ABSTRACT

PRATHER, REBECCA JOELLE. Use of 3D Apparel Simulation in the Prototyping and Visualization of Women's Denim. (Under the direction of Dr. Anne Porterfield).

The purpose of this research was to gain insight into consumer perception of 3D apparel simulation software. Specifically, if consumers can make customization and intent to purchase decisions based on viewing 3D simulations of apparel, how they believe 3D simulations represent the fit and fabric of a garment, and how accurately consumers believe virtual avatars reflect human bodies was researched.

This study used a mixed method design, combining qualitative and quantitative data collection, to gain a more complete understanding of participants' feelings. The study consisted of two general parts: fit model and consumer data collection. The fit models, chosen to be representative of the average size of US women, took part in an initial survey, a fitting session, and a post-fitting survey, designed to gather information on perceptions of 3D apparel simulations versus reality. The consumer group participated in an anonymous online survey intended to collect data on using 3D simulations to evaluate garment fit and make purchase decisions. This group was a convenience sample of 129 participants recruited mainly from university students and employees.

Results suggest that 3D apparel simulation is not an effective representation fit of the garment, but it is useful for evaluating overall silhouette and style details. Two types of consumers emerged from the analysis: self-focused and technologically focused individuals. Self-focused individuals tended to be more concerned with the personal aspects of shopping, and did not believe that 3D simulation could replace trying on a garment. Technologically focused individuals were more concerned with the accuracy of the 3D apparel simulation

itself. While consumers are hesitant to rely solely on the 3D simulation, participants indicated that the use of 3D virtual try-on would positively affect their purchase decisions.

Use of 3D Apparel Simulation in the Prototyping and Visualization of Women's Denim

by
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BIOGRAPHY

Rebecca Prather was born July 12th, 1994 in Atlanta, GA. In May 2012, she graduated from Cary High School in Cary, NC. Rebecca continued her education at North Carolina State University College of Textiles, where she received a Bachelor of Science in Fashion and Textile Management with a concentration in Fashion Development and Product Management in May 2016, graduating Manga Cum Laude. Having participated in the Accelerated Bachelors and Master's Program, Rebecca went on to graduate school with an assistantship funded by the Department of Textile and Apparel, Technology and Management. After finishing the requirements for her Master of Science degree she plans to pursue work in the apparel industry with a focus in 3D apparel simulation.

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1. INTRODUCTION

Consumer dissatisfaction with ready-to-wear apparel is widespread and escalating. Better sizing options and greater consumer understanding of sizing is necessary to provide well-fitting clothing to a large number of people. Sizing systems are ineffective, leading to marketplace confusion and consumer dissatisfaction, especially in reference to online shopping.

Three dimensional (3D) apparel simulation is a tool that can help solve these problems. 3D apparel CAD can be used to facilitate the development of better fitting clothing, either through more effective sizing systems, or through reducing product development time and cost. Three dimensional apparel simulation can be used for prototyping purposes, allowing designers to picture a garment during the product development stages (Easters, 2011). The extent to which 3D virtual prototyping technologies can accurately and efficiently predict what garments will look like when produced has been highly debated since the software emerged. Many factors influence the usefulness and accuracy of 3D apparel simulation, such as allowed input parameters and the extent to which different elements of the software can be manipulated. Independent studies have revealed varying opinions of the technology, creating confusion for companies who wish to adopt 3D prototyping.

Much of the recent research into 3D apparel technology suggests 3D simulation can be implemented to allow consumers to either virtually try-on or customize clothing. Virtually trying on clothing allows users to visualize the fit of clothing on various body types (Lee & Park, 2016). This is done by bringing 2D patterns into a 3D apparel simulation software and

converting the pieces into a polygonal mesh. These pieces are then positioned around an avatar that resembles the users' body (Kim & LaBat, 2013). Three dimensional apparel simulation technology could also aid in the customization of clothing as well as assisting product developers to create custom fit garments based on consumers' exact measurements (Kim & LaBat, 2013). There is little research into how consumers perceive 3D try-on technology or would like to use it in their everyday lives. This lack of knowledge is a hindrance to companies implementing 3D try-on technologies. More information on the capabilities and perceptions of both 3D prototyping and 3D try on software is vital for successful implementation and use of the technologies

This research aims to determine how female consumers view the experience of interacting with various aspects of 3D virtual prototyping software, focusing on the extent to which viewing 3D apparel simulations aides in making customization and purchase decisions, as well as consumers' comfort viewing avatars, and perceived quality of simulations. This research will provide information on how consumers view and interact with 3D apparel technology, as well as suggest strategies for its implementation. Women's clothing is an important sector of the apparel market, with $42 billion in revenue spent at women's clothing stores in 2017 alone (Hurley, 2017). The denim market in the United States is valued at $17.6 billion, making up the largest segment of world denim purchasing ("Denim with a Twist," 2017). Because of the huge market value in both women's clothing and denim, focusing this research on women's denim has great potential for industry impact. Utilizing this research, companies will gain a better understanding of how consumers view 3D technologies. In addition, this research will inform brands how to best present and facilitate the use of 3D technologies by consumers to maximize mutual trust and benefits.

2. LITERATURE REVIEW

2.1 Sizing Systems

The apparel industry today has faced the same challenge since its beginning: making well-fitting clothing. Three factors lead to ineffective sizing systems: the use of proportional sizing systems, inconsistent measurement data used to create unique sizing systems for each brand, and the practice of vanity sizing. These factors combine, building a barrier to producing well-fitting clothing, and decreasing consumer satisfaction with their own bodies. Due to the incorrect assumption that bodies are proportional, inconsistencies in sizing systems across brands, and changes in sizing, the apparel industry fails to offer effective sizing even today. All of these factors result in great confusion in the marketplace and frustrate consumers.

To understand the issues with sizing systems today, it is necessary to consider their development. Historically, a variety of methods have been used to measure the body and create sizing systems for apparel (Bye, LaBat & DeLong, 2006). Two ways of pattern drafting were developed in the mid 19th century: using standard patterns for less fitted garments, and developing more fitted garments based on custom measurements for each customer (Bye et al., 2006). When garments began to be produced in mass and sold through catalog, they were labeled and sold by bust or waist measurement, and graded 2 inches between sizes (Workman, 1991). This practice of a proportional sizing system has been a standard for the apparel industry since the 19th century. This system of proportional sizing may have been most effective in that time, when styles were relatively simple and the population was less diverse, however it is no longer beneficial for today's consumers.

Proportional sizing systems are intended to create a range of sizes that fit as many people as possible (Ashdown, 1998; Shin & Istook, 2007). Unfortunately, the assumption that the relationship between torso height, leg height, and arm reach, or between chest and hip girth, are measurable and proportional is errant (Bye et al., 2006). Because the human body is not necessarily proportional in shape across sizes, the proportional grading system does not fit the majority of the population as intended (Ashdown & Dunne, 2006; Alexander, Connell & Presley, 2005). Increased diversity in the population today renders proportional sizing more ineffective, as different ethnicities tend to have even more varied body shapes and sizes (Shin & Istook, 2007). Such an ineffective system of grading has led to great consumer dissatisfaction. In a 2003 survey reported by Intellifit Corp, 57% of respondents claimed problems of fitting into standard sizing (as cited in Shin & Istook, 2007). In a survey of 232 females, over half of respondents indicated that they were only somewhat satisfied to mostly unsatisfied with the fit of ready to wear apparel (Alexander et al., 2005). Proportional sizing systems, while intended to fit as many consumers in as few sizes as possible, frustrate consumers that do not fit into standard sizing.

In addition to proportional sizing systems, inconsistent use of measurement data further disorders sizing systems developed by apparel firms and creates consumer dissatisfaction. The first attempt at a comprehensive collection of measurements in the United States was in 1941. These measurements were used to create voluntary sizing standards, CS 251-58 and later PS 42-70, by the Federal Trade Commission and Department of Commerce (Alexander et al., 2005; Bye et al., 2006). Many industry members did not adopt these standards, instead creating a myriad of sizing systems that confuse consumers.

Instead of adopting available industry standards, brands develop unique sizing systems based on a specific target market, which is a population of women with distinct body shapes (Alexander et al., 2005). As a result, brands have unique measurement techniques and specifications that are used to create their sizing systems (Workman, 1991). According to Alexander, Connell, and Presley (2005), brands and retailers typically optimize sizing systems for the target consumer, to build brand loyalty with the consumers who find their body proportions work with the brands' sizing system. Thus, the sizing a brand uses becomes a selling tool (Alexander et al., 2005). While the use of unique sizing systems are intended to enhance a brand's identity, there are several drawbacks. Consumers must try on many brands to find the right fit, which is time consuming and frustrating (Workman, 1991). Furthermore, the apparel market consists of such a variety of brands that many consumers become exasperated with the array of sizing systems (Alexander et al., 2005). While proportional sizing systems are implemented by brands to fit a large number of consumers, their ineffectiveness results in overwhelmed and dissatisfied consumers.

Further complicating the apparel marketplace and bewildering consumers, brands change their sizing systems over time. In a study of various brands size charts from 1976 to 1986, Workman (1991) demonstrated that sizing systems became more inconsistent across brands. Changes in proportions of fit models were also evident over this period, including a significant increase in fit models' hip size, with no change in the height, bust, or waist measurements (Workman, 1991). Proportions of a company's fit model are used to create the sizing system, so changing these proportions over time adds to consumer confusion about sizing.

Vanity sizing is another element causing disorder the apparel marketplace. The practice of vanity sizing is labeling garments with smaller numbers, despite having larger measurements (Alexander et al., 2005). In a study of many brands' sizing systems by Workman (1991), it was found that a size 8 in 1986 was significantly larger than a size 10 in 1976, indicating that the sizes were getting smaller. In a subsequent study, the same trend of sizes getting smaller was found in brands during the 10 year period from 1986 to 1997 (Workman & Lentz, 2000). This practice of vanity sizing is just one of the many ways in which sizing systems are both ineffective and frustrating to the consumer.

On top of the dissatisfaction experienced based on ineffective sizing systems, inconsistent measurement data, changes in sizing, and vanity sizing, consumers are faced with societal pressures about clothing. Consumers experience the negative social norm that expects bodies to match clothing standards, as opposed to requiring clothing that fits all bodies (Bye et al., 2006). A lack of available clothing with good fit affects consumer's body satisfaction. Body cathexis is a person's levels of satisfaction about parts of his or her body (Alexander et al., 2005). Studies have linked fit satisfaction to body cathexis, and lower body sites, such as the abdomen, hips, and thighs, have scored the lowest for both fit and body satisfaction (LaBat & DeLong, 1990). Alexander, Connell and Presley (2005) found that women are particularly displeased with their body shape, as many women have broader hips than the proportional hourglass body shape. This is evident in studies that have found most fit problems occur with lower body garments (Alexander et al., 2005). While fit preference does not depend on body type, women with pear and hourglass body types are more likely to experience problems in the fit of lower body apparel. Issues of fit preference and body

cathexis need to be addressed by brands to maintain customer loyalty (Alexander et al., 2005). This is one of the problems that 3D prototyping or virtual try on can solve.

Through the incorrect assumption that bodies are proportional, the use of unique sizing systems, changes in sizing systems, and the practice of vanity sizing, sizing systems have become ineffective. Inadequate sizing systems make it difficult for brands to produce well-fitting clothing for a wide range of body sizes and shapes. This leaves customers confused and frustrated with the apparel marketplace and leads to lower body cathexis. Implementing virtual try on technology or allowing for product customization are both feasible solutions to counteract these issues.

2.2 3D Apparel Technology

2.2.1 Lower Product Development Time and Costs

Virtual apparel simulation enables users to convert 2D flat patterns into a sewn garment on the virtual fit model or avatar (Lee & Park, 2016). Avatars are simulated static human forms used in 3D apparel technology (Power, 2013). Simulations allow users to visualize what a garment might look like on different sizes and shapes of humans (Park, Kim & Sohn, 2010). While the use of body scanning and virtual fit technology aids in the visualization of clothing, the accuracy of the rendering depends on many factors, such as usability and efficiency (Easters, 2011). Usability of 3D apparel simulation is determined by factors such as user knowledge and varying input parameters. Despite potential limitations, many believe that these technologies greatly facilitate rapid prototyping of apparel (Park et al., 2010).

Power (2013) describes the product development process as the initial design of a garment, material selection, creation of the 2D pattern, cutting and prototyping of the garment, fit sessions with a live model, and any number of fit and pattern adjustments before a full production run is possible. Because 3D prototyping software allows real-time visualization of a garment and any adjustments made to the 2D pattern, the sampling and fitting stages of product development can be done with minimal physical prototyping (Power, 2013). In addition, designers are able to view the garment on various avatars and in different fabrics before manufacturing, reducing sampling costs significantly. The use of 3D prototyping, therefore, can shorten the product development cycle and make the process more productive (Apeagyei & Otieno, 2007). Using 3D prototyping also reduces or eliminates the need for fit models during development. As these models can become exhausted during fit sessions and sometime provide unreliable feedback, use of 3D prototyping is beneficial (Kim, 2016). 3D prototyping software also enhances speed of communication in the global product development environment while reducing the costs associated with it (Easters, 2011).

Use of 3D prototyping addresses many common issues of product development: misunderstanding in interpretation of patterns and technical packages, lack of trust among various companies working together, and lack of information causing slowdowns in the process. Still, Easters (2011) discovered that some are concerned with the security of information and ability to protect the firm's intellectual property. Managers and apparel product development experts have differing views of the efficacy of 3D apparel simulation (Easters, 2011), perhaps limiting the acceptance and use of the technology in industry. Three dimensional apparel simulation allows users to visualize apparel in a variety of fabrications

and silhouettes, and on any number of avatars with different shapes and sizes, ultimately lowering product development time and cost. Understanding consumer perception of 3D apparel simulation software is essential in determining how to best adopt the technology.

2.2.2 Create More Effective Sizing Systems

Three dimensional body scanning can be used to create more effective sizing systems by allowing for quick and accurate measurement of the human body, as well as creating easily accessible data. In a 2001 study, Mckinnon and Istook concluded 3D body scanning is a fast and consistent way to extract body measurements. These instruments use white light or laser light to capture a 360° view of the body, producing a point cloud of data that can be accessed and analyzed by various software (Bye et al., 2006). 3D body scanning has been used in efforts to collect a representative size sample of the population, such as the Civilian American and European Surface Anthropometry Research (CEA-SAR) and SizeUSA projects. SizeUSA data has been used in research to improve sizing systems (Alexander, Pisut & Ivanescu, 2012; Kim, Song & Ashdown, 2016). Additionally, 3D body scanning technology is evolving to be more efficient and accurate. These advances have the potential to be used to collect better measurements, create effective sizing systems quickly and efficiently, or create custom avatars for use in virtual try on technologies.

2.3 3D Prototyping Capabilities

2.3.1 Avatars

There are two general methods of creating a virtual avatar: using a stock avatar and manipulating it within the software, and creating a custom avatar from 3D body scan data

(Kim & LaBat, 2013). Using 3D body scan data to create an avatar is the most accurate in terms of replicating the human body, though there are some technical limitations in the form of "holes" caused by missing data (Power, 2013; Kim & LaBat, 2013). When using pre-programmed avatars, additional problems arise. Inputting measurements into a program to alter dimensions does not necessarily produce an avatar that reflects the dimensions of the body (Baytar & Ashdown, 2015; Lim, 2009). Lim (2009) showed that several 3D apparel simulation software cannot reflect asymmetry of bodies and that viewing avatars that reflect the real body is preferred by consumers.. Importantly, Lim also showed that 3D apparel simulations with avatars that more closely reflected the human body also more accurately replicated the look of the clothing (Lim, 2009). Accuracy of avatars is imperative to the product development process as well. Some information about garment fit, such as tightness and comfort, are difficult to assess using virtual avatars. To overcome this limitation, 3D apparel simulation use tension maps showing a virtual garments' strain distribution (Ancutiene & Sinkeviciüté, 2011). In a study comparing simulated real and virtual ease and strain values for a garment, Ancutiene and Sinkeviciüté (2011) concluded that the virtual tension map on the avatar is only somewhat effective at predicting areas of ease, and even then only with positive ease values. Missing data, inability to reflect asymmetry or to convey fit information are limitations of virtual avatars. As one of the factors that affect 3D apparel simulation quality as a whole, it is important to consider how avatars might influence a study, as consumer perception of the avatar can affect how they perceive the clothing as well.

2.3.2 Representation of Fabric

Virtually representing fabrics is highly complex; the availability of innumerable materials with a huge variety in aesthetic and functional properties combines to create an intricate garment to simulate (Power, 2013). Power (2013) tested differences in fabric simulation quality when fabric parameters are input into the software, using both FAST and Browzwear FTK fabric testing methods. This research concluded that because CAD software is built with algorithms predicting fabric properties, truly realistic simulations cannot be produced (Power, 2013). With added abilities to input fabric parameters, simulations become more accurate, yet the physics modeling that fabric simulation is based on still needs improvement to become truly realistic (Ancutiene & Sinkeviciüté, 2011). Because inputting fabric parameters into 3D apparel technology enhances the simulation quality, apparel simulation software should move towards this added capability. However, users are limited in the fabric information or testing capabilities available to them, and simulation software capabilities vary greatly.

In addition to simulating how a fabric behaves, 3D virtual prototyping must show interacting forces with the body or other materials it contacts (Power, 2013). Certain problems that may arise in constructing a garment, such as puckering seams and thread tensions, are not possible to simulate (Lee & Park, 2016). Additionally, simulation technologies are limited in simulating various fabric textures or wrinkles that result from improper clothing fit (Kim & LaBat, 2013). Ultimately, the appearance of a garment results from the properties of materials it is constructed with, so researchers conclude that virtual technologies are useful in visually evaluating garments when fabric properties can be input (Ancutiene, Strazdiene & Lekeckas, 2014). Despite the existing limitations, many in the

apparel industry agree that 3D prototyping software is accurate enough in representing fabric behavior to aid in making preliminary design decisions (Ancutiene & Sinkeviciüté, 2011). Various researchers have concluded that the accuracy of virtual simulations of fabric depends on the capability to input fabric properties (Ancutiene et al., 2014; Power, 2013). However, there is great variation in different softwares' ability to input parameters, as well as user access to fabric testing methods. Improving the ability to input fabric testing parameters will greatly improve the accuracy of 3D apparel technology in simulating fabric properties. Additionally, it is important to measure how consumers view the accuracy of fabric simulation to gain a better understanding of the factors that influence acceptance of the technology.

2.3.3 Fit is Difficult to Evaluate

Textile and apparel industry experts have different opinions from consumers about the ability to assess fit onscreen. This dichotomy has created confusion in the adoption and implementation of 3D apparel technology. Understanding how consumers view 3D apparel simulation is essential in implementing the technology for consumer use. Adding to the body of research, this study provides information and consumer insight into experiencing 3D apparel simulation.

Some discrepancies in research findings are due to the myriad of software available for use in 3D apparel simulation. Modaris 3D Fit, Browzwear, Gerber, Tukatech, and Vidya are a few of the large apparel players that provide 3D apparel simulation technology (Seyam, Kennon & Clarke, 2010). Depending on the brand and version of software used, 3D simulations have varying levels of capabilities all factoring into the final simulation quality.

The method used to evaluate 3D simulations might also have an effect on the conclusions; apparel experts, fit models, and participants all have different perspectives on what makes a well-fitting garment or good virtual simulation. Despite all of these variables, previous research into how virtual and real garments compare is valuable. Table 1 below summarizes the several recent research projects into this subject.

Table 1

Summary Review of Garment Simulation Studies

Authors (Year)	Method	Sample Size	Sample Source	Garment tested	Simulation Software	Findings
Lim (2009)	Survey	79	Students and employees	Shirt, pants, and jacket	OptiTex and V-stitcher	Virtual garments rendered on a 2D body scan avatar is most similar to the actual garment on a model.
Abram et al. (2010)	Expert evaluation	1	Fit model	100% viscose woven dress	OptiTex PDS	Real and simulation had similar appearances; 3D apparel simulation has the potential as a silhouette evaluation tool
Huang et al. (2012)	Fit model evaluation	18	Fit models	Muslin dress sloper	Not disclosed	Real and simulated dresses were similar. The simulated customized dress was rated best fit and shape compared to those developed using Japan and British Block Methods
Kim & LaBat (2013)	Fit model survey and interview	37	Students and employees	Pants	Not Disclosed	Virtual pants were an accurate representation of the actual pants, but did not give as much visual information. Fit assessment limited due to inability to determine the pants relation to body.
Ancutiene (2014)	Fit model survey	4	Fit Models	100% linen close fitting dress	Lectra Modaris 3D Fit	3D representation of draglines and puckering in garment in static posture is good; ease and strain representation of simulation not accurate when compared to wearing experience with dynamic postures.
Kim (2016)	Question-naire	37	Under-graduates	Virtual pants	Not disclosed	Able to identify too big or too small pants on simulation; participants satisfied with simulation quality. Inaccurate fit judgement determined to be caused by the inability of seeing the pants in relation to the avatar's body.
Lee & Park (2016)	Question-naire	248	Partici-pants	60% cotton/40% polyester knit dress; 65% polyester/35% cotton woven dress	Not disclosed	Unable to identify fit issues in the 3D simulation software because it provides the "ideal drape." The technology is therefore more suitable for overall silhouette evaluation than for identifying issues with garment fit.
Lin & Wang (2016)	Evaluation of vacant space	6	Subjects	Men's Shirts	Not disclosed	Determining appropriate clothing fit and size by evaluating vacant space is possible.

Fit is difficult to determine in 3D apparel simulation software due to a number of reasons, namely because the viewer cannot tell how the garment relates to the body (Kim, 2016). In one study it was determined that simulations tend to provide "ideal drape," meaning simulations show few fit issues (Lee & Park, 2016). Several researchers have concluded that, while simulations do not provide as much fit information as actually trying on a garment, they are generally accurate (Ancutiene, 2014; Kim & LaBat, 2013). Ultimately, in the study by Abram, Stjepanovic, and Kapel (2010), apparel experts concluded that 3D apparel simulation is useful as a tool in evaluating fit. This study will contribute to the body of knowledge on consumers ability to evaluate 3D apparel simulation fit for customization and purchase decisions. Additionally, this research will discover how consumers view simulation accuracy in terms of avatar, fit, and fabric representation.

2.4 Applications of 3D Simulation

2.4.1 Virtual Try-on

Some research suggests that experts in the apparel industry view 3D prototyping and try-on software as more suitable to marketing and promotion, rather than production (Easters, 2011). Virtual try-on is one of the ways the 3D apparel simulation software can be adapted for consumer use, as opposed to 3D prototyping which is used in the product development process. Possible applications of virtual try-on are as virtual fitting rooms or virtual mirrors (Baytar & Ashdown, 2015; Divivier et al., n.d.). Virtual fitting rooms utilize a 3D avatar and garments that have been rendered in 3D, allowing consumers to browse through catalogs of garments and visualize the clothing on themselves. These virtual fitting rooms can be used in retail stores or at home, with custom avatars made from 3D scans or real-time visualization

of the user captured by cameras or sensor bars (Baytar & Ashdown, 2015; Divivier et al., n.d.). Virtual mirrors are another application of this try-on technology in which consumers stand in front of a life size display showing their avatar in different clothing (Divivier et al., n.d.; Hauswiesner, 2013). In Baytar and Ashdown's (2015) research, it was concluded that both of these technologies allow consumers to visualize the fit of a garment before purchase, solving one of the biggest obstacles in e-commerce. These applications of virtual try-on have several limitations to adoption, both with consumers and the technology itself. Consumers are hesitant to adopt and trust virtual try-on, and often treat the technology as merely a novel experience. Implementing virtual try-on also brings the challenge of rendering complicated garments in real time and creating a realistic representation of the garment, which requires complicated computer programing and processing capabilities which is not available to all consumers.

In order for brands to successfully adopt virtual try-on, consumers need to be convinced to both trust and consistently use it. Consumers are hesitant to accept their virtual avatar as accurate, the technology is not widespread for consumer use, and the software to support virtual try-on is complicated and difficult to develop (Baytar & Ashdown, 2015; Divivier, et al., n.d.; Kim & LaBat, 2016). The only way to test how consumers will accept new technologies is to facilitate actual user experience and measure their opinions and experience after their interaction with the technology (Kim & LaBat, 2013). Consumers tend to enjoy virtual try-on as a new and innovative experience. In experiments testing consumer interaction with 3D simulation, both Kim and Forsythe (2008) and Kim and LaBat (2013) found that consumers believed the technology to be fun and interesting, as if captivated by

the novel experience. This leads researchers to question if consumers will continue to use the technology after the novelty wears off (Kim & Forsythe, 2008; Kim & LaBat, 2013).

To ensure repeat use of virtual try-on, brands need to convince their customers that the technology is both convenient and useful. Doing this will increase consumers' frequency of shopping online (Childers, Carr, Peck & Carson, 2001). Additionally, apparel companies utilizing 3D simulation should highlight the advantages of using this technology over in-store experiences (Kim & LaBat, 2013). Customers are more likely to use and revisit e-commerce sites that give them enjoyment (Childers et al., 2001). Virtual try-on has also been shown to increase interactions between consumers and retailers (Ashdown & Loker, 2010). Interactivity within a website increases time spent with the retailer's website and likelihood to purchase a product from that website (Fiore & Jin, 2003). Ultimately, if the interaction with virtual try-on is interesting and useful, consumers will continue to interact with it. This research will give insight into consumers' perception and trust of virtual avatars and the virtual try-on experience.

Another challenge to the implementation of virtual try-on, specifically in relation to e-commerce, is the amount of data involved. Real-time rendering of a simulated garment is too slow for use on the internet (Cordier, Lee, Seo & Magenant-Thalmann, 2001; Divivier et al., n.d.; Hauswiesner, 2013). To combat this, either pre-processed clothing or stock avatars can be used. Use of pre-simulated clothing is very limiting, as users only visualize a small number of options through virtual try-on (Cordier et al., 2001; Divivier et al., n.d.; Hauswiesner, 2013). Using stock avatars is another way to reduce processing time and data of apparel simulation. Stock avatars are advantageous due to decreased online processing time and better accessibility; users generally select a body type that reflects their own, alter

measurements, and sometimes select cosmetic options such as hair color and skin tone (Cordier et al., 2001; Kim & Forsythe, 2008). In a study of consumer interaction with virtual-try on, participants stated that, while avatars and virtual try-on are useful to see how a garment's color would look with their skin tone or how an outfit goes together, they still did not believe the simulation reflected what the clothes would look like once tried on (Kim & Forsythe, 2008). Additionally, simply inputting measurements does not necessarily generate a certain body type in the simulation (Baytar & Ashdown, 2015), and most consumers are unable to accurately report their body measurements or size (Lim, 2009). Despite the ability to adjust the dimensions of an avatar, there is no way to exactly recreate the body using this method (Kim & LaBat, 2013).

Furthermore, 3D simulations must be as realistic as 2D images in order to compete for adoption in an online shopping environment (Kim & LaBat, 2013). In Kim and LaBats' (2013) study, consumers expressed they believe that 3D simulations have "good potential" to be adopted in online shopping. Consumers also prefer to see apparel simulated on their own body, as opposed to an image of the garment on a catalog model (Kim & LaBat, 2013). One reason viewing products in 3D is preferred by consumers is that it is simply easier to look at and process 3D images (Park et al., 2016). However, in a study of consumer perception of virtual try-on, Kim and Forsythe (2008) found that most consumers do not believe that virtual try-on conveys reliable fit information. Despite all of its limitations, virtual try-on does have the potential to aide in consumer decision making. This research explores consumer customization and purchase decision making, as well as consumers perceived effectiveness of the technology's rendering capabilities in terms of the avatar, fabric, and fit of jeans.

People generally engage in direct and indirect experiences when interacting with products; direct experiences are when consumers are engaged with the product in person, indirect experiences do not allow consumers to interact with the product itself, but rather garner information in some other manner (Li, Daugherty & Biocca, 2001). While traditional online shopping is an indirect experience, interaction with 3D simulation replicates direct experiences more closely due to the affordances that the 3D environment offers. In a study of consumers interacting with 3D simulations of various objects, it was found that participants interacting the simulations focused and evaluated attributes of each product in the same way they would in person (Li et al., 2001). Affordances, such as the ability to zoom in on textures, create a similar experience to the consumers actually interacting with products (Baytar & Ashdown, 2015; Li et al., 2001). Ultimately, the indirect experience with affordances that are available in 3D simulations create a unique virtual presence, enhancing online shopping experiences by giving consumers information about the product not experienced with traditional online shopping (Li et al., 2001). This results in a significantly reduced risk perception when compared to viewing 2D images (Shim & Lee, 2011). Considering this, using virtual try-on to aide mass customization will increase consumer trust of their purchase. While there are challenges in convincing consumers to trust and use 3D virtual try-on, and limited capabilities of online rendering are hindering its implementation, use of the technology is beneficial to both brands and consumers.

2.4.2 Customization

Mass customization is a production model defined as "developing, producing, marketing and delivering affordable goods, and services with enough variety and customization that nearly everyone finds exactly what they want" (Piller & Tseng, 2010).

This method of production allows a company to cater to the individual needs of each consumer, while maintaining a manufacturing efficiency similar to mass production (Piller & Tseng, 2010). Mass customization can be utilized to offer stylistic, functional, or fit customization to the consumer (Bauer, Düll & Jeffery, 2010). Utilization of various technologies is important for the mass customization model of production – however, even with the use of CAD and other technologies, successful implementation of mass customization is difficult (Fletcher, 2010). Allowing only certain parts of a product to be customized where possible is more feasible in manufacturing than a fully customized garment (Fletcher, 2010). Options to be customized are often fabric selections or shapes of certain elements of a garment, such as collars, cuffs, and pockets. Creating customized apparel allows consumers to "co-design" their desired product (Baytar & Ashdown, 2015). This creates a strong relationship between the consumer and brand and give them the exact product they need (Fletcher, 2010). Mass customization, used to create made-to-measure garments or to customize apparel or other products, has limitations to overcome in their implementation, namely accuracy in measurements, lack of consumer understanding, challenges in manufacturing and the question of to what extent should options go.

With so many variables, it is impossible to create garments that have an ideal fit for all consumers. One solution is to produce clothing on a made-to-measure system. By incorporating individual consumer information into pattern design, clothing is individualized for a better fit. Made to measure clothing uses a basic pattern for a garment that is altered to fit individual consumers' measurements (Apeagyei & Otieno, 2007). Applications of mass customization of apparel have a wide range, from fitted shirts to custom designed shoes (Corcoran & Furukawa, 2007). In the case of jeans, customization would especially help to

solve common fit issues related to ease, crotch length, and side seam placements (Song & Ashdown, 2012). In a study of consumer acceptance of customized apparel by Lee, Kunz, Foire, and Campbell (2002), 62% of female participants wanted to customize jeans, specifically to their size, body shape, and length. This study also concluded that fit and size of a garment are the factors that consumers most want to customize (Lee et al., 2002). It is also possible to customize apparel by creating a 2D pattern directly on top of a 3D body scan, and then extracting and flattening the pattern (Huang, Mok, Kwok & Au, 2012). This method created a dress sloper with the best shape and fit in a study of customizing muslin dresses, and since it is "not computationally expensive," it is suitable for implementation (Huang et al., 2012). However, limited access to body scanners and high production cost impedes use of this customization method.

Mass customization of apparel raises the issues of accuracy in measurements. Consumers inputting their own body size and shape could be inaccurate, as they cannot reliably take measurements or unbiasedly report on their body shape (Lim, 2009). Incorporating 3D scan data into designs and patterns would allow for a more reliable automated pattern generation system (Apeagyei & Otieno, 2007).

Use of 3D prototyping or virtual try on in mass customization requires highly skilled laborers and reorganization of production practices (Apeagyei & Otieno, 2007). Both made-to-measure and customized apparel require additional cost, time, and consumer interaction during the manufacturing process, and therefore may not be the best solution in providing better fitting apparel to consumers. Consumers rarely know what is feasible for manufacturers, and expect customized goods on a similar time frame as mass produced goods (Fletcher, 2010). Higher cost and differences between desired and actual product has a

negative effect on consumer acceptance of mass customized apparel (Bauer et al., 2010). Research into how implementation of 3D apparel simulation can better facilitate customization would benefit brands. Many brands, such as Levi & Strauss, Lands End, JCPenny, and QVC, have at one time offered mass customized apparel (Lee et al., 2002; Corcoran & Furukawa, 2005, Song & Ashdown, 2012), and all have since stopped production of the customized lines of products. This research informs apparel manufacturers to what extent customization of denim is feasible from a manufacturing standpoint and desired by consumers.

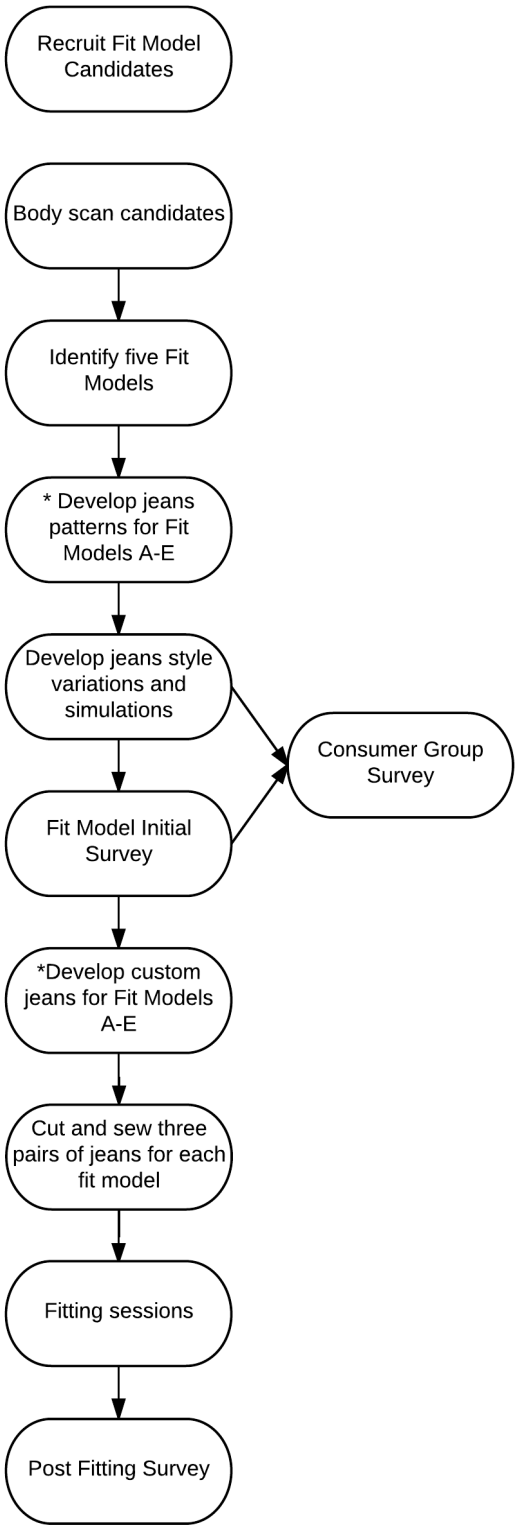
2.5 Summary of Literature Review

Review of the literature shows that multiple issues contribute to ineffective sizing of commercially available garments (Ashdown & Dunne, 2006; Alexander et al., 2005; Bye et al., 2006; Intellifit, 2003 as cited in Shin & Istook, 2008; Shin & Istook, 2008; Workman, 1991; Workman & Lentz, 2000). 3D apparel simulation can improve sizing systems either by creating better fitting clothes during product development (Lee & Park, 2016; Park et al., 2010; Power, 2013) or helping consumers with virtual try-on or customization (Byatar & Ashdown, 2015; Divivier et al., n.d.). Many of the barriers to adoption of this technology are related to the limited understanding of consumer perception. This study focuses specifically on how consumers view 3D apparel simulation technology, and how they might use it in their lives.

3. METHODOLOGY

3.1 Research Design

The purpose of this research was to determine if consumers can make intent to purchase decisions or customization decisions based on 3D apparel simulations, as well as the extent to which consumers believe virtual avatars look similar to real bodies, and how accurately consumers believe that fit and fabric is represented in 3D apparel simulations. This study was developed as a pilot for a larger study exploring how much patternmaking, fit evaluation, and customization can be accomplished solely with software. A mixed methods research design was used to determine the approachability and efficacy of 3D apparel simulation in terms of the avatar, the rendered fabric, and the apparent fit of the garment. Mixed method research allows for qualitative and quantitative data to be used in parallel for a more complete analysis of the research (Creswell, 2014). The small number of fit models was chosen to maintain feasibility of experiment, and the size constraints to ASTM 14 and 16 were chosen to reduce variability (Salkind, 2010). Surveys were distributed to both a fit model group and a larger consumer group to collect data for this study. The process flow of this research study can be found in Figure 1 below.



* These activities were carried out by the principal investigator as part of a pilot for a larger study.

Figure 1: Data Collection Process

3.2 Research Questions

RQ 1: Can consumers make intent to purchase decisions based on simulations?

RQ 2: Can consumers make customization decisions based on simulations?

RQ 3: How closely do consumers believe the avatar reflects real bodies?

RQ 4: How do the consumers feel about the accuracy of the fit and fabric in the simulation?

This study focused on consumers' perceptions of the effectiveness of 3D prototyping. It was conducted in two general parts. First, five female fit models were recruited for the study, and custom jeans patterns were made for each. This process is explained in detail in section 3.4. The model then participated in a survey designed to replicate the aspects of an online shopping experience, in which she could select the jeans she most liked, as well as indicate any fit changes and style customizations she preferred. Finally, the fit model participated in a live fitting session where she tried on actual jeans, and completed an ending survey. In the second part of the study, a survey showing simulations of each pair of jeans and asking for evaluations of fit and general perception of apparel simulations was sent to a large participant group. These findings were used in analysis and validation of the smaller fit model sample.

3.3 Population and Sample

Upon receiving IRB approval, a pre-screening form sent to university students was used to identify females who were interested in this study. Thirty-three candidates responded

to the pre-screening form. These candidates were body scanned, and their measurements were compared to ASTM D5585-11 Misses sizes 14 and 16 curvy measurements. This size range was used because these sizes are widely accepted to correspond with the average size of women in the United States (Christel & Dunne, 2017). The first five candidates whose waist measurement was between ASTM size 14 curvy and 16 curvy were selected as fit models for this study. Measurements of the five selected fit models are found in Table 2 below.

Table 2

Fit Model Measurements in Inches

	Height	Bust	Waist	High Hip	Hip
Fit Model A	65.52	37.071	32.566	N/A	N/A
Fit Model B	66.74	34.33	33.76	36.36	39.81
Fit Model C	60.42	37.32	32.88	35.48	40.95
Fit Model D	63.894	34.698	33.142	34.74	38.92
Fit Model E	64.8	38.73	33.31	35.24	40.389

The consumer group consisted of a convenience sample of female participants who completed an online survey, distributed via email to students and university employees. The sample consisted of 234 total respondents with ages ranging from 18 to 60.

3.4 Development of Research Stimuli

The jeans were custom drafted for each fit model using Lectra Modaris software by the primary investigator on the study. While each pair of jeans was custom made for the fit models, measures were taken to remain consistent in fit across all five models. The custom jeans were drafted in Lectra Modaris using a hybrid of Kawashima's and Joseph-Armstrong's methods for drafting jeans (Kawashima, M., 1974; Joseph-Armstrong, 2010).

Once the foundation of each pair of jeans was developed, the leg shape was changed to develop three styles – slim, straight, and boot cut. Examples of each of these styles can be found in Figures 2-4 below. Custom avatars were developed for use both during pattern drafting and creation of the research stimuli. The stock avatar in Lectra Modaris 3D fit was altered to reflect each fit model's measurements.

Figure 2: Example of slim jean simulation

Figure 3: Example of straight jean simulation

Figure 4: Example of boot cut jean simulation

Fit models also viewed images showing options of the shape for the back pocket, the back pocket stitching design, and the inclusion of belt loops or not. Images of these options are in Appendix A. These options were provided to replicate a customization experience for the fit models.

After the five fit models had completed the initial survey indicating her preferred custom jeans style, three pairs of actual jeans were made for each fit model: the preferred style with no changes, the preferred style customized based on fit preferences indicated in the initial survey, and a second style with no changes. This pair of jeans was selected to give the fit model a broad range of fit experiences. For example, if the model choose to have the boot cut jeans made for her, the second style would be the slim cut, as demonstrated in Figures 5-7.

Figure 5: Boot Cut Jeans

Figure 6: Customized Boot Cut Jeans

Figure 7: Straight Jeans

While fit preferences could not be exact due to the scope of this study, it was expected that the slight adjustments made in the custom jeans would give the researchers a baseline for understanding how custom fit can be communicated and measured by both makers and wearers of custom apparel.

3.5 Data Collection

Data was collected for each survey online via Qualtrics. Fit model pre-screening, body scanning, and subject selection took place over a four-week period from March 15th, 2017 to April 11th, 2017, ending when five fit models that met the research criteria were found. The initial fit model survey data was collected from April 24th to May 1st, 2017. Fittings with each fit model, and collection of the final survey data took place from May 9th

to May 18th, 2017. The consumer group survey data was collected anonymously from May 15th to July 8th 2017.

3.6 Fit Model Initial Survey

The questionnaire sent to the five fit model subjects was designed to obtain information on general denim shopping habit and fit preferences, as well as participants' opinions of the 3D virtual prototyping technology and custom jean preferences. The Initial Survey can be found in Appendix B. First, several basic questions about denim and online shopping habits were asked. Second, the fit model viewed three customized denim simulations on her custom avatar and indicated her degree of satisfaction with the fit of each pair of jeans. Fit models evaluated the jeans fit at five body parts, the waist, hips, seat, thigh, and abdomen. After viewing the simulation of each style, the participant had the option to indicate in what ways she would adjust the jeans (a tighter or more relaxed fit in various areas) for a more satisfactory fit. The participant then ranked the three simulated jeans styles from best to worst fit. This process was meant to mimic an online shopping experience in which they were given options to "customize" a pair of jeans. Next, the participant answered a series of questions about her interaction with 3D apparel prototyping, the perceived usefulness of this technology, and how she would like to see 3D apparel prototyping integrated into everyday life. Finally, the fit model participants had the opportunity to answer a series of open ended questions to describe how the availability of 3D virtual prototyping might change their shopping experience and preferences. See Appendix A for the full Fit Model Initial Survey.

3.7 Fitting Sessions

Once each initial fit model survey had been collected, each fit model participated in a fitting sessions. Fit sessions were conducted by the Researcher and Principal Investigator, with each fit model trying on each of the three pairs of jeans. During these fittings, subjects were asked to comment on the style and fit of each pair of jeans, and to indicate fit corrections. The script for the fittings can be found in Appendix C.

3.8 Post-fitting Survey

Upon completion of the fit session, each model filled out an online survey gauge their perceptions of the accuracy of the 3D simulation of the fit of jeans compared to reality, their satisfaction with the fit adjustments made to the custom jeans, and their opinions of the process overall. This survey can be found in Appendix D. The first section of the survey consisted of Likert scale statements scored from 1 to 7, with 1 being "strongly disagree" and 7 being "strongly agree". The final two questions were open ended responses designed to capture information of the fit models' impressions of virtual try-on and their experience overall.

3.9 Consumer Group Questionnaire

The consumer group questionnaire was designed to gain a broader perspective of how people perceive the effectiveness of 3D virtual prototyping technology, as well as how it might be integrated into their lives. First, basic questions about denim and online shopping habits were asked, similar to those in the initial fit model survey. Next, participants were shown the simulations from a randomly selected fit model. Randomization was performed

using a feature in Qualtrics. Participants viewed the simulation for each style and were asked to indicate the degree of garment fit in several areas, as well as what fit changes they would make in those areas. After viewing all simulations, participants ranked the three styles of jeans from best to worst fitting. A series of questions were then asked about interactions with 3D virtual prototyping, the perceived usefulness of this technology, and how they would like to see 3D virtual prototyping integrated into everyday life. Finally, participants were asked two open ended questions to describe how the availability of 3D virtual prototyping might change their shopping experience and preferences. A copy of the Consumer Group questionnaire can be found in Appendix E.

3.10 Analysis

Analysis of both fit model and consumer group survey data was performed using JMP analytics software to preform t-tests and ANOVA. NVivo Pro analytics software was used to organize and analyze qualitative data collected from the open ended questions in the consumer group survey.

4. RESULTS AND DISCUSSION

Because of the mixed method research model, the results and discussion are presented together in this section. This allows for a more complete understanding of the results of this research. First, results from the fit model online survey and fittings, and post-fitting survey are discussed. Next the consumer group survey results are described. Finally, the results and conclusions from both the fit model and consumer group data are discussed. Results relating to the research questions is found in both the qualitative and quantitative data in this study, as detailed in Table 3 below.

Table 3

Research Question Matrix

Research Question	Data
RQ 1: Can consumers make intent to purchase decisions based on 3D simulations?	Consumer Group Survey
RQ 3: Can consumers make customization decisions based on simulations?	Fit Model Initial Survey and Fitting Sessions
RQ 3: How closely do consumers believe the avatar reflects real bodies?	Fit Model Fitting Sessions, Post-fitting Survey, and Consumer Group Survey
RQ 4: How do the consumers feel about the accuracy of the fit and fabric in the simulation?	Fit Model Fitting Session, Consumer Group Survey

4.1 Fit Model Experience

The five fit models in this study completed an initial survey, participated in a fitting, and then completed a post-fitting survey. The initial survey was intended to get fit model's initial reactions to interacting with 3D apparel simulation technology, as well as simulate an online shopping experience. Data on the perception of the simulation versus the jeans in reality was collected based on the fitting sessions with each fit model. Finally, the post-fitting survey captured any changes in opinions about the 3D apparel technology, and allowed fit

models to reflect on the process overall. Following is a summary of the data gathered from the initial fit model survey, followed by discussions of the fitting sessions and results from the post fitting survey. Fit models are referred to as Fit Model A, B, C, D, and E throughout this reporting.

4.1.1 Purchasing Behavior

In the initial survey, the fit models gave information about their denim purchasing habits, as well as an evaluation of several jeans that had been drafted based on their individual measurements. The full Fit Model Initial Survey can be found in Appendix B. The first four questions were intended to capture demographic information and general denim purchasing habits (Table 4). It is important to note that these fit models are not a representative sample and generalization of the results is not appropriate.

Table 4

Fit Model Purchasing Behavior

Fit Model	Ethnicity	Age Range	Frequency of purchasing jeans	# of Jeans Owned	Mean Price Paid for Jeans
A	White	18-24	Less than 1/year	2-5	$25-50
B	White	18-24	Every 4-6 months	5-10	$50-100
C	White	31-35	Every 6-12 months	5-10	$50-100
D	Other	18-24	Less than 1/year	2-5	Less than $25
E	White	18-24	Less than 1/year	2-5	$25-50

The next several questions were about online shopping behavior. Only Fit Model C indicated that she shopped online for jeans less than once a year; the other four indicated they do not shop online for jeans. Fit models then indicated how often they returned clothing that had been bought online: Fit Model D choose “I do not purchase clothing online,” A and E selected “less than once a year,” Fit Model C selected “once every 6-12 months,” and Fit

Model B choose “once every 4-6 months.” Subsequently, the four fit models who did shop online (A, B, C, and E) were asked to indicate the reasons they returned clothing online using these options: “I do not like the fit,” “The item was the wrong color,” “The item did not look the way I expected,” “The item was too small.” All four indicated “I did not like the fit” and “The item did not look the way I expected;” Fit Model A, C, and E selected “The item was two small,” and “The item was too big;” and only Fit Models A and E selected “The item was the wrong color.” Finally, fit models were asked two questions about customized jeans. None of the fit models had indicated they had previously ordered customized jeans. When asked to indicate if they would consider purchasing customized jeans in the future, Fit Model C indicated “definitely yes,” A, B, and E indicated “probably yes,” and Fit Model D indicated “probably not.”

4.1.2 Custom Jeans Experience

When viewing each simulation, fit models were asked to rank how well the jeans fit in various areas on a 1-7 Likert point scale, with the choices being “very poor,” “poor,” “somewhat poor,” “neutral,” “somewhat good,” “good,” and “very good.” These scale points were coded with numerical values of 1 to 7, with 1 being “very poor” and 7 being “very good”. The areas of fit to evaluate were waistband, hip, seat, thigh, and abdomen. This process was then repeated with the other styles of jeans. Across all styles of jeans, fit models indicated the waistband to be the best fitting area, with scores ranging from 5 to 7. The waistband was the only area consistently evaluated as “good” or “very good” by all fit models, for all styles of jeans. The thigh was judged as the worst fitting area across all styles. Results show at most a difference of 1 point between styles for each fit model, indicating that

fit preferences remained consistent despite differences in styles. When the average of the fit models average scores were calculated for each pair of jeans, every style had a similar overall score: 4.8 for slim, 4.8 for straight, and 4.84 for boot cut. Scores for each area of fit can be found in Table 5 below.

Table 5

Jeans Styles Fit Evaluation

Slim

	Waistband	Hips	Seat	Thighs	Abdomen	MEAN
Fit Model A	6	6	5	5	4	5.2
Fit Model B	6	5	3	4	5	4.6
Fit Model C	7	2	2	1	3	3
Fit Model D	7	7	7	5	4	6
Fit Model E	6	6	5	5	4	5.2
MEAN	6.4	5.2	4.4	4	4	4.8

Straight

	Waistband	Hips	Seat	Thighs	Abdomen	MEAN
Fit Model A	6	6	6	5	6	5.8
Fit Model B	6	2	2	2	6	3.6
Fit Model C	6	3	2	1	3	3
Fit Model D	7	6	7	5	4	5.8
Fit Model E	6	6	6	5	6	5.8
MEAN	6.2	4.6	4.6	3.6	5	4.8

Boot Cut

	Waistband	Hips	Seat	Thighs	Abdomen	MEAN
Fit Model A	6	6	6	6	6	6
Fit Model B	6	4	4	3	6	4.6
Fit Model C	6	3	3	1	2	3
Fit Model D	7	6	6	5	4	5.6
Fit Model E	5	5	5	5	5	5
MEAN	6	4.8	4.8	4	4.6	4.8

Fit models were also asked what changes, if any, they would make to the jeans in order to achieve a preferred fit. The areas of fit possible to change were the waistband, seat, hip thigh, and abdomen. Fit models were able to indicate preference on a 1 to 5 point scale, with the choices being “much less fitted,” “less fitted,” “no change,” “more fitted,” and

“much more fitted,” which were coded 1 to 5. For all three styles of jeans, fit models indicated they either wanted no change to the fit of the jeans, more fitted, or much more fitted in all areas of fit. All fit models indicated they desired no change at the waistband for all styles of jeans. Participants also tended to give the same preference in areas of fit across all styles of jeans. The results from this section of the survey are in Table 6 below.

Table 6

Fit Model Desired Fit Alterations

Slim

	Waistband	Hips	Seat	Thighs	Abdomen
Fit Model A	3	3	4	4	3
Fit Model B	3	4	4	4	3
Fit Model C	3	4	4	5	4
Fit Model D	3	3	3	4	3
Fit Model E	3	3	4	4	3
MEAN	3	3.4	3.8	4.2	3.2

Straight

	Waistband	Hips	Seat	Thighs	Abdomen
Fit Model A	3	3	3	4	3
Fit Model B	3	4	4	4	3
Fit Model C	3	4	4	5	4
Fit Model D	3	4	3	4	3
Fit Model E	3	3	3	4	3
MEAN	3	3.6	3.4	4.2	3.2

Boot Cut

	Waistband	Hips	Seat	Thighs	Abdomen
Fit Model A	3	3	3	3	3
Fit Model B	3	3	3	4	3
Fit Model C	3	4	4	5	4
Fit Model D	3	4	3	4	3
Fit Model E	3	3	3	3	3
MEAN	3	3.4	3.2	3.8	3.2

After viewing all the simulations, fit models were asked to rank each style from best to worst fitting. Fit Model rankings of the jeans styles can be found in Table 7 below. In the last section of the survey, fit models were guided through the process of selecting preferred style of jeans, back pocket shape, stitching design, and waistband option. Images of these options can be found in Appendix B. Only two fit models chose the pair of jeans that she deemed best fitting to be made for her, perhaps indicating that style choice outweighs perceived fit of a product simulation (Table 8).

Table 7

Fit Model Jean Fit Rankings

	Best Fitting	Middle	Worst Fitting
Fit Model A	Straight	Boot	Slim
Fit Model B	Slim	Boot	Straight
Fit Model C	Boot	Slim	Straight
Fit Model D	Straight	Slim	Boot
Fit Model E	Straight	Boot	Slim

Table 8

Fit Model Jean Preferences

	Style	Pocket Shape	Pocket Stitching	Waistband
Fit Model A	Slim	A	B	B
Fit Model B	Boot	A	B	A
Fit Model C	Boot	A	B	A
Fit Model D	Straight	A	A	A
Fit Model E	Slim	C	Not chosen	A

4.1.3 Perceptions of 3D Apparel Technology

The next section of the survey was designed to determine the fit models perceptions about 3D apparel technology and its potential application for e-commerce. Each statement was answered with the following options: strongly disagree, disagree, somewhat disagree, neither agree nor disagree somewhat agree, agree, and strongly agree. These were coded with numerical values from 1 to 7, with 1 being "strongly disagree" and 7 being "strongly agree."

While most received a relatively neutral answer from all fit models, several statements, included in Table 9 below, stood out. For the statement "I would virtually try on garments if given the chance, only Fit Model C dissented, indicating she "strongly disagrees," while the other fit models either "agreed" or "strongly agreed." This change in opinion after viewing the simulations contrasts with her previous answers that were favorable towards both online shopping and customization of apparel – both experiences that virtual

try-on technology is intended to enhance. Fit Model D remained consistent in her online shopping attitudes, being the only fit model to answer the statement "being able to try clothes on an avatar would help me make purchase decisions when shopping online" negatively. Interestingly, only the statement "the virtual jeans accurately represents the look of denim" was answered similarly by all fit models. The average answer to this statement was 2.4, indicating that all fit models believed that the virtual jeans were not a good representation of jeans. Finally, all but Fit Model C were comfortable with the look of the virtual avatar provided. All other statements in this section of the Fit Model Initial Survey can be found in Appendix F.

Table 9

Fit Model Perceptions of 3D Apparel Technology

	Fit Model A	Fit Model B	Fit Model C	Fit Model D	Fit Model E	MEAN
I would virtually try on garments if given the chance	6	6	1	7	7	5.4
Being able to try clothes on an avatar would help me make purchase decisions when shopping online	7	6	4	1	5	4.6
The virtual jeans accurately represent the look of real denim	3	3	1	2	3	2.4
I am comfortable with the look of this virtual avatar	5	3	2	7	5	4.4

In the final section of the initial survey, fit models were asked two open ended questions to determine how the use of 3D virtual try-on technologies might affect their shopping habits. When asked about how virtual try-on might affect their willingness to try on new brands and styles of jeans, whether in store or online, three of the fit models raised concerns about the accuracy of simulations. Fit Model B stated she would use virtual try on only if it is "truly accurate about the shape of my body and the size/fit of the clothes." Fit

Model C didn't like the avatar, which she wrote looked "frumpy, old, and out dated," and viewing the jeans on such an avatar negatively affected her purchase decisions. Fit Model D, who remained disinterested in all 3D apparel technologies, stated that the use of virtual try-on would not affect her purchase decisions at all, as she relies on "actual try on and feeling the fit and make of the jean" to make purchase decisions. She goes on to state she doesn't trust online purchases in general, which may explain her negative reactions to 3D virtual try on possibilities. Fit model E also had doubts about using virtual try on, stating she is worried about the accuracy of virtual try-on "depicting how it would look on [her] in real life." Despite these concerns, fit models A, B, and E noted positively that virtual try on would allow them to try new and different styles of clothing. When asked about using virtual try-on affecting their purchase decisions, both fit models A and C indicated they would rely on the quality of the simulation to determine if they would purchase an item or not. Fit model D again stated that she would not use the technology at all. Fit Model E indicated it would encourage her to buy more items online, but would still rely on actually trying on the garment to make the final decision of keeping or returning it.

The initial survey provided some basic knowledge about the fit models, their shopping habits, and perceptions of 3D technologies. Some interesting patterns of the fit models thoughts and feelings emerge. It is apparent, through Fit Model C's shopping behavior and answers, that she is both very interested in online shopping and hopeful about apparel customization. Conversely, Fit Model D does not shop online, and indicated she would likely not purchase customized apparel. Having this range of shopping habits and opinions is valuable in seeing how the experience provided by this experiment might change the fit models' opinions of 3D apparel technology. The fit models had a diverse range of

shopping habits, especially when it comes to online shopping, providing a range of perspectives in the results. These perspectives gives a deeper understanding of the many reactions people have to 3D apparel technologies.

4.1.4 Fitting Experience

Following is a discussion of results from the fitting sessions, including analysis of observations made by researches and comments transcribed from the fit models. The fit models were fitted in three pairs of jeans each: their preferred style with no fit changes, their preferred style adjusted based on their fit comments, and a second style with no fit changes. The jeans produced for each fit model can be found in Table 10 below. During the fittings, each fit model was asked to share their feelings about the feel, fit, and design of the jeans, as well as any changes they would make to each pair of jeans. Sessions were recorded and transcribed by the researcher. The jeans were referred to as Jeans 1, 2, and 3 during each fit session.

Table 10

Jeans Produced for Fit Sessions

	Jeans 1	Jeans 2	Jeans 3
Fit Model A	Slim	Customized Slim	Straight
Fit Model B	Boot	Customized Boot	Straight
Fit Model C	Boot	Customized Boot	Straight
Fit Model D	Straight	Customized Straight	Boot
Fit Model E	Slim	Customized Slim	Straight

During the fitting sessions, some common themes arose. All of the jeans, regular and customized, were much too big for the fit models. Comparing physical measurements to the body scan output which was used to draft the jeans patterns revealed that the body scan

measurements were 1 to 2 inches larger than the fit models actual measurements. An example of the jeans simulation versus actual jeans can be found in Figures 8 and 9 below. Images of all jeans and simulations can be found in Appendix E.

Figure 8: Fit Model C Boot Cut Jeans Simulation

Figure 9: Fit Model C Boot Cut Jeans

Because the body scan measurements were used to both draft the jeans and create each fit models virtual avatar, the incorrect sizing could not have been detected until this point in the process. The use of the body scanner to collect measurements does have usability issues, such as operator training, which may have caused these inaccurate measurements. While the most consistent solution, using 3D scan data either in this way or simply for more accurate measurements is not always feasible as not all consumers have access to body scan

booths. The difference in measurements might also explain why several fit models did not believe the virtual avatar reflected their own body shape in the initial survey, as the avatar measurements were adjusted to best reflect each fit model. The average response to the statement “this avatar accurately represents my body shape” was 3.8 “The simulation looks like me in a pair of jeans” was 3.2, and “I am comfortable with the look of this virtual avatar” was 4.4 (see Appendix F). Pictures of each fit model in their customized jeans can be found in Figures 10-14 below.

Figure 10: Fit Model A Custom Jeans

Figure 11: Fit Model B Custom Jeans

Figure 12: Fit Model C Custom Jeans

Figure 13: Fit Model D Custom Jeans

Figure 14: Fit Model E Custom Jeans

Despite the incorrect measurements used to draft the jeans, the fittings still provided good insight. All of the fit models preferred the customized jeans over the first pair through the thigh, which was the area in which all fit models preferred a tighter fit. This suggests evaluating the simulation and customizing jeans could potentially allow fit models to achieve their preferred fit. All the fit models reported their sample jeans were too short. This is especially intriguing because this fit issue could not be detected with the simulation, and did not come up at all during the initial survey, though Fit Model D did mention it during her fitting. This points to a limitation in the ability of participants to fully judge the fit of the simulations.

Four of the fit models also commented on the pocket and waistband options provided in the initial survey. Fit Model A stated she liked the pockets, stating she had “never paid

attention to pockets in the back before," but she liked the option to choose her preference. Fit Models B and E shared this sentiment. Fit Model C mentioned that the pockets sat lower on the jeans than what she was expecting from the simulation. This shows that while customizing style details is interesting and fun, fit models were much more interested in customizing the fit of jeans. Fit Model D raised concerns with the simulation, saying she could not tell the waistband option was showing belt loops, was unable to fully answer questions about the abdomen because the image was cut off above the waist, and thought her simulation might have been on a male avatar. Having had trouble evaluating the fit of the simulated denim, Fit Model D suggested that showing an outline of the leg under the jeans would have helped her.

4.1.5 Post-fitting Survey

In the post-fitting survey, the fit models were asked a series of questions to determine their perceptions of the effectiveness of simulations, and their ideas about using 3D simulations in everyday life. Statements were answered with the following options: strongly disagree, disagree, somewhat disagree, neither agree nor disagree, somewhat agree, agree, and strongly agree. These options were coded with numerical values from 1 to 7.

The first several statements were designed to determine how the jeans compared to expectations based on the simulations. Each fit model had differed on whether the jeans looked like and fit like she expected based on the simulations. For the statement "My jeans fit the way I thought they would based on the simulations I viewed," only Fit Model C answered favorably, indicating she strongly agreed. All the other fit models responded with either "disagree" or "somewhat disagree." This is not surprising considering the

discrepancies between the body scan measurements and the fit models' actual body measurements. Contrastingly, when asked about the overall look of the jeans based on the simulation, four of the fit models answered more favorably. This indicates that while the simulation may not be reliable in terms of fit information, it does provide accurate information about the overall silhouette and style details of the garment.

The last few Likert-scale statements were focused on the application of 3D simulations in e-commerce. Again, each fit models' opinion varied with the exception of one statement. When presented the statement "If I had ordered these custom jeans online I would definitely not return them," two fit models disagreed, and the remaining three strongly disagreed. Four fit models indicated they would use virtual try-on technology again if given the chance. Only Fit Model D would not, again showing her general aversion towards using this technology. Fit Models A, B, and E indicated agreement with the statement "I would pay to have a custom avatar that I could use to virtually try clothing online," despite their negative feeling about their jeans and opposite answers to a similar statement in the initial survey. All of these statements and each fit models' answers can be found in Table 11 below.

Table 11

Fit Model Perceptions of 3D Apparel Technology after Experience

	Fit Model A	Fit Model B	Fit Model C	Fit Model D	Fit Model E	MEAN
Expectation versus actual fit of jeans						
My jeans fit the way I thought they would based on the simulations I viewed	2	3	7	2	3	3.4
My jeans look the way I thought they would based on the simulations I viewed	3	6	7	5	6	5.4
My custom jeans fit the way I thought they would based on my feedback in survey 1 and my design selections	3	3	2	1	3	2.4
My custom jeans look the way I thought they would based on my feedback in survey 1 and my design selections	2	3	3	5	5	3.6
My custom jeans look the same on me as they do on the avatar in the virtual simulation	2	5	3	2	2	2.8
3D simulation application in e-commerce						
If I had ordered these custom jeans online I would definitely not return them	2	2	1	1	1	1.4
I would virtually try on garments if given the chance	7	6	4	2	6	5
I would rather virtually try on garments than try them on in a store	5	3	1	1	7	3.4
I would pay to have a custom avatar that I could use to virtually try on clothing online	5	5	4	1	6	4.2
Being able to try clothes on a custom avatar would help me make purchase decisions while shopping online	7	5	4	2	7	5

Lastly, fit models were asked two open ended questions about their impressions of the virtual-try on experience they had been through via the first survey, how they predict the technology might be used in the future, and any way they would improve the experience. Four of the fit models were impressed and excited about the potential use of the technology.

Despite Fit Model Cs' skepticism about the accuracy of the technology, she was hopeful that a more advanced option would prove more useful. Fit Model D was not as optimistic, stating that she would never use virtual try-on based on her experiences. All of the models suggested ensuring more accurate body measurement and fit data if the technology were to be adopted in the future.

4.1.6 Summary of the Fit Model Experience

The experience of the fit models provided valuable information, and answered two of the research questions. Most fit models did not believe their jeans fit the way they would based on the simulations. But when asked about the overall look and style, four of the fit models answered more favorably. While the simulation may not be reliable in terms of fit information, it does provide accurate information about the overall silhouette and style details of the garment. Four fit models indicated they would use virtual try-on technology again if given the chance. Only Fit Model D would not, again showing her general aversion towards using this technology. Fit Models A, B, and E indicated they would pay for a custom avatar for virtually trying on clothing, despite their negative feeling about their jeans and opposite answers to a same statement in the initial survey. This is interesting because despite believing the simulations to not be accurate, they would all use it again. Four of the fit models were impressed and excited about the potential use of apparel simulation technology. Despite Fit Model Cs' skepticism about the accuracy of the technology, she was hopeful that a more advanced option would prove more useful in the future. Fit Model D was not as optimistic, stating that she would never use virtual try-on based on her experiences. All of the

models suggested ensuring more accurate body measurement and fit data if the technology were to be adopted in the future.

The fit model experience addresses three of the main research questions: Fit models did not believe the avatars reflected the shape of their bodies, and the simulations were not generally a good representation of the real jeans in the fit, and desired all jeans to be more fitted in most areas. Despite the issue of incorrect measurement data from the body scanner caused all jeans to be too large, fit models liked the customized jeans best, and felt they fit the best. Fit models enjoyed the customization aspect of their experience, and believed the simulations provided accurate silhouette and style details.

4.2 Consumer Group

4.2.1 Sample Characteristics and Purchasing Behavior

A total of 231 anonymous online survey responses were collected from May 15th to July 8th 2017. 105 responses were excluded from data analysis due to failure to indicate consent, indication that the participants' gender was male, or incomplete survey response, leaving a total of 129 complete responses for analysis. Many of the questions in the consumer group survey were the same as in the fit model initial survey. First, general demographic questions were asked. Participants' ages ranged from 18 to 60 years old. 83% of participants were White, 4.6% Asian, 1.6% Black, and 10.8% other or prefer not to say their ethnicity. This data was collected primarily from a convenience sample of students, and should not be considered a representative sample. After collecting demographic information, questions about the participants' purchasing behavior were asked, the results of which are summarized in Table 12. Participants did not buy jeans very often, 69% of them only buy jeans once or

twice a year if that. The majority of participants owned 2 to 10 pair of jeans and paid about $50 a pair. About half of all participants did not buy jeans online, and 20% of participants didn't shop online for any form of clothing. This finding underscores the need for this research, as using virtual try-on has been shown to decrease risk perception of, and therefore encourage, online shopping.

Table 12

Consumer Group Purchasing Behavior in Percentage

	Less than 1/year	Every 6-12 months	Every 4-6 months	Every 2-3 months	Once a month	
How often do you buy jeans?	24.031	45.736	19.38	10.078	0.775	
	0-2	2-5	5-10	10-15	15-20	20 or more
How many pairs of jeans do you own?	9.302	42.636	37.209	8.572	1.55	0.775
	Less than $25	$25-50	$50-100	$100-200		
Average price paid for jeans	10.853	50.388	31.783	6.977		
	Less than 1/year	Every 6-12 months	Every 4-6 months	Every 2-3 months	Once a month	N/A
How often do you purchase jeans online?	27.907	14.729	6.202	3.101	0	48.062
	Less than 1/year	Every 6-12 months	Every 4-6 months	Every 2-3 months	Once a month	N/A
How often do you return clothing that you purchase online?	31.783	15.504	14.729	14.729	0	20.155
	I did not like the fit	The item was too small	The item was too big	It did not look as expected	Wrong color	Other (please specify)
What are the reasons you returned clothing that you purchased online? (Select all that apply)	76.74	32.5	23.2	35.6	6.9	7.7

Some of the other reasons for returning online purchases that participants listed were dislike of the material or construction quality, needing extended sizing, or damage to the

merchandise. A majority of respondents (48%) do not purchase jeans online. The most common reasoning for return of online purchases was not liking the fit.

4.2.2 Evaluation of Denim Simulations

In the next section of the survey, participants viewed the simulations for one of the fit models, ranked the fit and indicated any changes preferred for each style of jeans. The fit model simulations were generated randomly for each participant to ensure an even amount of responses were collected for each fit models' simulations. The count for each fit model simulation is in Table 13 below.

Table 13

Distribution of Fit model Images by Count

Fit Model A	25
Fit Model B	26
Fit Model C	26
Fit Model D	26
Fit Model E	26

In the survey, each participant viewed the three styles of jeans and evaluated each pair's degree of fit and desired fit changes in five areas. The "Degree of Fit" category was a seven point Likert scale, coded with numerical values – 1 being "very poor fit" and 7 "very good fit". A score of 4 or lower indicates a poor fit, 4 a neutral fit, and 5 or more a good fit. No simulation was judged to have a good fit on average (see Table 15 below). Only five pairs of the simulated jeans were determined to have a good fit in specific areas, all five with a good fit at the waistband and two with a good fit at the abdomen. All other areas of fit received a score of 4.9 or below, indicating a neutral or poor fit.

To understand the overall fit evaluation of each pair of jeans, the scores of the five areas were averaged to create the mean degree of fit. The standard deviation of these means was high, showing that a great deal of variation in participant responses. Mean and standard deviations for each fit model's styles of jeans can be found in Appendix G. A comparison of Fit Model and the Consumer Group mean Degree of Fit is in Table 14.

Table 14

Degree of Fit Means

Fit Model A

	Consumer Group Mean	Fit Model Mean
Slim	3.776	5.2
Straight	4.056	4.8
Boot Cut	4.575	6

Fit Model B

	Consumer Group Mean	Fit Model Mean
Slim	3.950	4.6
Straight	3.240	3.6
Boot Cut	3.061	4.6

Fit Model C

	Consumer Group Mean	Fit Model Mean
Slim	3.865	3
Straight	4.084	3
Boot Cut	3.838	3

Fit Model D

	Consumer Group Mean	Fit Model Mean
Slim	4.169	6
Straight	3.784	5.8
Boot Cut	3.840	5.6

Fit Model E

	Consumer Group Mean	Fit Model Mean
Slim	4.669	5.2
Straight	4.615	5.8
Boot Cut	4.720	5

To determine if the Fit Model had any effect on Degree of Fit means for each style of jeans, a one way ANOVA with a 95% confidence interval was performed. The test revealed that for all three styles of jeans, at least one mean Degree of Fit was significantly different between the Fit Models. To determine which mean, or means, were different, a Tukey-Kramer HSD (honestly significant difference) test was performed. It was found that for the slim jeans, Fit Model Es' simulation had a significantly higher mean than Fit Model A or C, with p-values of 0.0157 and 0.0361 respectively. The mean Degree of Fit mean for Fit Model

Es' straight jeans were significantly higher than Fit Model Bs' with a p-value <0.0001, and higher than Fit Model Ds' straight jeans with a p-values of 0.0311. Fit Model Cs' straight jeans had a significantly higher mean Degree of Fit than Fit Model B, with a p-value of 0.0272. The mean Degree of Fit mean for Fit Model As' straight jeans was significantly higher than Fit Models B's, with a p-value of 0.0390. For the boot cut jeans, the mean Degree of Fit score for Fit Model Es' simulation was significantly higher than B, C and D, with p-values of <0.0001, 0.0330, and 0.0362 respectively. Additionally, Fit Model As' mean Degree of Fit was significantly higher than Fit Model Bs' with a p-value of <0.0001.

Fit Model Es' had a significantly higher mean Degree of Fit value than at least one other Fit Model's for each style of jean. Contrary to this, Fit Model Bs' mean Degree of Fit was significantly lower than at least one other Fit Model for every style. These trends could be attributed to a several different factors, perhaps some of the fit models have body shapes that are more difficult to customize jeans for or the simulation did not accurately represent the fit model body type. Comparing the consumer group Degree of Fit means to the Fit Model Degree of Fit means (Table 15) reveals that the consumer group gave a generally lower score on all styles of jeans, with differences in means vary as much as 3.05 points. This suggests that consumers might be more accepting of the fit of their own custom avatar, and more critical about others.

4.2.3 Virtual Try-on Effects on Attitude

Evaluation of qualitative data gathered in the open ended survey questions was preformed using NVivo Pro. Of the 129 survey respondents total, only 111 filled in the final two open ended questions. The first open ended question "How would the availability of 3D

virtual try-on affect your decision to try a new style or brand of jeans whether in-store or through online shopping?" was first coded into the following categories: would affect – positive, would affect – negative, and would not affect. 59.459% of respondents indicated that the availability of 3D virtual try-on would positively affect their decision try new styles or brands of jeans. 25.225% stated that it would not affect this decision. Only two participants indicated that using virtual try-on would negatively affect this decision.

Responses were then coded further if more information was given. Additional categories were captured in two themes, those related to the technology and those related to the self. Categories that related to technology were most focused on the virtual simulation itself, mentioning the accuracy and reliability of the technologies. Those categories that related to the self were more about the experience of using virtual try-on. Categories in descending frequency order were: skeptical, branch out, prefer in-person try on, fit issue to address, inform in-store purchase, novelty, feeling/comfort is important, use virtual try-on (VTO) for a different garment, not comfortable using VTO, reduce risk, and do not trust the technology. Explanations for each category and a matrix of the sub categories can be found in Tables 15 and 16 below.

Table 15

Decision to Try: Coding Frequency by Count

Code	Explanation	Count
Would affect – positive	Using VTO would positively influence decision to try	66
Would not affect	Using VTO would not influence decision to try	29
Would affect - negative	Using VTO would negatively influence decision to try	2
Relate to technology		
Skeptical - technology	Mistrust in efficacy of avatar or garment simulation	23
Novelty	Would only try VTO because it's new and fun	5
Apply to a different garment	Use VTO to asses a different garments' fit (i.e. shirts)	2
Do not trust the technology	Does not believe VTO is accurate	2
Total		32
Relate to self		
Prefer in person try on	Would rather try on in store than virtually	9
Fit issues to address	Mentioned personal area that is hard to fit	7
Inform in-store purchase	Would use VTO to decide what to try on in person	5
Feeling/comfort is important	Feeling the fabric/fit of garment imperative	4
Skeptical – self	Mistrust in process of ordering/returning product	2
Reduce risk of purchase	Would use VTO because it informs purchase	1
Not comfortable using VTO	Not comfortable using VTO	1
Total		29
Branch out	Would use VTO to try brands/styles never tried before	18

Table 16

Decision to Try: Consumer Views of Virtual Try-on Matrix by Count

	Would affect – positive	Would not affect
Relate to technology		
Skeptical - technology	15	2
Specific fit issue to address	3	2
Novelty	1	0
Do not trust technology	0	1
Relate to self		
Prefer in person try-on	0	5
Inform in-store purchase	5	0
Feeling/comfort important	1	2
Skeptical - self	1	0
Reduce risk or purchase	0	0
Not comfortable using VTO	1	0
Branch out	18	0

The majority of participants (59.45%) indicated that the technology would have a positive effect on their decision to try on different brands and styles of jeans. Age seemed to

have little correlation with attitude towards the technology, all age groups of participants had at least 50% positive responses. This is somewhat counterintuitive to the popular belief that older consumers are more averse to online shopping and technology. Interestingly, participants experience shopping online has little effect on the effect of this technology; 56% of participants who indicated they did not shop online still stated virtual try-on would have a positive effect on their decisions, 31.5% of those stated the availability of the technology would have no effect. This indicates that the presence of virtual try-on could encourage people who do not normally shop online to do so.

27.27% of participants specifically mentioned using virtual try-on to branch out into trying different styles and brands of clothes that they would not normally shop for. All of these participants also indicated that using the technology would positively affect them. This shows that virtual try-on would be used primarily for online shoppers, and would be especially helpful for consumers who have no access to a brick-and-mortar store.

4.2.4 Virtual Try-on Effects on Purchase Decisions

The second open ended question was "How would the availability of 3D virtual try-on affect your purchase decisions?" While this question seems similar to the previous, the distinction between trying out a new technology and actually having it influence a consumers' purchase decision is very important. This question was first coded into the categories "would affect – positive", "would not affect", and "unsure." The responses were then further coded when additional information was provided by the participant. The additional categories fall under two themes: those related to the technology, and those related to the self. The categories related to technology are: skeptical – technology, increase online

purchases, novelty, and depend on garment. The only category related to self is skeptical – self. Counts for each category and the matrix of sub categories can be found in Tables 17 and 18 below.

Table 17

Purchase Decision: Coding Frequency by Count

Code	Explanation	Count
Would affect – positive	Using VTO would positively influence purchase decision	53
Would not affect	Using VTO would not influence purchase decision	42
Unsure	Unsure if using VTO would influence purchase decision	8
Relate to technology		
Skeptical – technology	Mistrust in efficacy of avatar or garment simulation	12
Increase online purchases	VTO would encourage me to buy more products online	13
Novelty	Would only try VTO because it's new and fun	3
Depend on garment	Use VTO to aide decision for some garments and not others	4
Total		32
Relate to self		
Skeptical – self	Mistrust in process of ordering/returning product	7
Total		7

Table 18

Purchase Decision: Consumer View of Virtual Try-on Matrix by Count

	Would affect – positive	Would not affect	Unsure
Relate to technology			
Skeptical – technology	7	2	1
Increase online purchases	13	0	0
Novelty	0	1	0
Depend on garment	0	1	0
No trust	0	0	0
Relate to self			
Skeptical – self	4	0	1

47.74% of respondents stated using virtual try-on would positively affect their purchase decisions. 37.83% indicated that the availability or use of virtual try-on would not affect their purchase decisions. Again, the majority of respondents in every age group indicated that virtual try-on would positively affect their purchase decision except those in

the group 31-35, in which 75% indicated that the technology would not affect their decisions. Online shopping habits also seemed to have little correlation with virtual try-on affecting purchase decisions. About half of those who do not purchase jeans online said that VTO would positively affect their decisions, but only about 33% of those who shop for jeans online frequently (once every 2-3 or 4-6 months) stated the technology would affect their purchase decisions. This might indicate that the availability of virtual try-on would encourage those who do not shop online to give it a try, but it would have little influence on those who already do. This answers the main research question of the study, most consumers will use virtual try-on as an aid to making their purchase decisions, but will not solely rely on the technology.

4.2.5 Self-focused Consumers

The first of two general themes that emerged from the data are those participants that were more self-focused. Self-focused participants were those that answered these questions in ways that related to themselves or the experience of using virtual try-on. Responses in this category were focused on actually feeling the jeans, or using virtual try-on to solve a personal problem.

While these respondents still expressed skepticism, they were more concerned how virtual try-on fit in with their regular shopping experience. Some participants expressed they would use virtual try-on "if it was easy to return still," or if "the return policy was very good." Several mentioned they would use virtual try-on to help gather information before going into a store, but would not solely rely on the technology. Others explained they would not use virtual try-on for jeans because the actual feeling of the garment is more important to

them. One brought up the fact that avatars wouldn't take into account different factors such as being bloated or the waistband being scratchy. Finally, a number of participants thought using virtual try-on would be good for them as they have specific fit issues to address that cannot be seen on a regular catalog model. These participants are drawn to the experience of shopping and trying on clothing. For these self-focused participants, using virtual try-on can be used as an aide to decision making but does not eliminate the need for direct interaction with products.

4.2.5 Technologically Focused Consumers

The second theme that emerged was answers focused around virtual try-on itself. These participants framed their answers in terms of the technology of virtual try-on, instead of relating to the experience of using it. Participants who framed their answers in terms of technology would only use it for fun, or to aide online shopping, and were skeptical of its effectiveness.

Using virtual try-on for the sake of novelty has been proven to be one of the barriers to acceptance (Kim & Forsythe, 2008; Kim & LaBat, 2013), which is confirmed by this research. Participants stated they would like to try it, "but [virtual try-on] wouldn't affect [their] decision." In the first question about using virtual try-on to try new brands or styles of jeans, just over half of all coding related to technology. This contrasts with the 82% of answers that related to technology when asked about using virtual try-on in a purchase decision. This rift underscores that people generally like the experience of virtual try-on but do not rely on it for purchases.

In 76% of the answers relating to technology, there is also mention that using virtual try-on would help participants branch out and try new styles or brands of jeans. Participants focused on the technological aspect tended to enjoy that they could try on clothes virtually, instead of being "force[d] to go into the store." 40% of participants stated they would use it to buy from stores they have no in-person access to. Six participants mentioned they would like to use virtual try-on for garments such as shirts other casual garments. Several participants specifically mentioned that virtual try-on would increase their confidence in purchasing jeans online, which is particularly impactful considering 48% of all participants do not buy jeans online at all.

20.7% of all respondents indicated skepticism about the effectiveness of virtual try-on through statements like "if the avatar were shaped like me." Most skepticism was founded in the accuracy of avatar measurements, as opposed to the simulation quality or accuracy of the clothing, indicating that they would like the technology *only if* they were convinced the avatar or clothing simulation was totally accurate. Despite this distrust, 78% indicated that using the technology would still affect them positively. This mistrust of 3D apparel simulation efficacy is widespread. As one participant stated: "I can look at that picture but that's not necessarily how it will fit in true life." Another mentioned that seeing the clothes on the avatar would give information on the seam lines and overall silhouette, even if the avatar is not an exact representation of the body. Many participants were skeptical only when it came to virtually trying on jeans, but would use it to try on and make purchase decisions about other garments. Additionally, 62% of participants who were skeptical about the technology also indicated that they do not purchase clothing online, and that number jumps to 71.8% when adding in those who purchase clothing online less than once a year.

Companies do face the challenge of convincing their consumers that 3D apparel simulation and virtual try-on technology is trustworthy and reliable. However many consumers will use virtual try-on regardless of their feelings about its' accuracy, especially if the simulation looked good.

5. CONCLUSIONS AND FURTHER RESEARCH

5.1 Conclusions

Three dimensional apparel simulation can be used to aid in the product development process to lower time and cost before production and create better fitting apparel (Apeagyei & Otieno, 2007; Easters, 2013; Power, 2011). The technology can also be used for consumers to virtually try-on jeans or aid in customization (Baytar & Ashdown, 2015; Divivier et al., n.d.; Fletcher, 2010). Adoption of 3D apparel simulation has been slow in the industry, partly due to lack of understanding consumers'' view of the technology. Understanding consumer perception of 3D apparel simulation is essential for effective implementation of the technology, either for use by brands in the product development process or for applications in e-commerce.

5.1.1 Consumer Ability to Make Purchase Decisions with 3D Apparel Simulations

This research has shown that consumers perceive 3D apparel simulation to be an aid to purchase decisions. Both self- and technologically-focused consumers indicated they would use virtual try-on to aide their decisions to try new styles and brands of clothing (Tables 15 and 16). Participants who did not normally shop online were more willing to use virtual try-on given the opportunity than those who shop online frequently This indicates that 3D apparel simulation would be best utilized in e-commerce, especially by brands that have few or no brick and mortar stores, as using virtual try-on encourages online shopping. Self-focused consumers were more concerned with the experience of using the technology, so brands catering towards this type of consumer should highlight that virtual try-on can provide

a more pleasurable shopping experience. Technologically focused consumers were more skeptical of the accuracy of simulation technology, and brands need to convince these consumers to trust the technology during implementation.

5.1.2 Consumer Ability to Make Customization Decisions Based on 3D Apparel Simulations

Results of this study suggest consumer mistrust of using 3D apparel simulation to develop customized jeans is high. While the fit models thought customizing their jeans style details was fun, they were more hopeful about customizing the fit. Silhouette choice outweighed perceived fit of the jeans for three of the fit models (Tables 7 and 8). All fit models were more satisfied with the fit of their custom jeans, showing they achieved a preferred fit by judging the apparel simulations and indicating their desired fit alterations. This shows that using 3D apparel simulation has potential to facilitate fit customization of products. This research has shown that fit customization is preferred over style customization, both through the fitting sessions and in the consumer group open ended responses. Brands should therefore focus on implementing 3D simulation to aid in customizing fit as opposed to style details in order to offer customized products while maintaining manufacturing feasibility.

5.1.3 Consumer Views of 3D Apparel Simulation Representation of Avatars, Fabric, and Garment Fit

Both fit models and those in the consumer group did not believe that avatars reflected their actual body and were skeptical as to whether clothing on the avatar is representative of real life (Tables 9 and 11). This hinders adoption of 3D prototyping for customized products,

as consumers might not risk reliance on a simulation to make their purchase decisions. Brands face the challenge of convincing consumers to trust 3D apparel simulation. This research has shown that consumers are likely to accept and use the technology after having a positive experience with it. Perceptions of the silhouette and style of jeans was positive, again showing that the technology might better serve as an aide in decision making. All participants were ultimately hopeful 3D apparel simulation technology will advance further and become more reliable.

5.2 Suggestions for Future Research

This research revealed several limitations in the simulation technology itself. Errors in measurement collection, possibly due to inadequate training of body scan operation, resulted in garments that were clearly too big for the fit models. The 3D simulations did not provide adequate visual information for the fit models to determine how the jeans related to their bodies, and so the fit models were unable to accurately judge the fit. Additional qualitative research into the effectiveness of different methods conveying visual information of the simulation to the fit model should be conducted. Methods conveying fit information could include showing how the simulated garment relates to the avatar or providing a key that clearly states what area on the avatar corresponds to areas of fit. Several fit issues were not represented in the simulations in this study, such as the length of the jeans, and simulation quality overall should improve to address this. Simulation quality can be improved by further development of effective 3D apparel simulation software, as well as more available options for the user to increase quality, such as avatars that can be manipulated to better reflect user's bodies.

Further research including a more comprehensive sample of participants should be conducted, as this study only included a convenience sample of female respondents. Research into consumer perception of 3D apparel simulation for the customization of different apparel products should also be conducted to determine if different apparel products are more suitable for virtual try-on applications. While this was not a limitation of this study, research into how increased interactivity with the 3D simulation could affect consumer confidence in the simulation should be explored. The effectiveness of various ways to increase interactivity, such as the ability to rotate the image and providing more information about areas of fit by using a key, should be explored. The effects of increased image interactivity on consumer trust should be researched, as image interactivity is one way to decrease consumer skepticism. Other ways in which to decrease consumer skepticism about using 3D apparel simulation technology should also be explored. A study designed to validate the presence of self-focused and technologically focused consumers, as well as further explore their relation should also be explored, as acceptance of 3D apparel technologies varies between the two groups in this study.

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APPENDICES

Appendix A

Fit Model Jeans Preference Options

Pocket Shape Options

Pocket shape A

Pocket shape B

Pocket shape c

Pocket Stitching Options (pictured on Pocket shape A)

Pocket stitching A

Pocket stitching B

Pocket stitching C

Waistband Options

Waistband option A (belt loops)

Waistband option B (no belt loops)

Appendix B

Fit Model Initial Survey

Demographics:

Please select the gender that you most identify with:

- Male
- Female
- Transgender
- Non-binary/genderqueer/gender fluid
- Other
- Prefer not to say

Please select your age

- 18-24
- 25-30
- 31-35
- 36-40
- 41-50
- 51-60

Please select your ethnicity

- White
- Black of African American
- American Indian or Alaska Native
- Asian
- Native Hawaiian or Pacific Islander
- Other
- Prefer not to say

Shopping Habits:

How often do you buy jeans?

- More than once a month
- Once a month
- Once every 2-3 months
- Once every 4-6 months
- Once every 6-12 months
- Less than once a year

How many pairs of jeans do you own?

- 0-2

- 2-5
- 5-10
- 10-15
- 15-20
- 20 or more

Select the average price you pay for jeans
- Less than $25
- $25-50
- $50-100
- $100-200
- $200 or more

How often do you purchase jeans online?
- More than once a month
- Once a month
- Once every 2-3 months
- Once every 4-6 months
- Once every 6-12 months
- Less than once a year
- Not applicable/I do not purchase jeans online

How often do you return clothing that you purchase online?
- More than once a month
- Once a month
- Once every 2-3 months
- Once every 4-6 months
- Once every 6-12 months
- Less than once a year
- Not applicable/I do not purchase clothing online

What are the reasons you typically return clothing you purchased online? Select all that apply
- I did not like the fit
- The item was the wrong color
- The item did not look the way I expected
- The item was too small
- The item was too big
- Other (please specify) _____

Have you ever purchased customized jeans?
- Yes
- No

If yes, please describe your experience with purchasing customized jeans.

Would you consider purchasing customized jeans in the future?
- Definitely yes

- ○ Probably yes
- ○ Might or might not
- ○ Probably not
- ○ Definitely not

Simulation Questions:

For the following questions you will view front, side, and back views of each pair of jeans we created for you. The avatar in these simulations is one that was customized according to your scan measurements.

Simulation A:

Indicate the degree to which you believe the following areas fit,

	Very Poor	Poor	Somewhat Poor	Neutral	Somewhat good	Good	Very good
Waistband	○	○	○	○	○	○	○
Hips	○	○	○	○	○	○	○
Seat	○	○	○	○	○	○	○
Thigh	○	○	○	○	○	○	○
Abdomen	○	○	○	○	○	○	○

Please indicate what change (if any) you would make to the simulated jeans above

	Much more fitted	More fitted	No change	Less fitted	Much less fitted
Waistband	○	○	○	○	○
Hips	○	○	○	○	○

Seat	○	○	○	○	○
Thigh	○	○	○	○	○
Abdomen	○	○	○	○	○

Simulation B:

Indicate the degree to which you believe the following areas fit,

	Very Poor	Poor	Somewhat Poor	Neutral	Somewhat good	Good	Very good
Waistband	○	○	○	○	○	○	○
Hips	○	○	○	○	○	○	○
Seat	○	○	○	○	○	○	○
Thigh	○	○	○	○	○	○	○
Abdomen	○	○	○	○	○	○	○

Please indicate what change (if any) you would make to the simulated jeans above

	Much more fitted	More fitted	No change	Less fitted	Much less fitted
Waistband	○	○	○	○	○
Hips	○	○	○	○	○
Seat	○	○	○	○	○
Thigh	○	○	○	○	○
Abdomen	○	○	○	○	○

Simulation C:

Indicate the degree to which you believe the following areas fit,

	Very Poor	Poor	Somewhat Poor	Neutral	Somewhat good	Good	Very good
Waistband	○	○	○	○	○	○	○
Hips	○	○	○	○	○	○	○
Seat	○	○	○	○	○	○	○
Thigh	○	○	○	○	○	○	○
Abdomen	○	○	○	○	○	○	○

Please indicate what change (if any) you would make to the simulated jeans above

	Much more fitted	More fitted	No change	Less fitted	Much less fitted
Waistband	○	○	○	○	○
Hips	○	○	○	○	○
Seat	○	○	○	○	○
Thigh	○	○	○	○	○
Abdomen	○	○	○	○	○

Below are all three simulations again for you to compare:

Drag and drop the following to rank the above simulations from best fitting to worst fitting jeans, with 1 being the best fit and 3 being the worst fit

Simulation A
Simulation B
Simulation C

General Questions

Now that you have experienced 3D simulations, please indicate the degree to which you agree with the following statements.

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
I would virtually try on garments if given the chance	○	○	○	○	○	○	○
I would rather virtually try on garments than trying them on in the store	○	○	○	○	○	○	○
I would pay to have a custom avatar that I could use to virtually try on clothing online	○	○	○	○	○	○	○
Being able to try clothes on an avatar would help me make purchase decisions when shopping online	○	○	○	○	○	○	○
The virtual jeans accurately represent the look of real denim	○	○	○	○	○	○	○
Seeing the jeans virtually tried on the avatar helps me decide if I like the jeans	○	○	○	○	○	○	○
The avatar accurately shows my body shape	○	○	○	○	○	○	○
The simulation looks like me in a pair of jeans	○	○	○	○	○	○	○
I am comfortable with the look of this virtual avatar	○	○	○	○	○	○	○

If the statement "I would pay to have a custom avatar that I could use to virtually try on clothing online" was answered favorable, the following question would be displayed.

Select the options that best fits you

	Less than $10	$10-20	$21-30	$31-40	$41-50	$50 or more
How much would you pay for a virtual avatar to try on clothes online at only one company?	○	○	○	○	○	○
How much would you pay for a virtual avatar to try on clothes online at any company?	○	○	○	○	○	○

How would the availability of 3D virtual try-on affect you decision to try a new style or brand of jeans whether in-store or through online shopping?

How would the availability of 3D virtual try-on affect your purchase decisions?

Customization

The next part of the survey will help us create a custom pair of jeans based on your fit and design preferences

Choose which jeans you would like to have made for you

○ Jeans A ○ Jeans B ○ Jeans C

Choose your back pocket shape

○ Pocket A ○ Pocket B ○ Pocket C



Choose your back pocket stitching design *(design displayed on pocket shape selected in previous question)*

○ Pocket A

○ Pocket B

○ Pocket C

Choose your waistband option

○ Waistband A

○ Waistband B

Appendix C

Fit Model Fitting Session Interview Script

The participant will arrive for her fitting appointment and will be greeted by the research assistant. She will be asked to go into a curtained room to change into her custom jeans. 3 pairs of jeans will be in the fitting room for her to try on. They will be labeled 1, 2, and 3.

When she is dressed in a pair of jeans, the participant will come out of the room and answer questions about the fit of her jeans. In the event that she is not able to get into her jeans, or not able to fasten them, she will be told to discard that pair and move to the next one.

Questions to be asked for each pair of jeans as they are being worn by the subject. This conversation will be audio recorded.

Now I'm going to ask you some questions about the jeans you are wearing.

1. How do these feel?
2. Do you like the way they fit?
3. What works and doesn't work about these? (prompt with suggestions such as, is the waist in the right place? Do the jeans feel too tight or too loose anywhere?)
4. What do you think about the design features? (prompt with suggestions such as, do you like the pockets? The belt loops? The length?)
5. What would you change about these jeans?

After these questions have been answered the participant will be photographed from the neck down in her jeans, then asked to step into the dressing room to change into the next pair. The PI will repeat the questions above for each pair of jeans that is tried on, and the participant will be photographed in each.

Thank you for trying on those jeans and answering those questions. Now I'm going to give you a link to your final online survey. This should take only a few minutes to complete. We really appreciate your participation in this study!

Appendix D

Fit Model Final Survey

Based on this fitting experience, please answer the following question about denim simulation in general.

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
My jeans fit the way I thought they would based on the simulations I viewed	○	○	○	○	○	○	○
My jeans look the way I thought they would based on the simulations I viewed	○	○	○	○	○	○	○
My custom jeans fit the way I thought they would based on my feedback in survey 1 and my design selections	○	○	○	○	○	○	○
My custom jeans look the way I thought they would based on my feedback in survey 1 and my design selections	○	○	○	○	○	○	○
My custom jeans look the same on me as they do on the avatar in the virtual simulation	○	○	○	○	○	○	○
If I had ordered these custom jeans online I would definitely not return them	○	○	○	○	○	○	○
I would virtually try on garments if given the chance	○	○	○	○	○	○	○
I would rather virtually try on garments than try them on in a store	○	○	○	○	○	○	○
I would pay to have a custom avatar that I could use to virtually try on clothing online	○	○	○	○	○	○	○
Being able to try clothes on a custom avatar would help me make purchase decisions while shopping online	○	○	○	○	○	○	○

What were your impressions of this virtual try-on experience?

How do you see virtual try-on being used for online shopping in the future? What changes would you suggest to improve the experience?

Appendix E

Consumer Group Survey

Demographics:

Please select the gender that you most identify with:

- Male
- Female
- Transgender
- Non-binary/genderqueer/gender fluid
- Other
- Prefer not to say

Please select your age

- 18-24
- 25-30
- 31-35
- 36-40
- 41-50
- 51-60

Please select your ethnicity

- White
- Black of African American
- American Indian or Alaska Native
- Asian
- Native Hawaiian or Pacific Islander
- Other
- Prefer not to say

Shopping Habits:

How often do you buy jeans?

- More than once a month
- Once a month
- Once every 2-3 months
- Once every 4-6 months
- Once every 6-12 months
- Less than once a year

How many pairs of jeans do you own?

- 0-2
- 2-5
- 5-10
- 10-15
- 15-20
- 20 or more

Select the average price you pay for jeans

- Less than $25
- $25-50
- $50-100
- $100-200
- $200 or more

How often do you purchase jeans online?

- More than once a month
- Once a month
- Once every 2-3 months
- Once every 4-6 months
- Once every 6-12 months
- Less than once a year
- Not applicable/I do not purchase jeans online

How often do you return clothing that you purchase online?

- More than once a month
- Once a month
- Once every 2-3 months
- Once every 4-6 months
- Once every 6-12 months
- Less than once a year
- Not applicable/I do not purchase clothing online

What are the reasons you typically return clothing you purchased online? Select all that apply

- I did not like the fit
- The item was the wrong color
- The item did not look the way I expected
- The item was too small
- The item was too big
- Other (please specify) _____

Simulations (participants are randomly shown simulation images from one of the five fit models)

Simulation one:

For the simulated jeans above, indicate the degree to which you believe the following areas fit:

	Very Poor	Poor	Somewhat Poor	Neutral	Somewhat good	Good	Very good
Waistband	○	○	○	○	○	○	○
Hips	○	○	○	○	○	○	○
Seat	○	○	○	○	○	○	○
Thigh	○	○	○	○	○	○	○
Abdomen	○	○	○	○	○	○	○

Please indicate what change (if any) you would make to the simulated jeans above

	Much more fitted	More fitted	No change	Less fitted	Much less fitted
Waistband	○	○	○	○	○
Hips	○	○	○	○	○
Seat	○	○	○	○	○
Thigh	○	○	○	○	○
Abdomen	○	○	○	○	○

Simulation two:

For the simulated jeans above, indicate the degree to which you believe the following areas fit:

	Very Poor	Poor	Somewhat Poor	Neutral	Somewhat good	Good	Very good
Waistband	○	○	○	○	○	○	○
Hips	○	○	○	○	○	○	○
Seat	○	○	○	○	○	○	○
Thigh	○	○	○	○	○	○	○
Abdomen	○	○	○	○	○	○	○

Please indicate what change (if any) you would make to the simulated jeans above

	Much more fitted	More fitted	No change	Less fitted	Much less fitted
Waistband	○	○	○	○	○
Hips	○	○	○	○	○
Seat	○	○	○	○	○
Thigh	○	○	○	○	○
Abdomen	○	○	○	○	○

Simulation three:

For the simulated jeans above, indicate the degree to which you believe the following areas fit:

	Very Poor	Poor	Somewhat Poor	Neutral	Somewhat good	Good	Very good
Waistband	○	○	○	○	○	○	○
Hips	○	○	○	○	○	○	○
Seat	○	○	○	○	○	○	○
Thigh	○	○	○	○	○	○	○
Abdomen	○	○	○	○	○	○	○

Please indicate what change (if any) you would make to the simulated jeans above

	Much more fitted	More fitted	No change	Less fitted	Much less fitted
Waistband	○	○	○	○	○
Hips	○	○	○	○	○
Seat	○	○	○	○	○
Thigh	○	○	○	○	○
Abdomen	○	○	○	○	○

View the following simulations and rank them from best to worst fitting:

Rank the above simulations from best fitting to worst fitting jeans, with 1 being the best fit and 3 being the worst fit

Jeans A
Jeans B
Jeans C

Please answer the following about jean simulations in general:

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
Seeing the jeans virtually tried on the avatar helps me decide if I like the jeans	○	○	○	○	○	○	○
Seeing the jeans virtually tried on the avatar helps me make a purchase decision on the jeans	○	○	○	○	○	○	○
I would virtually try on garments if given the chance	○	○	○	○	○	○	○
I would rather virtually try on garments than trying them on in the store	○	○	○	○	○	○	○
I would pay to have a custom avatar that I could use to virtually try on clothing online	○	○	○	○	○	○	○
Being able to see clothes on a custom avatar would help me make purchase decisions when online shopping	○	○	○	○	○	○	○

If the statement "I would pay to have a custom avatar that I could use to virtually try on clothing online" was answered favorable, the following question would be displayed.

Please select the options that best fits you

	Less than $10	$10-20	$21-30	$31-40	$41-50	$50 or more
How much would you pay for a virtual avatar to try on clothes online at only one company?	○	○	○	○	○	○
How much would you pay for a virtual avatar to try on clothes online at any company?	○	○	○	○	○	○

Free response

How would the availability of 3D virtual try-on affect your decision to try a new style or brand of jeans whether in-store or through online shopping?

How would the availability of 3D virtual try-on affect your purchase decisions?

Appendix F

Fit Model Perceptions of 3D Apparel Technology

Fit Model Perceptions of 3D Apparel Technology

	Fit Model A	Fit Model B	Fit Model C	Fit Model D	Fit Model E	MEAN
I would virtually try on garments if given the chance	6	6	1	7	7	5.4
I would rather virtually try on garments than trying them on in the store	5	5	1	1	3	3
I would pay to have a custom avatar that I could use to virtually try on clothing online	6	3	2	1	5	3.4
Being able to try clothes on an avatar would help me make purchase decisions when shopping online	7	6	4	1	5	4.6
The virtual jeans accurately represent the look of real denim	3	3	1	2	3	2.4
Seeing the jeans virtually tried on the avatar helps me decide if I like the jeans	4	5	1	1	5	3.2
Seeing the jeans virtually tried on the avatar helps me make a purchase decision on the jeans	5	5	1	2	5	3.6
This avatar accurately shows my body shape	5	3	4	4	3	3.8
The simulation looks like me in a pair of jeans	5	3	1	4	3	3.2
I am comfortable with the look of this virtual avatar	5	3	2	7	5	4.4

Appendix G

Fit Models Sewn Jeans Compared to Simulations

Fit Model A Slim Jeans Simulation

Fit Model A Slim Jeans

Fit Model A Custom Slim Jeans Simulation

Fit Model A Custom Slim Jeans

Fit Model A Straight Jeans Simulation

Fit Model A Straight Jeans

Fit Model B Boot Cut Jeans Simulation

Fit Model B Boot Cut Jeans

Fit Model B Custom Boot Cut Jeans Simulation

Fit Model B Custom Boot Cut Jeans

Fit Model B Straight Jean Simulation

Fit Model B Straight Jeans

Fit Model C Boot Cut Jeans Simulation

Fit Model C Boot Cut Jeans

Fit Model C Custom Boot Cut Jeans Simulation

Fit Model C Custom Boot Cut Jeans

Fit Model C Straight Jeans Simulation

Fit Model C Straight Jeans

Fit Model D Straight Jeans Simulation

Fit Model D Straight Jeans

Fit Model D Custom Straight Jeans Simulation

Fit Model D Custom Straight Jeans

Fit Model D Boot Cut Jeans Simulation

Fit Model D Boot Cut Jeans

Fit Model E Slim Jeans Simulation

Fit Model E Slim Jeans

Fit Model E Custom Slim Jeans Simulation

Fit Model E Custom Slim Jeans

Fit Model E Straight Jeans Simulation

Fit Model E Straight Jeans

Appendix H

Consumer Group Evaluation of Denim Simulations Degree of Fit

Fit Model A – Degree of Fit

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	5.160	1.518	3.520	1.503	3.120	1.536	2.600	1.384	4.480	1.503
Straight	4.760	1.422	3.920	1.497	3.760	1.422	3.080	1.411	4.760	1.331
Boot Cut	5.083	1.176	4.500	1.474	4.458	1.614	4.000	1.719	4.833	1.239

Fit Model A – Fit Changes

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	3.000	0.288	2.280	0.737	2.120	0.927	1.640	0.637	2.720	0.613
Straight	2.880	0.725	2.680	0.900	2.800	1.080	1.960	0.734	2.760	0.435
Boot Cut	2.840	0.472	2.760	0.723	2.840	0.687	2.600	1.000	3.040	0.454

Fit Model B – Degree of Fit

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	4.423	1.677	3.653	1.695	3.080	1.913	3.692	1.691	4.615	1.358
Straight	3.961	1.561	3.653	1.695	2.640	0.250	2.192	1.327	3.923	1.440
Boot Cut	3.846	1.461	3.115	1.503	2.423	1.361	2.384	1.387	3/653	1.412

Fit Model B – Fit Changes

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	3.461	0.646	3.461	0.811	2.243	1.101	2.615	0.897	3.230	0.587
Straight	3.153	0.674	2.346	0.891	1.653	0.981	1.500	0.761	2.961	0.527
Boot Cut	3.076	0.744	2.153	0.924	1.500	0.707	1.384	0.697	2.730	0.919

Fit Model C – Degree of Fit

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	5.384	1.168	4.615	1.358	2.520	1.557	1.730	0.837	5.000	1.095
Straight	4.961	1.280	5.040	0.934	3.217	1.536	2.500	1.029	4.615	1.235
Boot Cut	4.923	1.440	4.384	1.498	3.153	1.433	2.115	0.951	4.615	1.134

Fit Model C – Fit Changes

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	2.961	0.527	2.500	0.583	1.807	0.938	1.192	0.401	3.000	0.489
Straight	3.076	0.483	2.653	0.485	2.076	0.796	1.692	0.928	3.115	0.515
Boot Cut	3.153	0.543	2.576	0.702	2.153	0.967	1.653	0.891	3.192	0.567

Fit Model D – Degree of Fit

	Waist	Hips	Seat	Thigh	Abdomen

	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	5.615	0.982	4.884	1.395	3.076	1.521	2.461	1.580	4.807	1327
Straight	4.615	1.498	4.653	1.383	3.269	1.484	2.423	1.331	3.961	1.148
Boot Cut	4.720	1.307	4.520	1.294	3.200	1.414	2.440	1.474	4.320	0.988

Fit Model D – Fit Changes

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	2.807	0.491	2.692	0.735	2.153	1.120	1.423	0.643	2.884	0.588
Straight	3.384	0.571	2.961	0.662	2.461	0.947	1.423	0.757	3.230	0.710
Boot Cut	3.307	0.470	3.308	0.598	2.307	1.086	1.730	0.874	3.076	0.627

Fit Model E – Degree of Fit

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	5.461	1.103	4.692	1.407	4.115	1.557	4.076	1.467	5.000	1.326
Straight	5.038	1.341	4.923	1.354	4.576	1.474	4.192	1.766	4.346	1.41
Boot Cut	4.720	1.429	4.520	1.446	4.600	1.527	4.791	1.318	2.884	0.431

Fit Model E – Fit Changes

	Waist		Hips		Seat		Thigh		Abdomen	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Slim	3.192	0.567	2.961	0.720	3.461	0.760	2.538	0.947	3.192	0.633
Straight	2.961	0.527	2.653	0.628	2.923	0.976	2.269	0.827	2.923	0.796
Boot Cut	2.884	0.431	2.769	0.651	2.807	0.749	2.423	0.856	2.846	0.674