741	0.459
AOI 12	Percentage of time spent on an AOI (%)	32.000	-0.278	0.781
AOI 13	Percentage of time spent on an AOI (%)	51.000	1.482	0.138
AOI 14	Percentage of time spent on an AOI (%)	36.000	0.107	0.915
AOI 15	Percentage of time spent on an AOI (%)	27.000	-0.741	0.459

Table A.19 Mann-Whitney U test results for differences between eye movements and design experience for hourglass round remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 16	Time to first fixation of an AOI (sec)	38.000	0.278	0.781
AOI 17	Time to first fixation of an AOI (sec)	53.000	1.674	0.094
AOI 18	Time to first fixation of an AOI (sec)	25.000	-1.031	0.303
AOI 19	Time to first fixation of an AOI (sec)	35.000	0.000	1.000
AOI 16	Number of fixations on an AOI (#)	58.500	2.184	< 0.050
AOI 17	Number of fixations on an AOI (#)	28.000	-0.649	0.516
AOI 18	Number of fixations on an AOI (#)	19.500	-1.561	0.118
AOI 19	Number of fixations on an AOI (#)	25.000	-0.929	0.353
AOI 16	Dwell time of first fixation on an AOI (sec)	22.000	-1.204	0.229
AOI 17	Dwell time of first fixation on an AOI (sec)	42.000	0.651	0.515
AOI 18	Dwell time of first fixation on an AOI (sec)	21.000	-1.444	0.149
AOI 19	Dwell time of first fixation on an AOI (sec)	30.000	-0.464	0.643
AOI 16	Total dwell time on an AOI (sec)	60.000	2.315	< 0.050
AOI 17	Total dwell time on an AOI (sec)	28.000	-0.648	0.517
AOI 18	Total dwell time on an AOI (sec)	18.000	-1.702	0.089
AOI 19	Total dwell time on an AOI (sec)	19.500	-1.436	0.151
AOI 16	Percentage of time spent on an AOI (%)	60.000	2.315	< 0.050
AOI 17	Percentage of time spent on an AOI (%)	28.000	-0.648	0.517
AOI 18	Percentage of time spent on an AOI (%)	18.000	-1.702	0.089
AOI 19	Percentage of time spent on an AOI (%)	19.500	-1.436	0.151

Table A.20 Mann-Whitney U test results for differences between eye movements and design experience for trapezoidal remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 20	Time to first fixation of an AOI (sec)	51.000	1.481	0.139
AOI 21	Time to first fixation of an AOI (sec)	26.000	-0.841	0.400
AOI 22	Time to first fixation of an AOI (sec)	36.000	0.130	0.897
AOI 23	Time to first fixation of an AOI (sec)	27.000	-0.744	0.457
AOI 20	Number of fixations on an AOI (#)	40.500	0.517	0.605
AOI 21	Number of fixations on an AOI (#)	43.000	0.750	0.454
AOI 22	Number of fixations on an AOI (#)	44.500	1.067	0.286
AOI 23	Number of fixations on an AOI (#)	25.500	-0.884	0.377
AOI 20	Dwell time of first fixation on an AOI (sec)	49.000	1.296	0.195
AOI 21	Dwell time of first fixation on an AOI (sec)	38.000	0.280	0.779
AOI 22	Dwell time of first fixation on an AOI (sec)	36.000	0.130	0.897
AOI 23	Dwell time of first fixation on an AOI (sec)	27.000	-0.745	0.457
AOI 20	Total dwell time on an AOI (sec)	25.000	-0.926	0.355
AOI 21	Total dwell time on an AOI (sec)	33.000	-0.186	0.852
AOI 22	Total dwell time on an AOI (sec)	46.000	1.234	0.217
AOI 23	Total dwell time on an AOI (sec)	29.500	-0.510	0.610
AOI 20	Percentage of time spent on an AOI (%)	25.000	-0.926	0.355
AOI 21	Percentage of time spent on an AOI (%)	33.000	-0.186	0.852
AOI 22	Percentage of time spent on an AOI (%)	46.000	1.234	0.217
AOI 23	Percentage of time spent on an AOI (%)	30.000	-0.463	0.643

Table A.21 Mann-Whitney U test results for differences between eye movements and design experience for rectangular stout remote design.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
AOI 24	Time to first fixation of an AOI (sec)	22.000	-1.204	0.229
AOI 25	Time to first fixation of an AOI (sec)	45.000	0.934	0.350
AOI 26	Time to first fixation of an AOI (sec)	22.500	-1.493	0.135
AOI 27	Time to first fixation of an AOI (sec)	59.000	2.222	< 0.050
AOI 24	Number of fixations on an AOI (#)	54.500	1.821	0.069
AOI 25	Number of fixations on an AOI (#)	35.500	0.046	0.963
AOI 26	Number of fixations on an AOI (#)	24.500	-1.063	0.288
AOI 27	Number of fixations on an AOI (#)	23.500	-1.068	0.285
AOI 24	Dwell time of first fixation on an AOI (sec)	35.000	0.000	1.000
AOI 25	Dwell time of first fixation on an AOI (sec)	35.000	0.000	1.000
AOI 26	Dwell time of first fixation on an AOI (sec)	22.500	-1.493	0.135
AOI 27	Dwell time of first fixation on an AOI (sec)	34.000	-0.093	0.926
AOI 24	Total dwell time on an AOI (sec)	35.500	0.046	0.963
AOI 25	Total dwell time on an AOI (sec)	32.000	-0.278	0.781
AOI 26	Total dwell time on an AOI (sec)	20.000	-1.502	0.133
AOI 27	Total dwell time on an AOI (sec)	21.000	-1.296	0.195
AOI 24	Percentage of time spent on an AOI (%)	36.000	0.093	0.926
AOI 25	Percentage of time spent on an AOI (%)	32.000	-0.278	0.781
AOI 26	Percentage of time spent on an AOI (%)	20.000	-1.502	0.133
AOI 27	Percentage of time spent on an AOI (%)	21.000	-1.296	0.195

APPENDIX B

COMPARISON OF IN-PERSON EYE METRIC VALUES FOR SIMILAR AOIS ACROSS DIFFERENT REMOTE DESIGNS

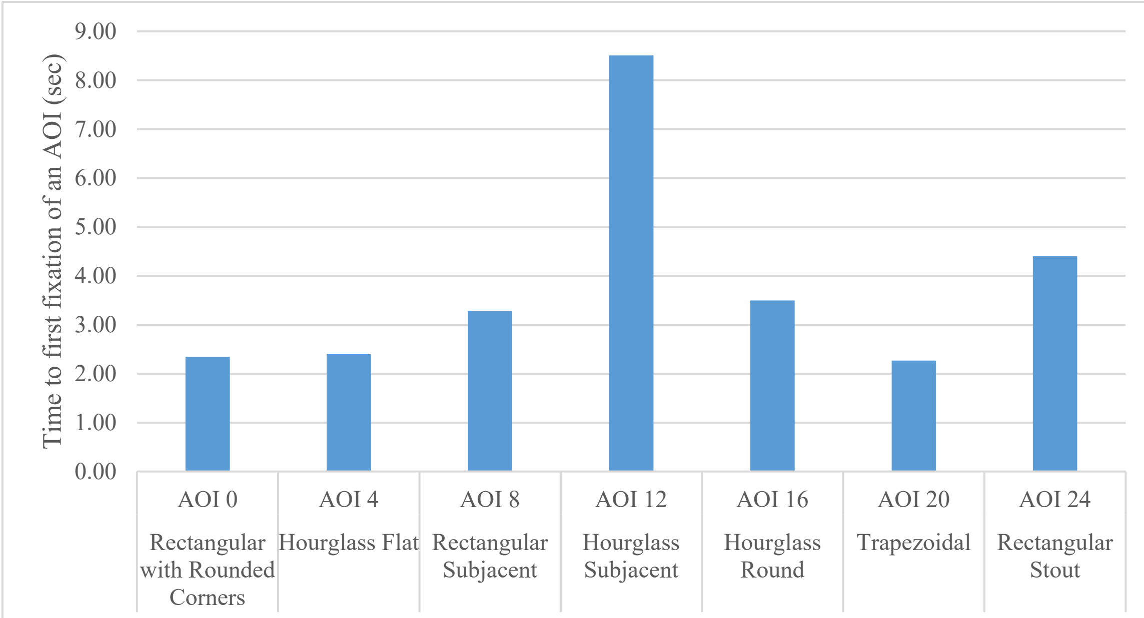

Figure B.1 Comparison of median values for time to first fixation of an AOI for AOIs 0, 4, 8, 12, 16, 20, and 24 across different remote designs.

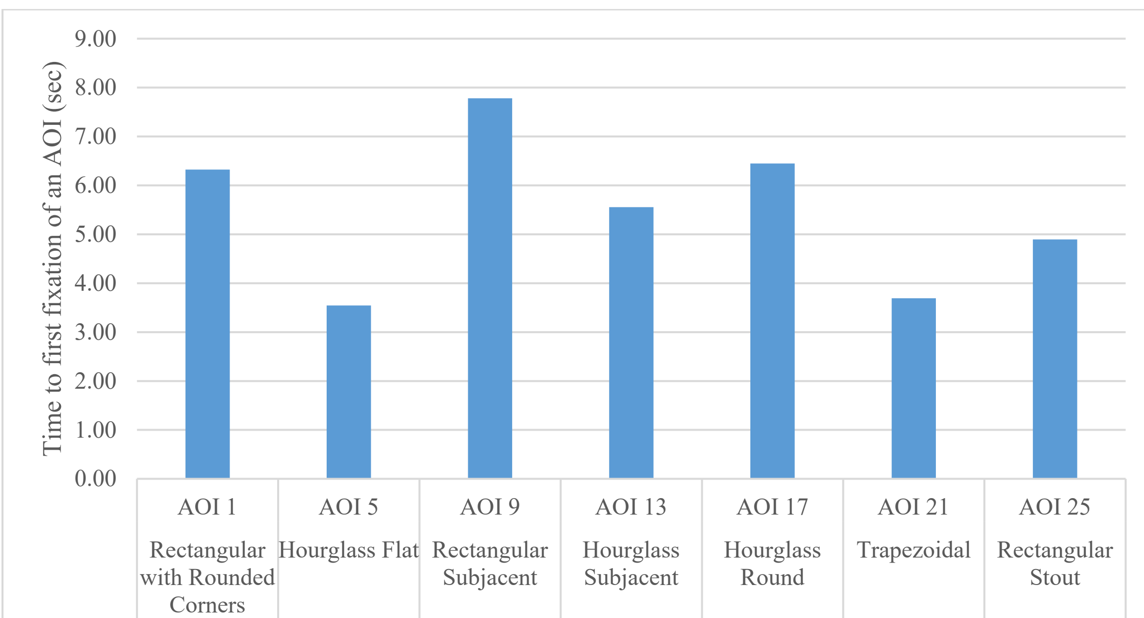

Figure B.2 Comparison of median values for time to first fixation of an AOI for AOIs 1, 5, 9, 13, 17, 21, and 25 across different remote designs.

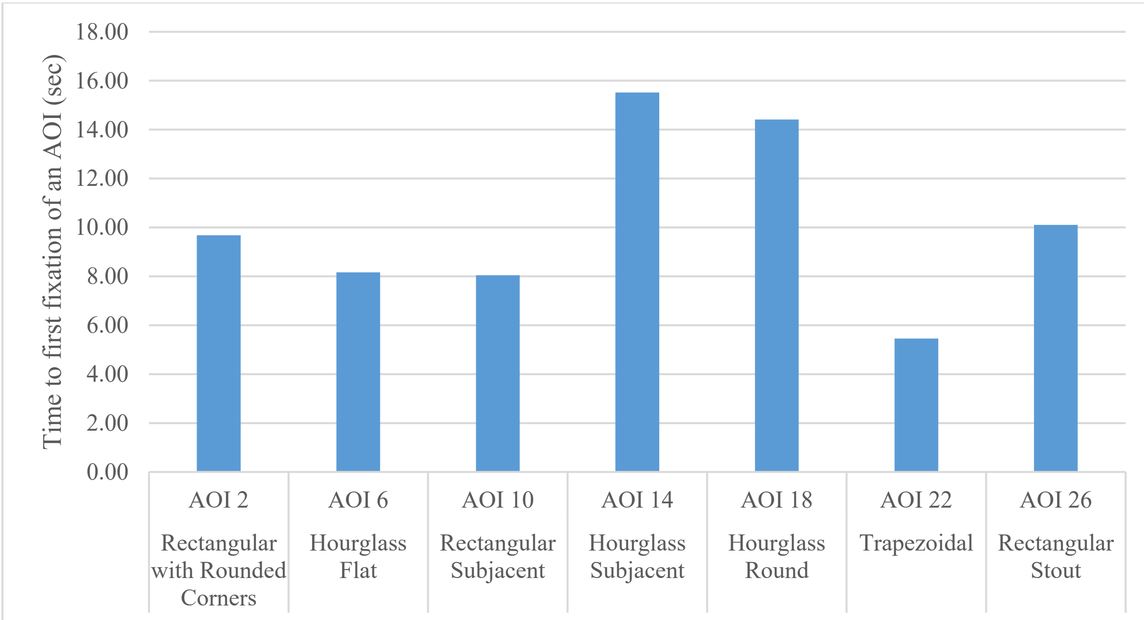

Figure B.3 Comparison of median values for time to first fixation of an AOI for AOIs 2, 6, 10, 14, 18, 22, and 26 across different remote designs.

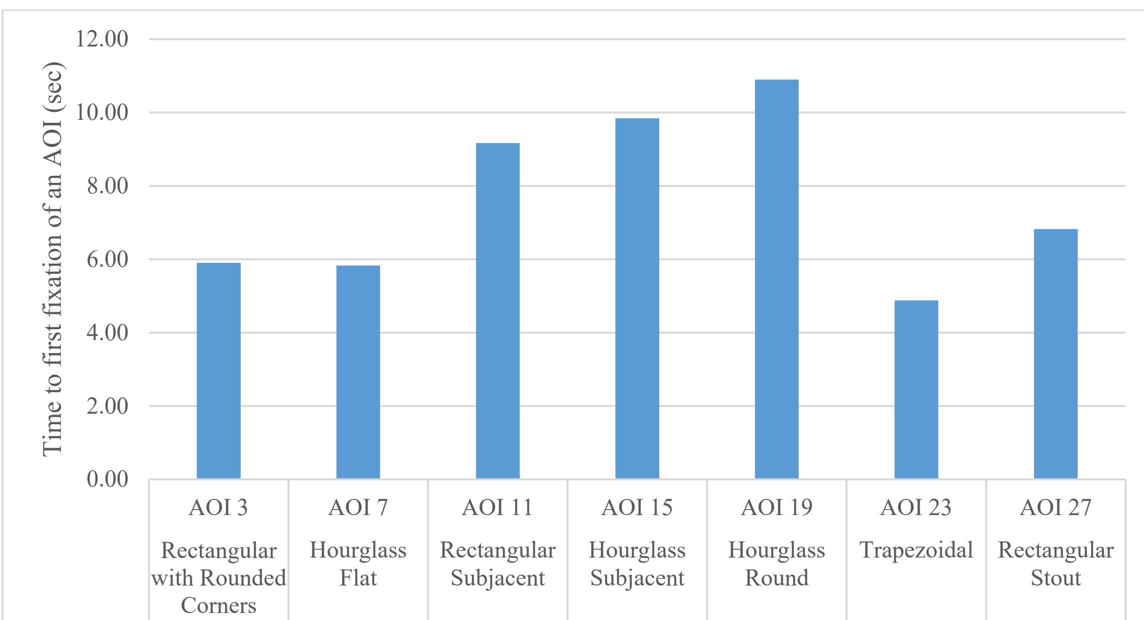

Figure B.4 Comparison of median values for time to first fixation of an AOI for AOIs 3, 7, 11, 15, 19, 23, and 27 across different remote designs.

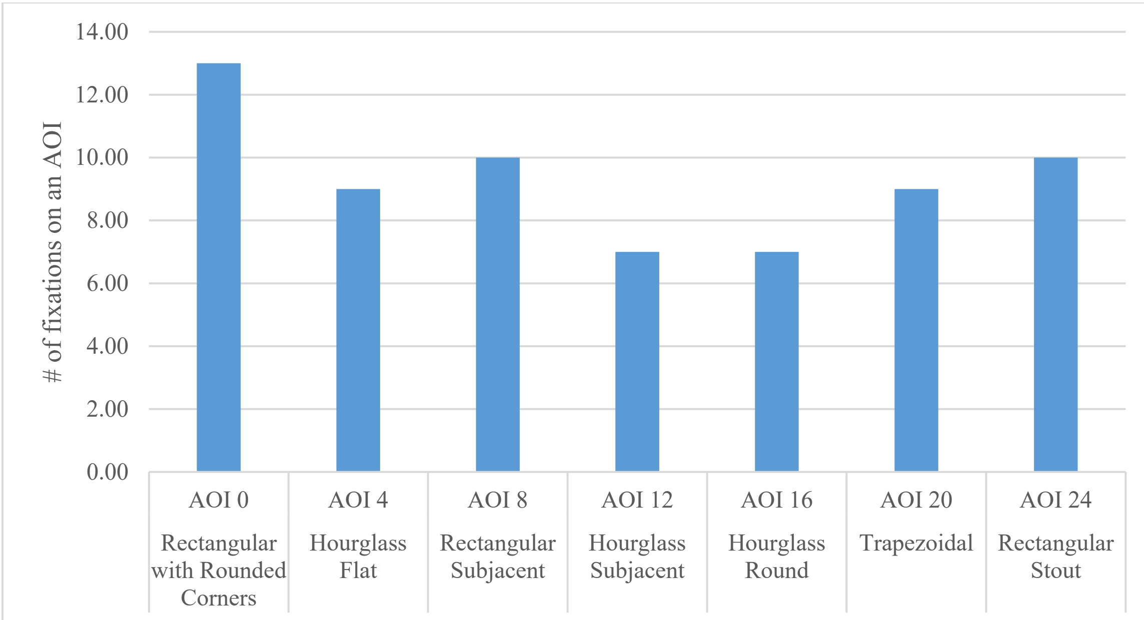

Figure B.5 Comparison of median values for the number of fixations on an AOI for AOIs 0, 4, 8, 12, 16, 20, and 24 across different remote designs.

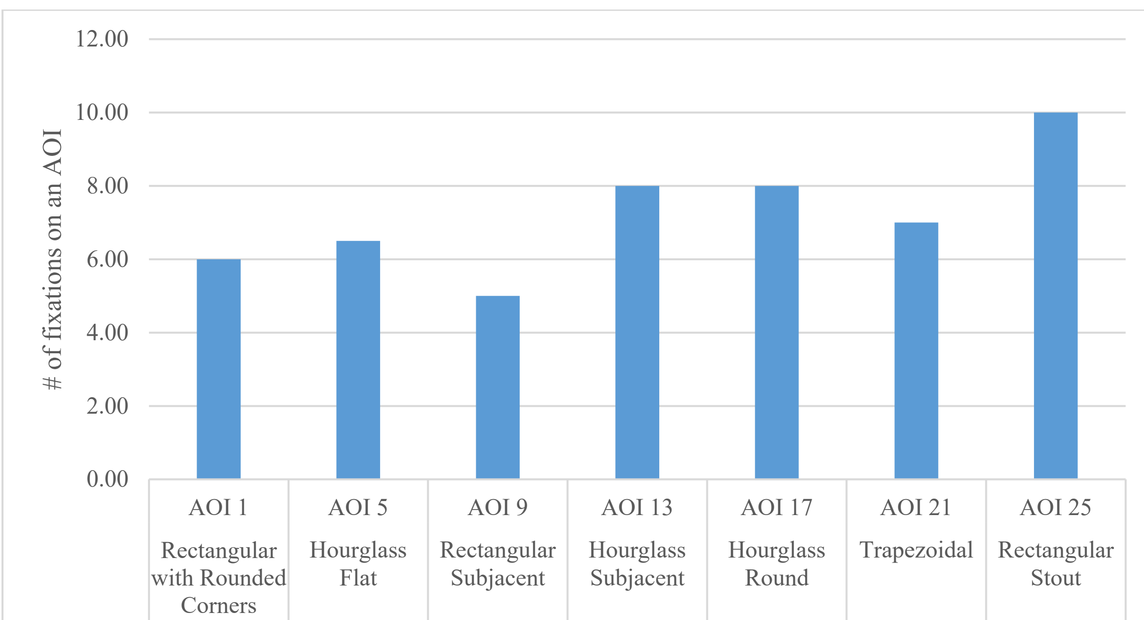

Figure B.6 Comparison of median values for the number of fixations on an AOI for AOIs 1, 5, 9, 13, 17, 21, and 25 across different remote designs.

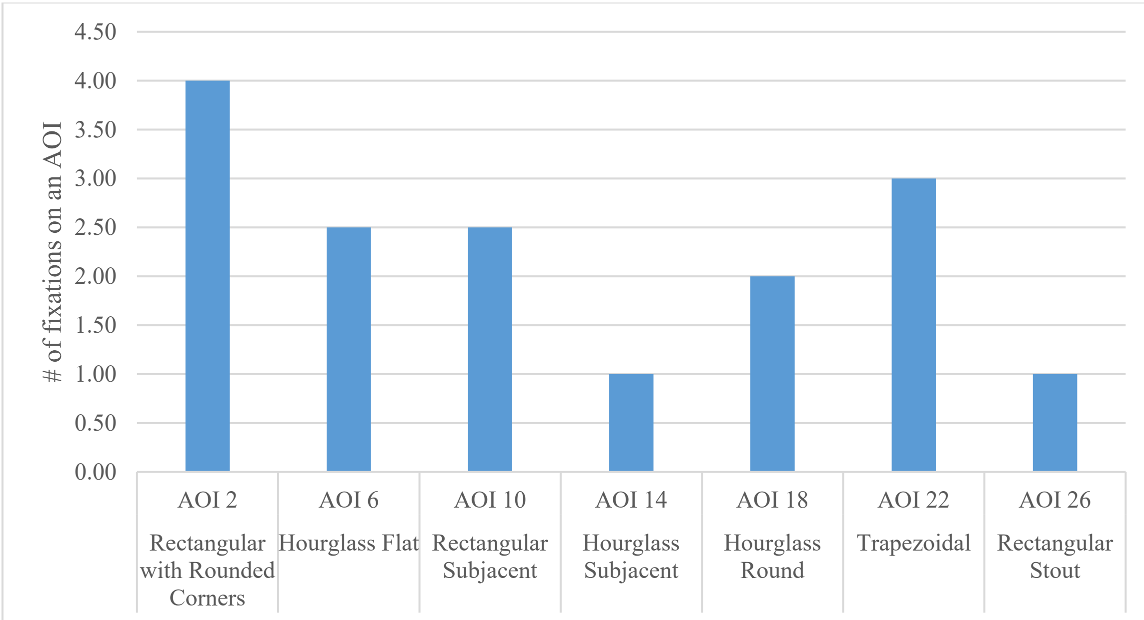

Figure B.7 Comparison of median values for the number of fixations on an AOI for AOIs 2, 6, 10, 14, 18, 22, and 26 across different remote designs.

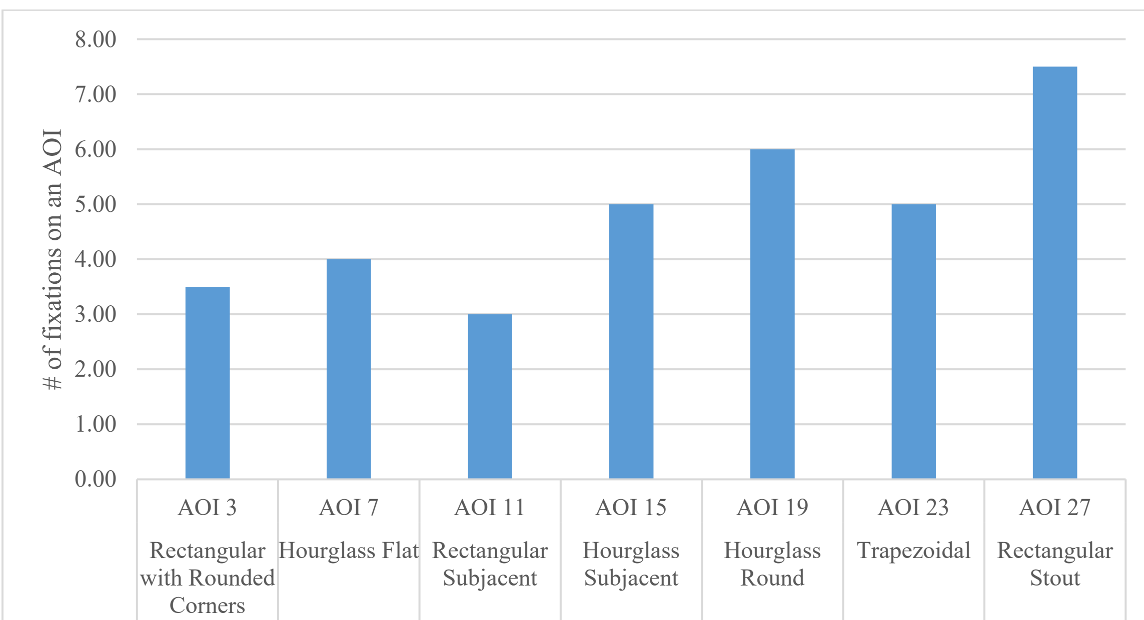

Figure B.8 Comparison of median values for the number of fixations on an AOI for AOIs 3, 7, 11, 15, 19, 23, and 27 across different remote designs.

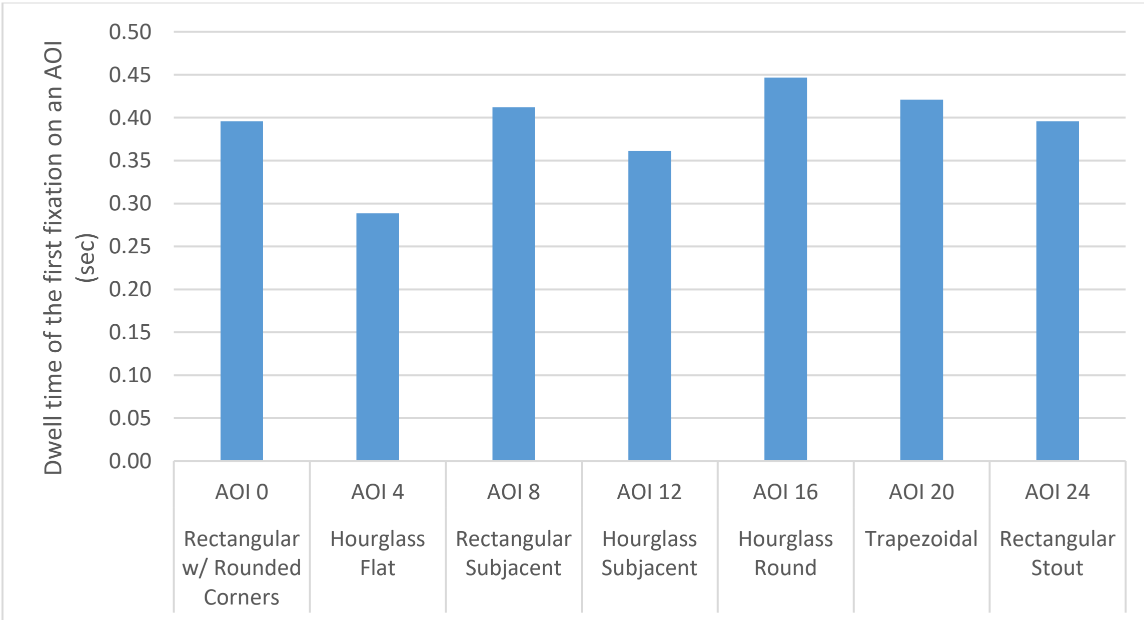

Figure B.9 Comparison of median values for the dwell time of the first fixation on an AOI for AOIs 0, 4, 8, 12, 16, 20, and 24 across different remote designs.

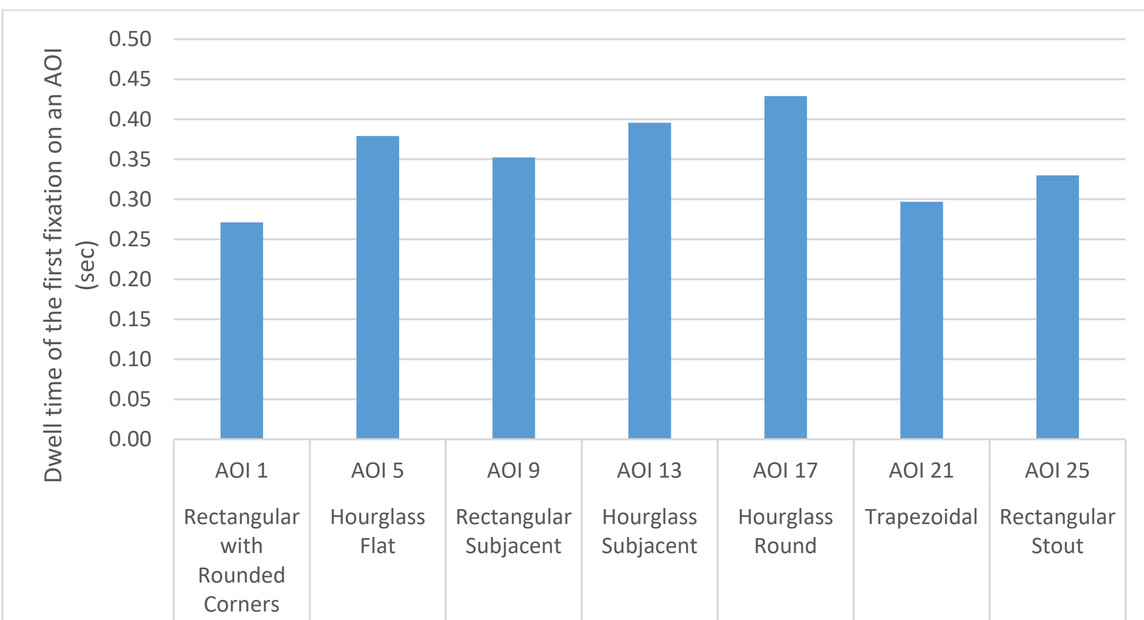

Figure B.10 Comparison of median values for the dwell time of the first fixation on an AOI for AOIs 1, 5, 9, 13, 17, 21, and 25 across different remote designs.

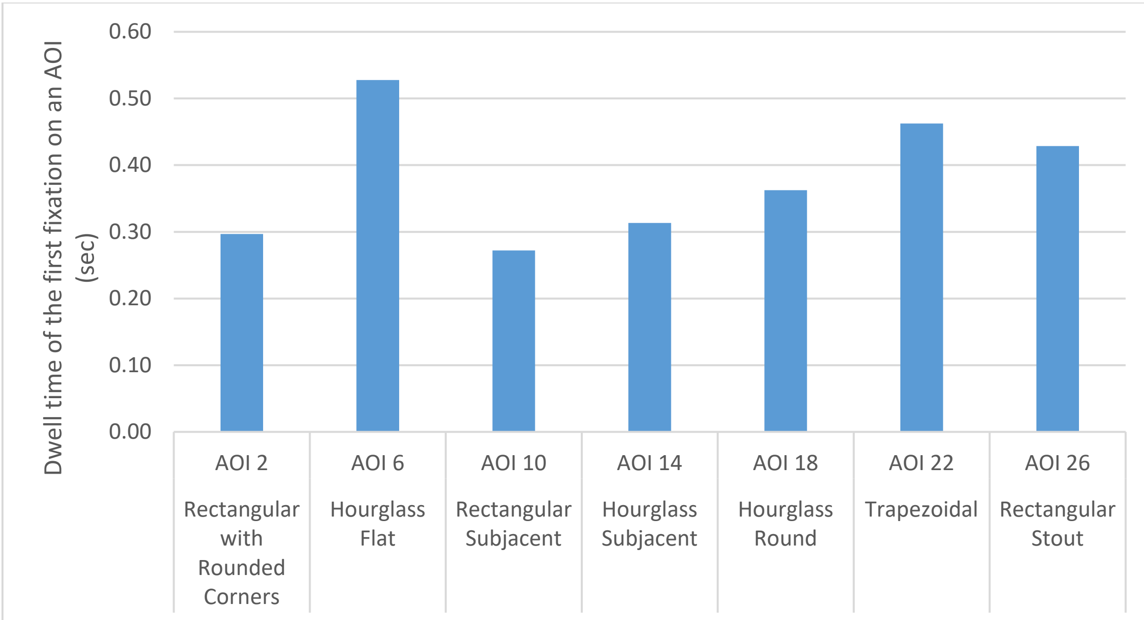

Figure B.11 Comparison of median values for the dwell time of the first fixation on an AOI for AOIs 1, 5, 9, 13, 17, 21, and 25 across different remote designs.

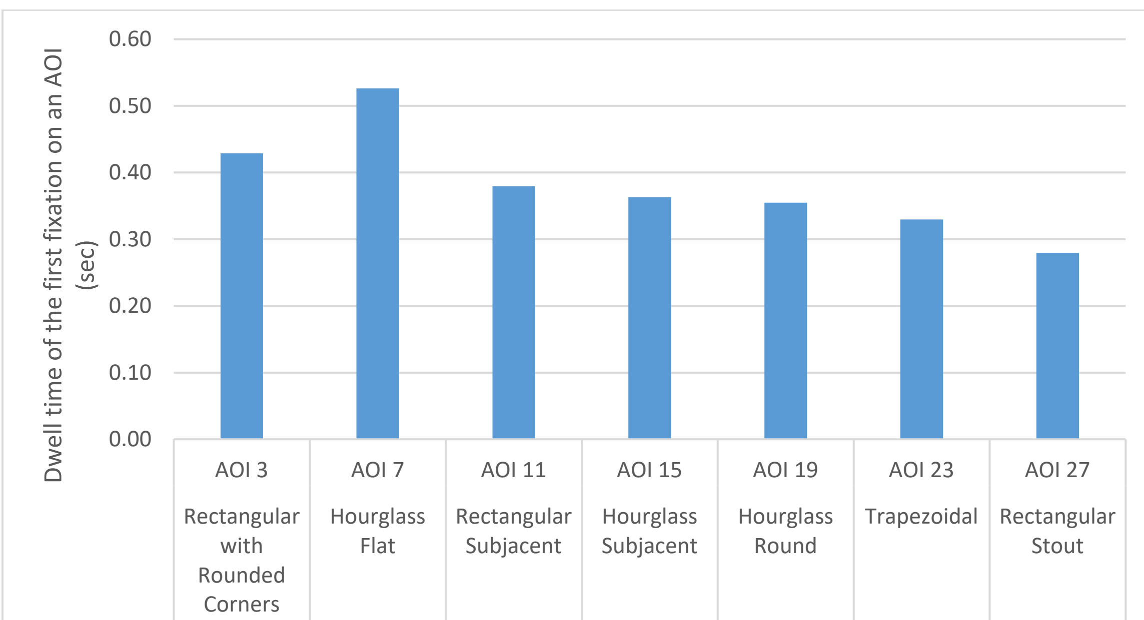

Figure B.12 Comparison of median values for the dwell time of the first fixation on an AOI for AOIs 3, 7, 11, 15, 19, 23, and 27 across different remote designs.

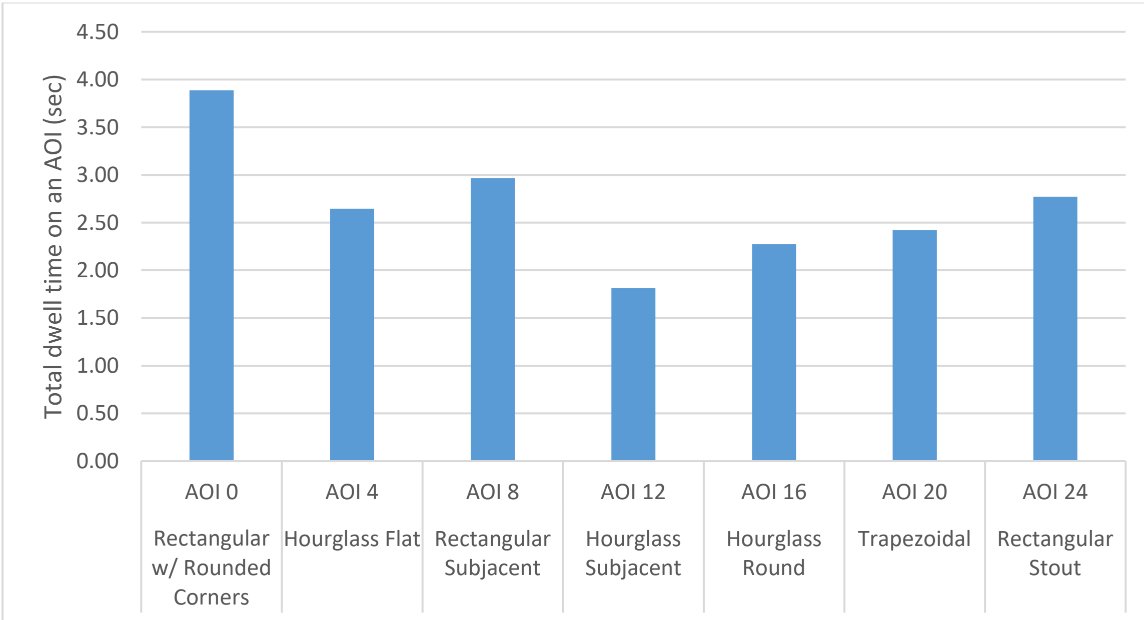

Figure B.13 Comparison of median values for the total dwell time on an AOI for AOIs 0, 4, 8, 12, 16, 20, and 24 across different remote design.

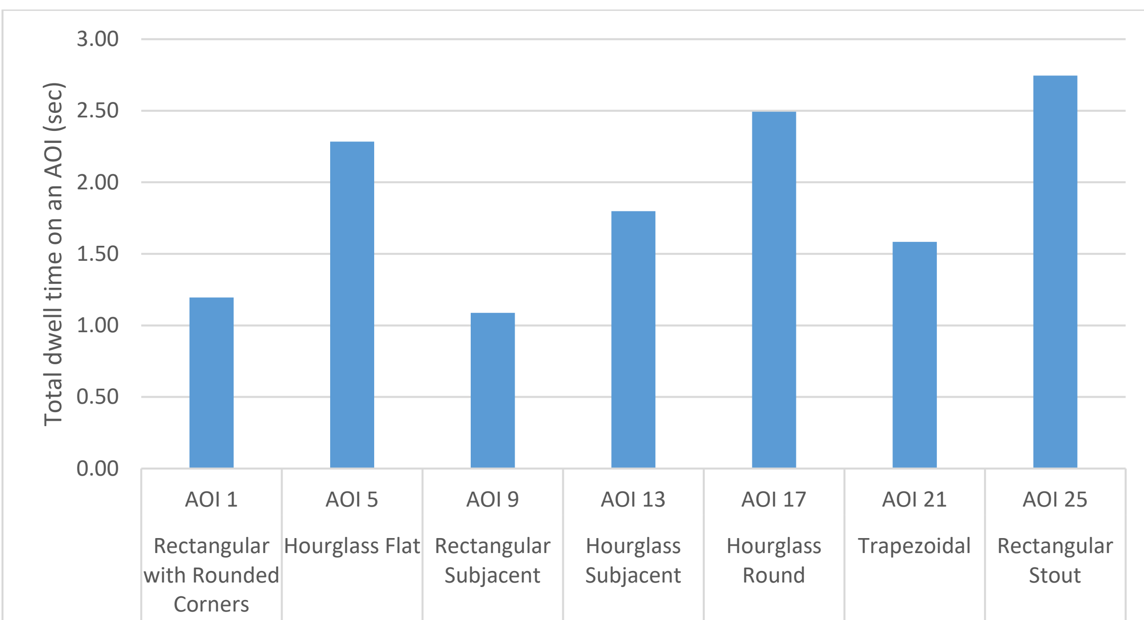

Figure B.14 Comparison of median values for the total dwell time on an AOI for AOIs 1, 5, 9, 13, 17, 21, and 25 across different remote design.

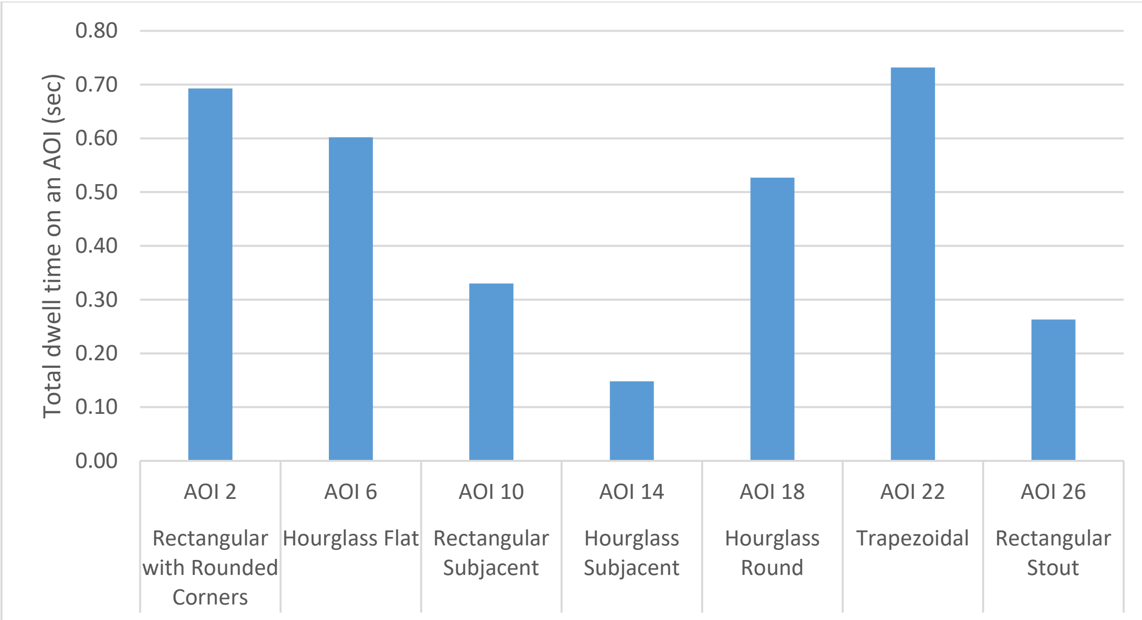

Figure B.15 Comparison of median values for the total dwell time on an AOI for AOIs 2, 6, 10, 14, 18, 22, and 26 across different remote design.

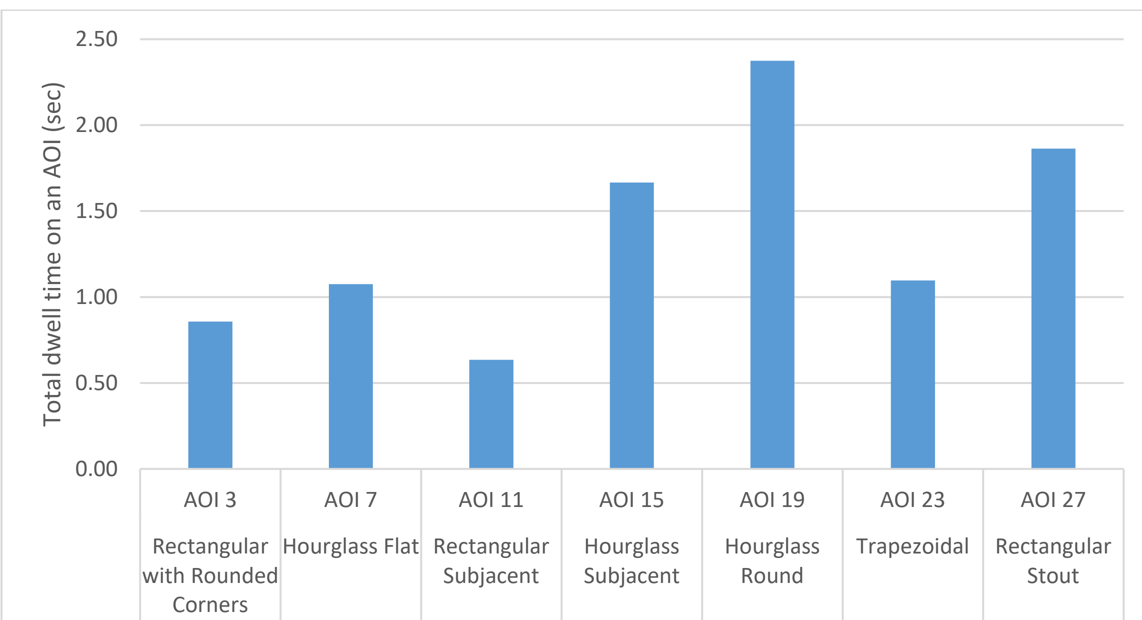

Figure B.16 Comparison of median values for the total dwell time on an AOI for AOIs 3, 7, 11, 15, 19, 23, and 27 across different remote design.

APPENDIX C

PAIRWISE COMPARISONS

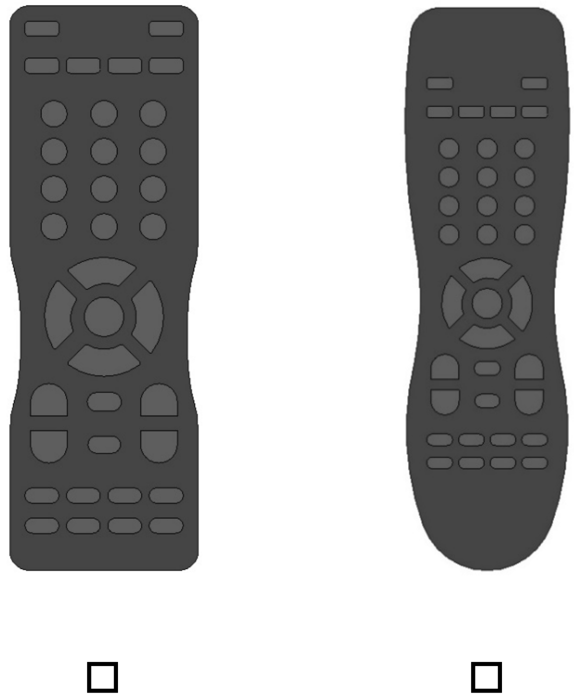

Figure C.1 Pairwise comparison. Flat bottom v. narrow rounded bottom.

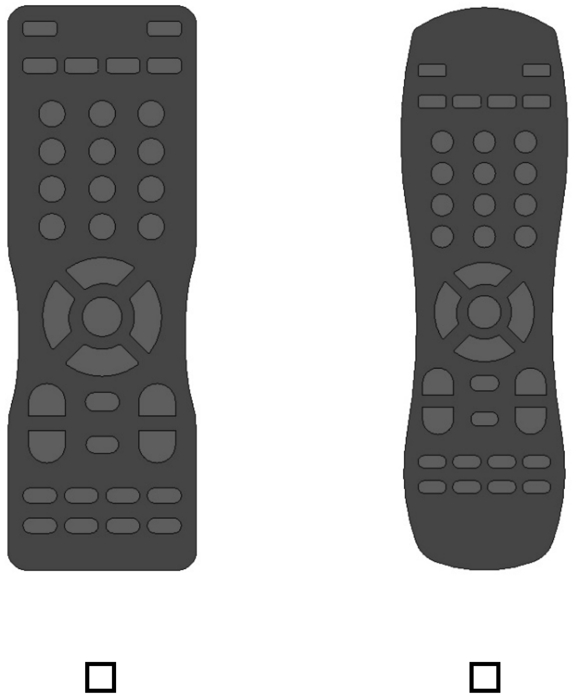

Figure C.2 Pairwise comparison. Flat top and bottom v. rounded top and bottom.

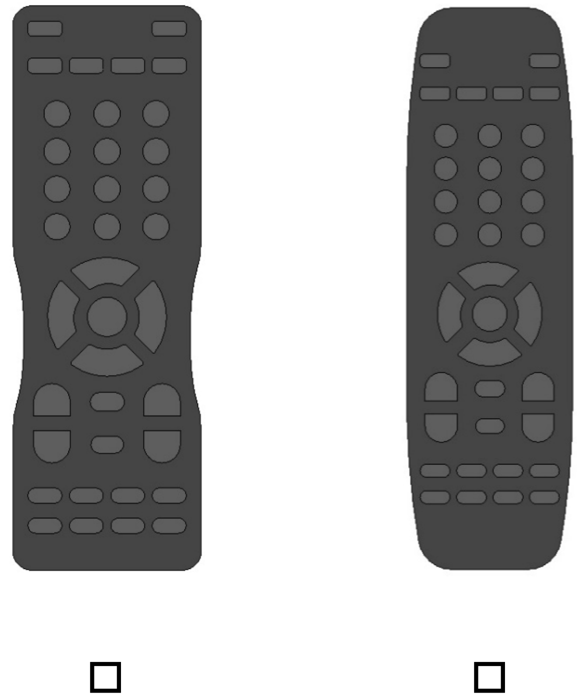

Figure C.3 Pairwise comparison. Pinched waist v. rounded sides.

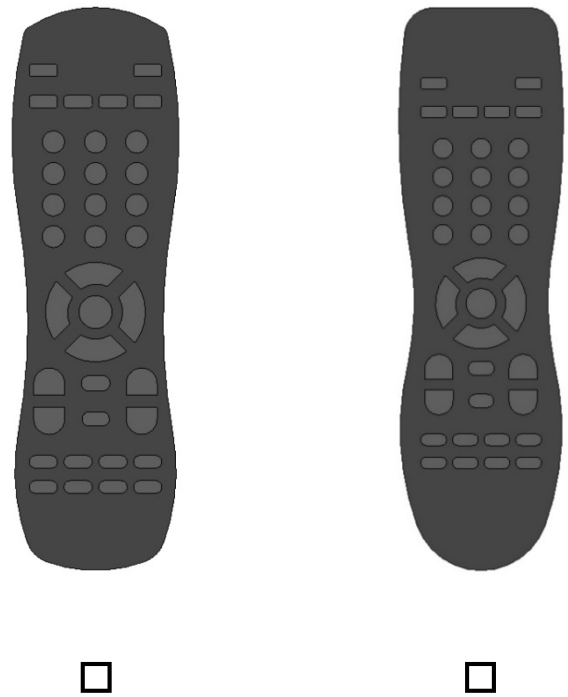

Figure C.4 Pairwise comparison. Rounded top v. flat top.

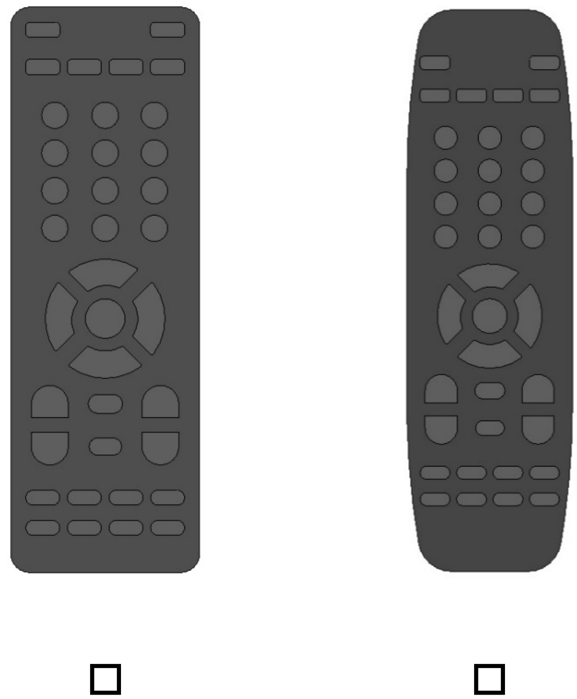

Figure C.5 Pairwise comparison. Flat sides v. rounded sides.

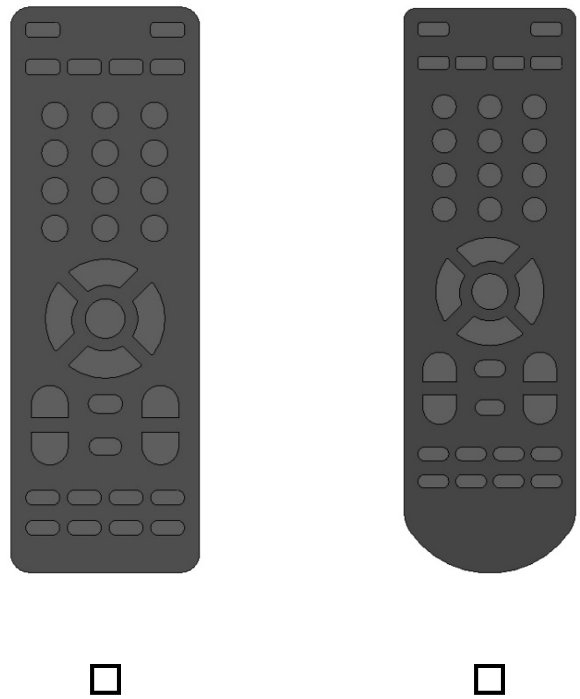

Figure C.6 Pairwise comparison. Flat bottom v. wide rounded bottom.

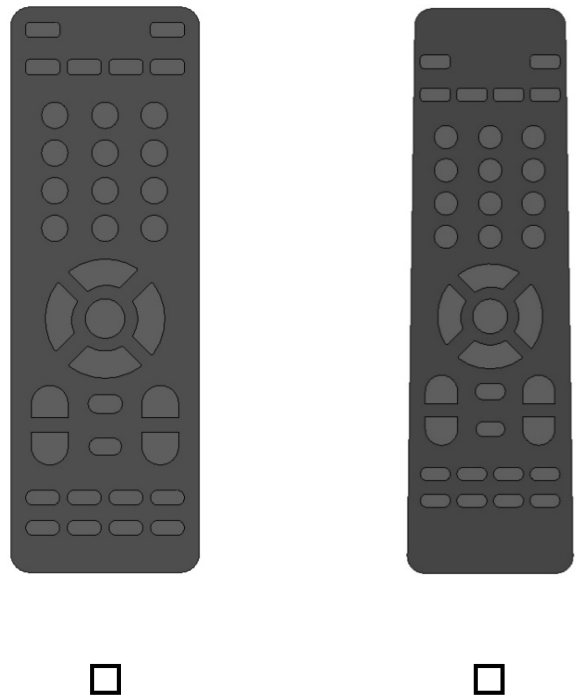

Figure C.7 Pairwise comparison. Flat sides v. tapered sides.

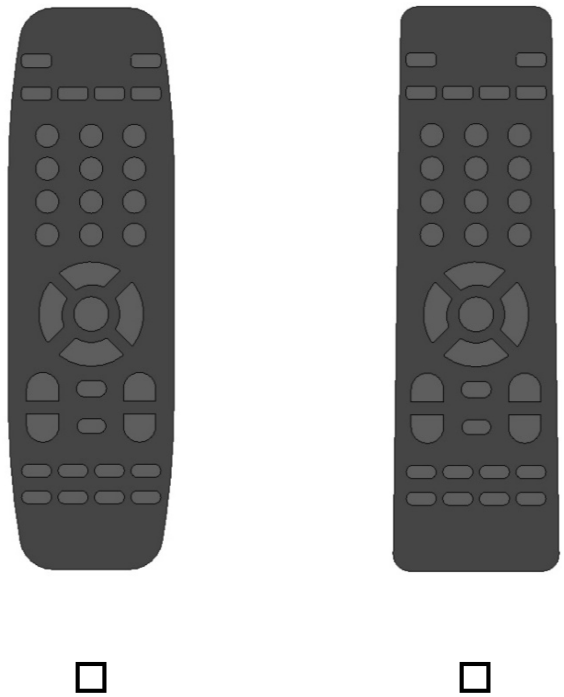

Figure C.8 Pairwise comparison. Rounded sides v. tapered sides.

APPENDIX D

IN-PERSON LIKERT SURVEY RESPONSES

Table D.1 Likert in-person appearance survey results for proportion of remote designs.

Overall Proportion (Appearance)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	2 11%	1 5%	8 42%	5 26%	3 16%
Hourglass Flat	1 5%	5 26%	6 32%	5 26%	2 11%
Rectangular Subjacent	1 5%	3 16%	8 42%	5 26%	2 11%
Hourglass Subjacent	1 5%	2 11%	5 26%	7 37%	4 21%
Hourglass Round	0 0%	1 5%	5 26%	12 63%	1 5%
Trapezoidal	2 11%	3 16%	9 47%	4 21%	1 5%
Rectangular Stout	0 0%	3 16%	9 47%	7 37%	0 0%

Table D.2 Likert in-person appearance survey results for shape of remote designs.

Overall Shape (Appearance)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	3 16%	3 16%	7 37%	3 16%	3 16%
Hourglass Flat	4 21%	6 32%	6 32%	1 5%	2 11%
Rectangular Subjacent	2 11%	5 26%	4 21%	8 42%	0 0%
Hourglass Subjacent	0 0%	2 11%	5 26%	6 32%	6 32%
Hourglass Round	0 0%	1 5%	6 32%	9 47%	3 16%
Trapezoidal	3 16%	4 21%	8 42%	3 16%	1 5%
Rectangular Stout	1 5%	3 16%	11 58%	4 21%	0 0%

Table D.3 Likert in-person appearance survey results for configuration of remote designs.

Overall Configuration (Appearance)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	1 5%	4 21%	8 42%	3 16%	3 16%
Hourglass Flat	3 16%	7 37%	6 32%	3 16%	0 0%
Rectangular Subjacent	2 11%	3 16%	8 42%	5 26%	1 5%
Hourglass Subjacent	0 0%	2 11%	3 16%	10 53%	4 21%
Hourglass Round	0 0%	1 5%	9 47%	8 42%	1 5%
Trapezoidal	1 5%	3 16%	12 63%	2 11%	1 5%
Rectangular Stout	0 0%	4 21%	12 63%	3 16%	0 0%

Table D.4 Likert in-person usability survey results for proportion of remote designs.

Overall Proportion (Usability)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	3 16%	4 21%	7 37%	4 21%	1 5%
Hourglass Flat	0 0%	3 16%	10 53%	5 26%	1 5%
Rectangular Subjacent	1 5%	3 16%	9 47%	3 16%	3 16%
Hourglass Subjacent	1 5%	1 5%	4 21%	7 37%	6 32%
Hourglass Round	0 0%	0 0%	4 21%	11 58%	4 21%
Trapezoidal	0 0%	4 21%	9 47%	6 32%	0 0%
Rectangular Stout	0 0%	3 16%	9 47%	7 37%	0 0%

Table D.5 LikeLikert in-person usability survey results for shape of remote designs.

Overall Shape (Usability)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	2 11%	6 32%	8 42%	1 5%	2 11%
Hourglass Flat	1 5%	3 16%	7 37%	7 37%	1 5%
Rectangular Subjacent	1 5%	4 21%	10 53%	2 11%	2 11%
Hourglass Subjacent	0 0%	2 11%	2 11%	9 47%	6 32%
Hourglass Round	0 0%	0 0%	3 16%	12 63%	4 21%
Trapezoidal	0 0%	5 26%	9 47%	4 21%	1 5%
Rectangular Stout	1 5%	1 5%	11 58%	6 32%	0 0%

Table D.6 Likert in-person usability survey results for configuration of remote designs.

Overall Configuration (Usability)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	2 11%	5 26%	8 42%	1 5%	3 16%
Hourglass Flat	0 0%	4 21%	9 47%	5 26%	1 5%
Rectangular Subjacent	1 5%	2 11%	10 53%	4 21%	2 11%
Hourglass Subjacent	0 0%	2 11%	4 21%	5 26%	8 42%
Hourglass Round	0 0%	0 0%	3 16%	13 68%	3 16%
Trapezoidal	0 0%	5 26%	11 58%	3 16%	0 0%
Rectangular Stout	0 0%	4 21%	10 53%	4 21%	1 5%

APPENDIX E

IN-PERSON MANN WHITNEY TEST RESULTS FOR DIFFERENCES BETWEEN REMOTE CONTROL DESIGNS AND DEMOGRAPHICS

Table E.1 Mann Whitney U test results for differences in appearance between remote control designs and gender.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	42.000	0.000	1.000
	Hourglass Flat	50.000	0.700	0.484
	Rectangular Subjacent	27.000	-1.333	0.183
	Hourglass Subjacent	40.000	-0.176	0.860
	Hourglass Round	42.500	0.049	0.961
	Trapezoidal	36.500	-0.495	0.621
	Rectangular Stout	32.000	-0.921	0.357
Overall Shape	Rectangular with Rounded Corners	37.000	-0.437	0.662
	Hourglass Flat	31.500	-0.921	0.357
	Rectangular Subjacent	41.500	-0.045	0.964
	Hourglass Subjacent	49.000	0.617	0.537
	Hourglass Round	41.000	-0.091	0.927
	Trapezoidal	44.500	0.221	0.825
	Rectangular Stout	26.000	-1.517	0.129
Overall Configuration	Rectangular with Rounded Corners	26.000	-1.417	0.156
	Hourglass Flat	46.000	0.354	0.724
	Rectangular Subjacent	22.000	-1.777	0.075
	Hourglass Subjacent	37.000	-0.460	0.645
	Hourglass Round	39.500	-0.233	0.816
	Trapezoidal	53.500	1.126	0.260
	Rectangular Stout	37.500	-0.443	0.658

Table E.2 Mann Whitney U test results for differences in usability between remote control designs and gender.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	42.000	0.000	1.000
	Hourglass Flat	43.000	0.093	0.926
	Rectangular Subjacent	35.000	-0.629	0.529
	Hourglass Subjacent	44.000	0.177	0.859
	Hourglass Round	34.500	-0.713	0.476
	Trapezoidal	43.500	0.137	0.891
	Rectangular Stout	38.000	-0.368	0.713
Overall Shape	Rectangular with Rounded Corners	40.500	-0.134	0.893
	Hourglass Flat	36.000	-0.535	0.593
	Rectangular Subjacent	31.500	-0.966	0.334
	Hourglass Subjacent	24.000	-1.638	0.101
	Hourglass Round	47.000	0.492	0.623
	Trapezoidal	50.000	0.726	0.468
	Rectangular Stout	39.000	-0.288	0.774
Overall Configuration	Rectangular with Rounded Corners	36.000	-0.533	0.594
	Hourglass Flat	39.000	-0.272	0.786
	Rectangular Subjacent	26.500	-1.425	0.154
	Hourglass Subjacent	42.500	0.045	0.964
	Hourglass Round	50.000	0.824	0.410
	Trapezoidal	48.000	0.572	0.567
	Rectangular Stout	17.500	-2.262	< 0.05

Table E.3 Mann Whitney U test results for differences in appearance between remote control designs and age.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	60.500	1.433	0.152
	Hourglass Flat	57.000	1.111	0.267
	Rectangular Subjacent	56.000	1.042	0.297
	Hourglass Subjacent	50.000	0.515	0.606
	Hourglass Round	47.000	0.290	0.772
	Trapezoidal	33.000	-0.967	0.333
	Rectangular Stout	38.000	-0.540	0.589
Overall Shape	Rectangular with Rounded Corners	62.000	1.536	0.125
	Hourglass Flat	57.500	1.157	0.247
	Rectangular Subjacent	51.500	0.653	0.514
	Hourglass Subjacent	40.000	-0.344	0.731
	Hourglass Round	43.500	-0.045	0.965
	Trapezoidal	32.000	-1.038	0.299
	Rectangular Stout	23.000	-1.945	0.052
Overall Configuration	Rectangular with Rounded Corners	47.500	0.303	0.762
	Hourglass Flat	45.500	0.130	0.897
	Rectangular Subjacent	51.500	0.651	0.515
	Hourglass Subjacent	39.500	-0.405	0.686
	Hourglass Round	29.000	-1.367	0.172
	Trapezoidal	32.000	-1.148	0.251
	Rectangular Stout	32.000	-1.154	0.248

Table E.4 Mann Whitney U test results for differences in usability between remote control designs and age.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	51.000	0.599	0.549
	Hourglass Flat	48.000	0.362	0.718
	Rectangular Subjacent	48.000	0.351	0.725
	Hourglass Subjacent	58.000	1.211	0.226
	Hourglass Round	51.500	0.697	0.486
	Trapezoidal	46.500	0.223	0.823
	Rectangular Stout	48.000	0.360	0.719
Overall Shape	Rectangular with Rounded Corners	53.500	0.830	0.407
	Hourglass Flat	58.000	1.220	0.223
	Rectangular Subjacent	55.000	0.988	0.323
	Hourglass Subjacent	53.000	0.800	0.424
	Hourglass Round	41.000	-0.289	0.773
	Trapezoidal	45.000	0.089	0.929
	Rectangular Stout	40.500	-0.328	0.743
Overall Configuration	Rectangular with Rounded Corners	60.500	1.433	0.152
	Hourglass Flat	64.000	1.772	0.076
	Rectangular Subjacent	49.000	0.449	0.653
	Hourglass Subjacent	48.500	0.392	0.695
	Hourglass Round	36.000	-0.805	0.421
	Trapezoidal	42.000	-0.186	0.852
	Rectangular Stout	33.000	-0.992	0.321

Table E.5 Mann Whitney U test results for differences in appearance between remote control designs and design experience.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	23.000	-1.168	0.243
	Hourglass Flat	30.500	-0.431	0.666
	Rectangular Subjacent	23.000	-1.168	0.243
	Hourglass Subjacent	29.500	-0.530	0.596
	Hourglass Round	39.000	0.433	0.665
	Trapezoidal	26.500	-0.838	0.402
	Rectangular Stout	29.000	-0.605	0.545
Overall Shape	Rectangular with Rounded Corners	22.000	-1.243	0.214
	Hourglass Flat	18.500	-1.585	0.113
	Rectangular Subjacent	35.500	0.049	0.961
	Hourglass Subjacent	44.000	0.869	0.385
	Hourglass Round	51.000	1.597	0.110
	Trapezoidal	27.000	-0.776	0.438
	Rectangular Stout	33.500	-0.156	0.876
Overall Configuration	Rectangular with Rounded Corners	26.000	-0.873	0.383
	Hourglass Flat	32.000	-0.291	0.771
	Rectangular Subjacent	28.000	-0.681	0.496
	Hourglass Subjacent	31.500	-0.353	0.724
	Hourglass Round	49.000	1.430	0.153
	Trapezoidal	37.000	0.215	0.830
	Rectangular Stout	21.500	-1.456	0.145

Table E.6 Mann Whitney U test results for differences in usability between remote control designs and design experience.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	34.500	-0.048	0.962
	Hourglass Flat	31.500	-0.355	0.723
	Rectangular Subjacent	42.000	0.689	0.491
	Hourglass Subjacent	29.000	-0.582	0.561
	Hourglass Round	27.500	-0.781	0.435
	Trapezoidal	30.000	-0.501	0.617
	Rectangular Stout	27.000	-0.807	0.420
Overall Shape	Rectangular with Rounded Corners	33.500	-0.147	0.883
	Hourglass Flat	29.000	-0.586	0.558
	Rectangular Subjacent	23.500	-1.158	0.247
	Hourglass Subjacent	37.500	0.249	0.803
	Hourglass Round	33.000	-0.216	0.829
	Trapezoidal	34.500	-0.050	0.960
	Rectangular Stout	33.500	-0.158	0.875
Overall Configuration	Rectangular with Rounded Corners	23.000	-1.168	0.243
	Hourglass Flat	27.000	-0.795	0.427
	Rectangular Subjacent	35.500	0.050	0.960
	Hourglass Subjacent	31.000	-0.391	0.696
	Hourglass Round	35.000	0.000	1.000
	Trapezoidal	32.000	-0.313	0.754
	Rectangular Stout	39.500	0.455	0.649

APPENDIX F

ONLINE LIKERT SURVEY RESPONSES

Table F.1 Likert online appearance survey results for proportion of remote designs.

Overall Proportion (Appearance)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	17 6%	55 18%	126 41%	88 29%	18 6%
Hourglass Flat	20 7%	61 20%	132 43%	79 26%	12 4%
Rectangular Subjacent	6 2%	40 13%	138 45%	104 34%	16 5%
Hourglass Subjacent	8 3%	28 9%	98 32%	137 45%	33 11%
Hourglass Round	8 3%	31 10%	82 27%	140 46%	43 14%
Trapezoidal	15 5%	61 20%	142 47%	72 24%	14 5%
Rectangular Stout	6 2%	45 15%	136 45%	97 32%	20 7%

Table F.2 Likert online appearance survey results for shape of remote designs.

Overall Shape (Appearance)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	22 7%	71 23%	130 43%	64 21%	17 6%
Hourglass Flat	28 9%	79 26%	115 38%	60 20%	22 7%
Rectangular Subjacent	8 3%	50 16%	131 43%	98 32%	17 6%
Hourglass Subjacent	8 3%	43 14%	75 25%	119 39%	59 19%
Hourglass Round	10 3%	35 12%	76 25%	112 37%	71 23%
Trapezoidal	20 7%	88 29%	111 37%	69 23%	16 5%
Rectangular Stout	10 3%	70 23%	126 41%	76 25%	22 7%

Table F.3 Likert online appearance survey results for configuration of remote designs.

Overall Configuration (Appearance)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	18 6%	49 16%	136 45%	82 27%	19 6%
Hourglass Flat	21 7%	60 20%	123 40%	80 26%	20 7%
Rectangular Subjacent	7 2%	35 12%	138 45%	104 34%	20 7%
Hourglass Subjacent	6 2%	35 12%	99 33%	124 41%	40 13%
Hourglass Round	7 2%	23 8%	98 32%	124 41%	52 17%
Trapezoidal	14 5%	53 17%	134 44%	82 27%	21 7%
Rectangular Stout	6 2%	38 13%	144 47%	91 30%	25 8%

Table F.4 Likert online usability survey results for proportion of remote designs.

Overall Proportion (Usability)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	17 6%	69 23%	121 41%	65 22%	25 8%
Hourglass Flat	17 6%	69 23%	126 42%	66 22%	19 6%
Rectangular Subjacent	12 4%	51 17%	135 45%	86 29%	13 4%
Hourglass Subjacent	8 3%	27 9%	82 28%	133 45%	47 16%
Hourglass Round	10 3%	34 11%	86 29%	128 43%	39 13%
Trapezoidal	20 7%	62 21%	131 44%	73 25%	11 4%
Rectangular Stout	9 3%	48 16%	152 51%	78 26%	10 3%

Table F.5 Likert online usability survey results for shape of remote designs.

Overall Shape (Usability)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	19 6%	82 28%	109 37%	60 20%	27 9%
Hourglass Flat	22 7%	76 26%	111 37%	67 23%	21 7%
Rectangular Subjacent	15 5%	54 18%	127 43%	87 29%	14 5%
Hourglass Subjacent	10 3%	29 10%	74 25%	132 44%	52 18%
Hourglass Round	11 4%	36 12%	65 22%	128 43%	57 19%
Trapezoidal	26 9%	77 26%	114 38%	68 23%	12 4%
Rectangular Stout	8 3%	60 20%	142 48%	73 25%	14 5%

Table F.6 Likert online usability survey results for configuration of remote designs.

Overall Configuration (Usability)	VERY POOR N (%)	POOR N (%)	OK N (%)	GOOD N (%)	VERY GOOD N (%)
Rectangular w/ Rounded Corners	20 7%	58 20%	124 42%	69 23%	26 9%
Hourglass Flat	17 6%	61 21%	122 41%	79 27%	18 6%
Rectangular Subjacent	11 4%	44 15%	138 46%	89 30%	15 5%
Hourglass Subjacent	6 2%	32 11%	93 31%	119 40%	47 16%
Hourglass Round	7 2%	34 11%	93 31%	116 39%	47 16%
Trapezoidal	18 6%	60 20%	131 44%	74 25%	14 5%
Rectangular Stout	11 4%	45 15%	146 49%	84 28%	11 4%

APPENDIX G

ONLINE MANN-WHITNEY TEST RESULTS FOR DIFFERENCES BETWEEN REMOTE CONTROL DESIGNS AND DEMOGRAPHICS

Table G.1 Mann Whitney U test results for differences in appearance between remote control designs and gender.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	12107.000	0.764	0.445
	Hourglass Flat	12418.500	1.197	0.231
	Rectangular Subjacent	12116.000	0.792	0.428
	Hourglass Subjacent	11157.000	-0.552	0.581
	Hourglass Round	11455.500	-0.134	0.893
	Trapezoidal	11624.000	0.100	0.920
	Rectangular Stout	11669.000	0.163	0.870
Overall Shape	Rectangular with Rounded Corners	11777.000	0.310	0.757
	Hourglass Flat	12161.500	0.829	0.407
	Rectangular Subjacent	12220.500	0.929	0.353
	Hourglass Subjacent	11942.500	0.533	0.594
	Hourglass Round	12566.500	1.380	0.168
	Trapezoidal	11316.000	-0.322	0.747
	Rectangular Stout	11944.000	0.539	0.590
Overall Configuration	Rectangular with Rounded Corners	12055.500	0.698	0.485
	Hourglass Flat	11974.000	0.578	0.563
	Rectangular Subjacent	12935.500	1.942	0.052
	Hourglass Subjacent	11823.000	0.374	0.708
	Hourglass Round	12117.500	0.781	0.435
	Trapezoidal	12434.000	1.221	0.222
	Rectangular Stout	11948.000	0.556	0.578

Table G.2 Mann Whitney U test results for differences in usability between remote control designs and gender.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	10981.000	-0.064	0.949
	Hourglass Flat	11074.000	0.068	0.945
	Rectangular Subjacent	10972.500	-0.077	0.938
	Hourglass Subjacent	11367.000	0.490	0.624
	Hourglass Round	11234.000	0.298	0.766
	Trapezoidal	11276.000	0.358	0.720
	Rectangular Stout	11512.500	0.716	0.474
Overall Shape	Rectangular with Rounded Corners	10694.000	-0.468	0.640
	Hourglass Flat	11730.500	0.993	0.321
	Rectangular Subjacent	10619.000	-0.583	0.560
	Hourglass Subjacent	11465.500	0.629	0.529
	Hourglass Round	11860.500	1.188	0.234
	Trapezoidal	10507.500	-0.733	0.463
	Rectangular Stout	11012.000	-0.020	0.984
Overall Configuration	Rectangular with Rounded Corners	11358.500	0.472	0.637
	Hourglass Flat	11826.000	1.138	0.255
	Rectangular Subjacent	10745.500	-0.407	0.684
	Hourglass Subjacent	11771.000	1.061	0.289
	Hourglass Round	11216.500	0.271	0.787
	Trapezoidal	11023.500	-0.004	0.997
	Rectangular Stout	11361.500	0.490	0.624

Table G.3 Mann Whitney U test results for differences in appearance between remote control designs and age.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	8751.500	-0.213	0.831
	Hourglass Flat	8714.000	-0.273	0.785
	Rectangular Subjacent	9497.500	0.976	0.329
	Hourglass Subjacent	8760.000	-0.203	0.839
	Hourglass Round	8688.500	-0.316	0.752
	Trapezoidal	9356.500	0.745	0.456
	Rectangular Stout	10185.500	2.065	< 0.05
Overall Shape	Rectangular with Rounded Corners	9266.500	0.595	0.552
	Hourglass Flat	9657.000	1.194	0.233
	Rectangular Subjacent	9574.000	1.088	0.277
	Hourglass Subjacent	8780.500	-0.166	0.868
	Hourglass Round	8550.500	-0.523	0.601
	Trapezoidal	9009.500	0.190	0.849
	Rectangular Stout	10988.500	3.294	< 0.05
Overall Configuration	Rectangular with Rounded Corners	9428.000	0.854	0.393
	Hourglass Flat	9632.500	1.164	0.245
	Rectangular Subjacent	9808.500	1.474	0.141
	Hourglass Subjacent	8445.500	-0.696	0.487
	Hourglass Round	9158.500	0.427	0.670
	Trapezoidal	9493.500	0.956	0.339
	Rectangular Stout	10961.000	3.318	< 0.05

Table G.4 Mann Whitney U test results for differences in usability between remote control designs and age.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	8817.000	0.445	0.657
	Hourglass Flat	9062.000	0.843	0.399
	Rectangular Subjacent	8828.500	0.471	0.637
	Hourglass Subjacent	9715.500	1.917	0.055
	Hourglass Round	8975.500	0.706	0.480
	Trapezoidal	8761.000	0.358	0.720
	Rectangular Stout	9266.000	1.212	0.226
Overall Shape	Rectangular with Rounded Corners	8293.000	-0.397	0.691
	Hourglass Flat	9591.000	1.682	0.093
	Rectangular Subjacent	8177.500	-0.591	0.554
	Hourglass Subjacent	9324.000	1.274	0.203
	Hourglass Round	8839.000	0.482	0.630
	Trapezoidal	8302.500	-0.383	0.702
	Rectangular Stout	8599.000	0.096	0.924
Overall Configuration	Rectangular with Rounded Corners	8695.000	0.248	0.804
	Hourglass Flat	9070.500	0.856	0.392
	Rectangular Subjacent	8460.000	-0.133	0.894
	Hourglass Subjacent	9463.500	1.493	0.135
	Hourglass Round	8639.500	0.159	0.874
	Trapezoidal	8313.000	-0.371	0.711
	Rectangular Stout	8959.000	0.694	0.488

Table G.5 Mann Whitney U test results for differences in appearance between remote control designs and design experience.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	5775.000	1.501	0.133
	Hourglass Flat	5537.500	1.010	0.313
	Rectangular Subjacent	5588.000	1.133	0.257
	Hourglass Subjacent	5500.500	0.943	0.346
	Hourglass Round	5161.500	0.226	0.821
	Trapezoidal	4441.500	-1.291	0.197
	Rectangular Stout	5249.500	0.412	0.680
Overall Shape	Rectangular with Rounded Corners	5277.500	0.465	0.642
	Hourglass Flat	5519.500	0.958	0.338
	Rectangular Subjacent	5667.500	1.289	0.197
	Hourglass Subjacent	4962.500	-0.189	0.850
	Hourglass Round	5542.500	1.005	0.315
	Trapezoidal	4600.500	-0.935	0.350
	Rectangular Stout	4595.000	-0.954	0.340
Overall Configuration	Rectangular with Rounded Corners	5291.500	0.498	0.619
	Hourglass Flat	5429.000	0.777	0.437
	Rectangular Subjacent	5773.500	1.527	0.127
	Hourglass Subjacent	4874.000	-0.376	0.707
	Hourglass Round	4696.500	-0.746	0.455
	Trapezoidal	4319.000	-1.538	0.124
	Rectangular Stout	4489.500	-1.198	0.231

Table G.6 Mann Whitney U test results for differences in usability between remote control designs and design experience.

		Mann-Whitney U	Z	Asymp. Sig. (2-sided test)
Overall Proportion	Rectangular with Rounded Corners	5060.000	0.786	0.432
	Hourglass Flat	5351.000	1.425	0.154
	Rectangular Subjacent	4756.000	0.128	0.898
	Hourglass Subjacent	5123.000	0.936	0.350
	Hourglass Round	5353.500	1.437	0.151
	Trapezoidal	4208.000	-1.075	0.282
	Rectangular Stout	4861.000	0.367	0.713
Overall Shape	Rectangular with Rounded Corners	4741.000	0.093	0.926
	Hourglass Flat	5454.000	1.633	0.103
	Rectangular Subjacent	4932.000	0.513	0.608
	Hourglass Subjacent	5608.000	1.996	< 0.05
	Hourglass Round	5526.500	1.807	0.071
	Trapezoidal	4389.000	-0.669	0.503
	Rectangular Stout	4351.000	-0.771	0.441
Overall Configuration	Rectangular with Rounded Corners	4713.500	0.034	0.973
	Hourglass Flat	5492.500	1.731	0.083
	Rectangular Subjacent	4559.500	-0.308	0.758
	Hourglass Subjacent	5006.500	0.673	0.501
	Hourglass Round	4819.000	0.263	0.792
	Trapezoidal	4409.500	-0.633	0.527
	Rectangular Stout	4888.000	0.425	0.671