Apparel Fit Evaluations of 3D Scans via Eye-Tracking

Lauren Bouvier

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Apparel Fit Evaluations of 3D Scans via Eye-Tracking

Lauren Bouvier

University of Arkansas
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Abstract

The primary objective of this study is to identify the differences in apparel fit ratings when represented by a 2D or 3D display in an effort to increase customer satisfaction and reduce the rate of returns, as well as develop an understanding of consumer shopping behavior.

Phase I of data collection involved participants wearing apparel that fit properly and apparel that did not fit properly. 2D images were captured of the front, side, and back, along with 3D body scans for each category of apparel. In phase II of data collection, participants were asked to examine the 2D images and 3D scans collected and evaluate the fit of each while considering the overall fit, bust, waist, and hip regions. Simultaneously, the participants gaze, and fixation was recorded via eye-tracking technology. Participants then completed a survey regarding their online shopping preferences.

When analyzing online shopping behavior, 70% of participants stated they purchased clothing online through online shopping. 80% of these participants stated they had returned an apparel item due to misfit within the last year. When asked what regions participants were primarily concerned with in terms of proper fit, the waist and pant length regions were most common follower by the hip and thigh regions. When analyzing the difference between 2D and 3D fit ratings, the waist region showed the greatest difference. When instructed to evaluate the fit of the given apparel item, participants focused mostly on the bust, underbust, waist, and hip regions. The sleeve length, shoulder, neck, and pant length regions were not considered by the participants.

The current online shopping experience has several limitations and often misrepresents the fit of the apparel items. Customers typically only see 2D images of the apparel worn by a fit
model. According to the study, a 3D display of the garment with a 360-degree rotation was highly preferred by the participants when evaluating the apparel fit. This offers a better understanding of the apparel fit upfront which would likely reduce the customers dissatisfaction after purchasing. As a result, there would be a potential decreased in the rate of returns.

*Keywords*: apparel fit, 3D body scanning, eye tracking, online shopping
Acknowledgements

I would like to acknowledge the people and resources that contributed to the completion of this research study.

I wish to express my deepest gratitude to my mentor, Dr. Mahendran Balasubramanian. I am in debt to him for the knowledge he shared throughout the entire research process. He guided me through the research structure and assisted me in developing the skills necessary to see the studies completion. I am grateful for his immense knowledge in 3D body scanning, eye-tracking technology, data analysis, and consumer behavior. I am very appreciative of his dedication to my academic and pre-professional success. All that I learned from him throughout this process will carry far into my future endeavors.

I would also like to pay special regards to my committee members, Dr. Laurie Apple and Dr. Lance Cheramie. I am grateful for their time and dedication developing suggestions for the research based on their industry experience and professional knowledge. I am appreciative of their constructive feedback throughout the study.

This study was possible through the generous funding of the University of Arkansas’ Honors College. Through this funding I was able to compensate participants for their involvement and fund other related costs. I would also like to thank the School of Human Environmental Sciences for the resources used during the study.

Lastly, I would like to thank all the participants for their time in contributing and testing the data as well as their opinions that made this study possible.
Introduction

Over the recent decade, online shopping has become a convenient and popular mode for consumers. However, it is still difficult for consumers to choose apparel with proper size and fit. Customers must visualize the garment shown on the websites and generate a mental perception of the 3D fit. Clothing fit is the relationship or balance of clothing to the body (Brown & Rice, 2001; LaBat, & DeLong, 1990). Fit models wear clothing for online consumers to perceive the aesthetic appearance and fit of the garment on a human body. However, in actuality, fit models represent only a subset of the population and are often limited to one garment size. While online shopping, dissatisfaction emerges when customers must match the fit of the garment worn by the model to their own body image. Commonly, customers must estimate 3D fit based only on 2D images. Studies have shown interaction, personalization, and visualization from advanced technologies to be vital influences on the customer’s experience and satisfaction (Apeagyei, P.R., n.d.). One of the approaches to improve fit estimation would be to have a 3D image representation of the apparel worn by a fit model and provide 3D visual images so the consumers can have access to a 360-degree visual of the apparel. This study will harness the data about the factors that influence a customer’s perception of apparel fit. For proper garment fit, it is important to identify the correct balance between the garment and the silhouette of the body. 3D scans are possible through recent technological advances in 3D body scanning technology. 3D body scanning is viewed as the frontier of solving garment fit issues (Apeagyei, P.R., n.d.). However, it is still not studied how a consumer visually evaluates the fit of the garment by seeing a 2D image or a 3D garment. Eye-tracking technology allows for a new dimension of understanding consumer preferences. In order to increase the user experience related to online
apparel shopping and to decrease the dissatisfaction of fit, the purchase psychology of humans must be studied.

**Purpose**

The purpose of this study is to explore how consumers evaluate fit of apparel shown on 2D image and on 3D scan with models. Understanding this perception will enable retailers to better comprehend how to effectively display garments online. For the customer, they will gain a better understanding of how the garment will fit to their body prior to making the purchase. As a result, the number of returns, unsold garments, and customer dissatisfaction can potentially be decreased.

**Literature Review**

This review of literature discusses apparel fit, online shopping, three-dimensional body scanning, and eye-tracking technology. In addition, this literature reviews research studies done in the past and relates them to current studies.

**Apparel Fit**

Clothing fit is defined as the relationship or balance of clothing to the body (Brown & Rice, 2001). There are two categories of clothing fit: (i) aesthetic or static fit meaning how the garment appears, and (ii) functional or dynamic fit meaning the comfort and performance of the garment, both in relation to the body (Eckman et al’, 1990; Outling, 2007). Retailers typically evaluate clothing fit using a standard fit model. The fit model selected by retailers are assumed to represent the ideal costumer (Ashdown & O’Connell, 2006). The fit model wearing the garment
is shown as an example for online consumers to perceive the aesthetic appearance and fit of the garment on a human body. However, in the real world, fit models represent only a subset of the population and often limited to one garment size.

Today many customers have a difficult time believing the recommended size will actually fit them because of the inconsistent sizing systems (Kasambala et al., 2016). These sizes are created with ease in the garment. Ease is known as the difference between the person’s measurements and the garment’s measurements. There are two types of garment ease, similar to the two categories of apparel fit. (i.) Functional or fit ease factors is the space needed for the bodies movement and (ii.) aesthetic or style ease is connected to the garment’s design (Ashdown & O’Connell 2006). Appropriate fit is achieved by appropriate functional and aesthetic ease.

**Online Shopping**

Images shown on the shopping websites are 2D, while the garment and the user body are 3D entities. The consumers have to estimate the fit of a 3D product on a 3D body by relating themselves to a 2D image. During online shopping, dissatisfaction emerges under these conditions such as the required extrapolation of the fit model to match their own body image and estimating 3D fit basing only with 2D images. It has been reported that online apparel retailers are experiencing a 28% return rate, with 80% of the returns caused by fit issues (Vozza, 2016). This stems from the challenge of effectively communicating accurate clothing fit to customers (Kartsounis, Magnenat-Thalmann & Rodrian, 2003).

**3D Body Scanning**
Three dimensional scans are possible through recent technological advances in 3D body scanning (See Figure 1). Currently, body scanners are used within the apparel industry to improve apparel fit and customer satisfaction in the retail and product development sectors. The intention is to ultimately increase sales. With this technology, companies are capable of rapidly capturing dozens of circumference, length, and volume body dimensions (Meality, 2017). This technology more accurately portrays precise the human body measurements compared to traditional measurements taken manually. These are essential since measurements are the foundation for apparel pattern development and creating the standardized sizing for ready-to-wear garments (Keiser & Garner, 2012).

The 3D garments acquired by 3D scanning is a true representation of how a garment appears on a real person wearing a real physical prototype. With the scans, it is very easy to see the drapability and fit of the garment.

Figure 1. 3-Dimensional body scan

Eye-Tracking
Eye tracking is used to measure the movement of the eyes. The purpose of measuring eye movement is to gain insight to the participant’s behavior (Duchowski, 2017). The movement of the eyes is closely connected with the participant’s visual attention; therefore, eye movement is an eminent indicator of the visual attention process (Wedel & Pieters, 2008). This is a powerful dimension in studying the participant’s perception of apparel fit. In order to study this movement, an eye tracking device is used. This eye tracking device focuses on the participant’s pupil. From there, the technology can determine the direction and concentration of the participant’s gaze. Eye fixation accounts for when the eye is visibly stable and suggests the participant is processing the given area more thoroughly (Wedel & Pieters, 2008). Measuring this perceived desirability of a design element will allow the opportunity to modify characteristics of the garment and allows for prediction of the garments future success before moving to the mass production (Rahulan, 2015). The data collected from eye-tracking devices are displayed through heatmaps (See Figure 2). Heatmaps represent where the participating gaze was concentrated and for how long. This is indicated by a color scale. Red regions indicate strong fixation, yellow regions indicate moderate fixation and blue/green regions indicate the least fixation. Regions without color represent areas that were unnoticed. Eye tracking is a well validated and established approach to study user experience through visual processing. Eye tracking helps to capture the visual scan path of a user for a given visual stimuli.
Methodology

Data Collection and Demographics

The data collection for this study involved two stages (1) 2D and 3D human subject image data generation and (2) fit evaluation via survey and eye-tracking. The 2D data was collected by taking images (front, back, and side) of subjects wearing professional garments. After collecting 2D images, each subject was scanned using the Vitus full-body scanner hosted in the human sciences lab. The scans were cleaned and a water-tight 3D model of the apparel representation was generated. In the second stage, visual representations of both 2D and 3D files (360 degrees) were shown to the participants and were asked to evaluate the fit perception of the shown images. The visual processing of the evaluation was captured by the eye-tracking tool, Tobii Pro. A total of 10 subjects evaluated the fit of apparel and also completed a survey containing questions related to shopping and fit evaluation.
For this study, two different sizes of women apparel – Missy and Plus size were tested. Six subjects (5 missy and 1 plus size) were recruited and asked to wear professional/formal shirts and pants that fall under any of the two fit conditions - loose fitting or tight fitting, and normal fitting. Though the original idea was to collect 12 cases (6 subjects X 2 fit conditions), due to the availability of the subjects/fit conditions, only 6 cases were chosen for fit evaluation. Out of the 6 cases, 2 cases represented each of the fit types, i.e., normal, loose and tight fit. All the 6 cases were displayed in both 2D and 3D format for the fit evaluators. The 10 subjects who performed the apparel fit evaluation were comprised of 2 apparel experts and 8 college students. The subjects who participated in the stage-1 image generation session were college students with ages ranging from 21 to 31 years, and apparel sizes ranging from XS to XL (as self-reported by the subjects). The age range of subjects that participated in the fit evaluation process was 21 to 56 years and all were white females. The entire data collection process was reviewed and approved by the IRB from the University of Arkansas.

**Data Analysis**

Descriptive statistics were performed for the survey data under three categories, (1) Consumer shopping behavior, (2) Fit Evaluation and (3) Preference of 2D and 3D. In the fit evaluation process, the eye-tracking data was collected, and the visual observation patterns were analyzed through the heat maps generated for the 2D and 3D display. The gazing and fixation of the images were shown as intensity heat maps and these heat maps were used to infer the region of focus on the apparel as gazed by the subjects during evaluation.
Results and Discussion

Consumer Shopping Behavior

The results of the online shopping behavior questions showed that 70% of the participants purchase clothing through online shopping and the remaining 30% do not purchase clothing online. The online apparel shopping website preferred by the participants are Revolve (3), Lululemon, Akira, Nordstrom (4), ASOS (2), Shopbop, Forever 21 (3), Zara, Topshop, J.Jill, Free People, Nasty Gal. Apparel fit is the primary concern of the participants. In the last year, 80% of participants have returned an apparel item due to misfit. To understand the common apparel misfit region experienced by shoppers, the participants were asked to select regions of concern when purchasing apparel. They were given the choices of bust, arms, sleeve length, waist, hip, thigh, and pant length and asked to select all that applied. The waist and pant length regions were selected by 60% of the participants. The hip and thigh regions were selected by 40% of the participants. The bust and sleeve length regions were selected by 30% of the participants, and the arm region was selected by 20% of the participants. Also, the level of apparel fit satisfaction was labeled ranging from highly dissatisfied to highly satisfied. The data revealed that 50% of participants were somewhat satisfied with apparel fit, 20% of participants were somewhat dissatisfied and neutral towards their satisfaction of apparel fit and 10% of participants were satisfied with apparel fit and no participants were highly dissatisfied with apparel fit.
Fit Evaluation:

After completing the shopping behavior survey, participants were asked to evaluate apparel fit of 6 cases presented in both the 2D and 3D. Since the primary objective is to find the difference in fit rating between 2D and 3D display, the absolute differences in the rating for all the 6 cases were calculated and percentage of change was computed based on the rating change. The difference between 2D and 3D fit ratings was 36.67% for the overall fit rating, 45% for the bust region apparel fit, 50% for the waist region and 45% for the hip region.

The eye-tracking results of the fit evaluation captured the visual inspection of the evaluators for each of the displayed image. Figure 3 shows a sample heat map of eye-tracking for the overall apparel fit of a single case. The heat map was generated for all the 6 cases, and visual analysis was performed for all the cases. Appendix A shows the heat map for all the 6 cases for overall fit.

*Figure 3. Overall apparel fit heat mapping*
The heat map shows colors ranging from green to red, where green was the area where fixation occurred minimally, and red shows the area where the amount of time focused or fixed was high. Based on the visual analysis, majority of the fit evaluators focused on the bust, underbust, waist and hip region while evaluating the overall fit. The areas of non-focus were sleeve length, shoulder, neck, pant length. However, the fit evaluations for individual bust, waist and hip regions showed high focus on the specific area of interest. For the evaluation of bust fit, bust regions of both front and side view showed high-intensity focus and for the waist fit, all the three views of the displayed images received focus from the evaluators. However, for the hip fit, foci were on the front and back view. Evaluators did not maintain intense focusing on the hip shape shown in the side view of the image.

For 3D samples, the heat map generated was a cumulative heat map of the 360-degree rotated view of the 3D scan (See Figure 4). The overall fit evaluation of 3D scans showed that foci were on the top region around the region of bust and waist. Similar to the 2D images, sleeve length was not a focus of importance in the 3D scans as well. However, focus was distributed throughout the entire scan, from head to toe.
Preference of 2D vs 3D

Following the apparel fit evaluation, participants answered survey questions related to their experience and preference of apparel display on the shopping website. Sixty percent of the participants preferred to have both 2D and 3D representation of the apparel displayed on shopping websites, 40% of the participants preferred only a 3D representation and none of the participants preferred only a 2D representation. Additionally, 70% reported that 3D representation was easy for evaluating the overall fit and 10% reported 2D was more preferable. In the fit evaluation process, wrinkle identification was easily observable in 3D (60%) while only 20% in 2D. 3D representations were the most preferred form for apparel fit evaluation in the
region of bust (60%) and waist (80%). However for the hip region, most of the participants preferred both 2D and 3D (60%)

Conclusion and Implications

Apparel fit is one of the primary concerns for online shoppers, especially for women apparel. The limitation of online shopping experience is that it prevents consumers from wearing the apparel to feel its fit and comfort. Almost always, the consumers estimate the apparel fit and appearance of the apparel on themselves by visually seeing the 2D images displayed on the website. However, the information obtained through 2D did not appear to help consumer estimate the fit of a garment. To improve the shopping experience of the consumers and to facilitate the retailers' marketing ability, this study analyzed the difference between the consumer fit evaluations between 2D and 3D display of apparel worn by live subjects. Results showed that 3D display of garment with 360 degrees rotation was highly preferred by the participants for apparel fit evaluation. Also, the eye-tracking data showed that the area that were visually perused by the participants was high on 3D display compared to the 2D images. Thus, 3D displays of apparel worn by models with 360 degrees rotation would facilitate the apparel fit estimation by consumers and potentially decrease the rate of return of the goods.

Limitations and Future Recommendation

Limitations of this study were limited participants and the choice of garment worn by the subjects during scanning was only professional shirts and pants. The participants in this study were females, and hence, the results may not be generalizable for other genders. Future studies
should involve different categories of apparel subjects from other genders. Additionally, different sized apparel should be included for evaluation.
References


Apeagyei, P.R. (n.d.) Application of 3D body scanning technology to human measurement for clothing Fit. England, UK


Keiser, S.J., & Garner, M. B. (2012). Beyond design the synergy of apparel product development


Appendix A

*Heat Maps of Images*

<table>
<thead>
<tr>
<th>Case</th>
<th>Overall Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Case 1" /></td>
<td><img src="image2.png" alt="Overall Fit 1" /></td>
</tr>
<tr>
<td><img src="image3.png" alt="Case 2" /></td>
<td><img src="image4.png" alt="Overall Fit 2" /></td>
</tr>
</tbody>
</table>
Appendix B

IRB Approval

To: Mahendran Balasubramanian  
    BELL 4188
From: Douglas James Adams, Chair  
      IRB Committee
Date: 03/06/2020
Action: Exemption Granted
Action Date: 03/06/2020
Protocol #: 2002248344
Study Title: Apparel Fit Evaluations of 3D Scans Via Eye-Tracking

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 100 MLK Building, 5-2208, or irb@uark.edu.

cc: Lauren E Bouvier, Investigator
Appendix C

Survey Questions

Part I

1. What is your current age? ________________

2. How would you describe yourself? Please select only one.
   a. American Indian or Alaskan native
   b. Asian
   c. Black or African American (not Hispanic)
   d. Hispanic or Latino
   e. Native Hawaiian or other Pacific Islander
   f. White (not Hispanic)
   g. Other/Combination

3. What size shirt do you typically purchase? Please select only one.
   a. X-Small
   b. Small
   c. Medium
   d. Large
   e. X-Large
   f. XX-Large

4. What size pants do you typically purchase? Please select only one.
   a. X-Small/0-2
   b. Small/4-6
   c. Medium/8-10
   d. Large/12-14
   e. X-Large/16-18
   f. XX-Large/20

5. What is your height? ________________

Part II

1. Do you buy clothes online?
   a. Yes
   b. No
1a. If yes, what is the name of the website(s).

___________________________________________________________________________
___________________________________________________________________________

2. Have you ever returned an apparel item due to misfit?
   g. Yes
   h. No

2a. If yes, approximately how many times in the last year from today?

   ______

3. What is your satisfaction levels of apparel fit?

<table>
<thead>
<tr>
<th>Highly Dissatisfied</th>
<th>Somewhat Dissatisfied</th>
<th>Neutral</th>
<th>Somewhat Satisfied</th>
<th>Satisfied</th>
</tr>
</thead>
</table>

4. What are you primarily concerned with in terms of clothing fit? (Select all that apply)
   a. Bust
   b. Arms
   c. Sleeve length
   d. Waist
   e. Hip
   f. Thigh
   g. Pant length

5. Do you prefer to have 2D or 3D representation of apparel on shopping websites?
   a. 2D
   b. 3D
   c. Both

6. In your opinion, which representation (2D or 3D) was easy to evaluate overall fit?
   a. 2D
   b. 3D
   c. Both

7. In your opinion, which representation (2D or 3D) was easy to observe wrinkles on clothing?
   a. 2D
   b. 3D
   c. Both
8. In your opinion, which representation (2D or 3D) was easy to observe fit on bust area?
   c. 2D
d. 3D
e. Both

9. In your opinion, which representation (2D or 3D) was easy to observe fit on waist area?
   a. 2D
   b. 3D
c. Both

10. In your opinion, which representation (2D or 3D) was easy to observe fit on hip area?
    a. 2D
    b. 3D
c. Both