



Evaluating garments in Augmented Reality when shopping online

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EVALUATING GARMENTS IN AUGMENTED REALITY WHEN SHOPPING ONLINE

1 Evaluating garments in Augmented Reality when shopping online**2 Introduction**

3 According to a recent report (Narvar, 2017), online shoppers returned apparel more than goods
4 from any category (43%); 70% of apparel is returned due to being the wrong size or color. In
5 online shopping environments, simulated reality enables consumers to “test drive” products
6 during the pre-purchase stage and decreases product returns (Edvardsson *et al.*, 2005). Especially
7 in fashion, such simulation systems provide companies substantial opportunities by
8 compensating for the lack of experiential shopping through enriching product information with
9 interactive visual cues (Fiore and Jin, 2003).

10 Image interactive technologies (IIT) are website features designed to simulate actual
11 product experiences by enabling online shoppers to (a) view products from different angles; (b)
12 change design features; and (c) see how apparel products look on their bodies/avatars to
13 understand garment fit and appearance (Fiore and Jin, 2003; Fiore *et al.*, 2005; Merle *et al.*,
14 2012). IIT creates a feeling of presence in online environments, fully immersing shoppers in the
15 environment and enabling interaction. Immersion in an online environment is an important
16 aspect that generates a psychological condition, which is necessary for experiencing presence
17 when there are only visual clues for making purchase decisions (Steuer, 1992; Witmer and
18 Singer, 1998).

19 For online apparel shopping, there are two distinct IIT approaches for virtually trying
20 garments. One approach requires customizing virtual avatars from an existing library of
21 parametric models to represent shoppers’ body measurements and shapes as closely as possible,
22 then trying digital garments on these avatars. Physical and mechanical properties of garments can
23 be modeled three-dimensionally (3D), allowing shoppers to view garments in transparent or

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24 tension modes and visually judge where the garment is tight or loose (triMirror, n.d). 3D
25 garments can be also generated from two-dimensional (2D) photographs for virtual try-on and
26 size recommendations (Metail, n.d.). However, such environments with both virtual garments
27 and virtual bodies can create artificial settings and make it difficult for consumers to make real-
28 world connections to the product (Azuma, 1997). As Li *et al.* (2001) indicated, presenting
29 products in their environmental context is important. Consumers prefer to see products within
30 their intended context, such as “the ring displayed on a hand or the laptop computer presented in
31 an office setting” (Li *et al.*, 2001, p. 28). Therefore, using Augmented Reality (AR) for virtual
32 try-on is another approach gaining popularity when shopping online, as consumers can see
33 garments or accessories on their bodies without spending time customizing avatars.

34 AR technology integrates computer-generated sensory information with a physical
35 environment in real-time. Pine and Korn (2011) described AR as using digital information “to
36 enhance, extend, edit, or amend the way we experience the real world” (p. 36). AR systems
37 appear 3D and can apply to all senses (Azuma, 1997). In order to operate an AR application,
38 users must have access to a display device with a video camera (e.g., smartphones, tablets,
39 computers, or mirror-looking screens). On this display device, users can see their environment
40 while computer-generated images of products are placed on top of the view in real-time
41 (Carmigniani *et al.*, 2011). From this perspective, AR can provide shoppers with an experience
42 that resembles physical interaction (Verhagen *et al.*, 2014) and can potentially compensate for
43 the lack of experiential information in online settings (Kang, 2014; Lee, 2012), thus bridging the
44 gap between online and offline shopping (Huang *et al.*, 2011; Lu and Smith, 2007).

45 Previously, researchers focused on the development, usability, and user acceptance of the
46 AR technology (Chang *et al.*, 2013; Huang *et al.*, 2011; Kang, 2014; Lu and Smith, 2007; Rese

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2
3 47 *et al.*, 2017), AR's experiential value at the pre-purchase stage (Bulearca and Tamarjan, 2010;
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5 48 Huang and Liu, 2014; Kang, 2014), and AR's impact on purchase intentions (Beck and Crié,
6
7 49 2018; Huang and Liu, 2014; Rese *et al.*, 2017). However, no researcher, to our knowledge, has
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9
10 50 specifically developed a study to compare consumers' perceptions of using AR for evaluating
11
12 51 garment sizes, fit, and product attributes when shopping online with their responses towards the
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14 52 physical garments once they were "ordered and received." Therefore, the purpose of the present
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16 53 study was to examine consumers' perceptions of a garment's size, fit, product performance,
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18 54 attitudes towards the product, and purchase intentions when using AR virtual try-on in an online
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20 55 shopping context as compared to when physically trying on the real garment. The focus of the
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22 56 present research was women. Specifically, we aimed to understand whether AR virtual try-on
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24 57 could provide a comparable representation of physically trying on a garment in terms of fit, size
25
26 58 and product performance, and if there would be a difference between AR virtual try-on and
27
28 59 physical try-on regarding their impact on attitudes towards the apparel product and purchase
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33 60 intentions.

61 **Literature Review**

62 *A brief overview of AR apparel applications in online environments*

63 In AR environments, apparel applications range from overlaying 2D static front images
64 of garments on the real-time static image of the viewer's body (e.g., Webcam Social Shopper by
65 Zugara) to 3D, which is simultaneous rendering or dynamic fitting of the garment around the
66 viewer's body to simulate garment drape as the viewer moves (e.g., Magic Mirror). In both cases,
67 AR imagery allows viewers to see immediately how clothes would look on them (Batista, 2013;
68 Huang and Liu, 2014; Pachoulakis and Kapetanaki, 2012). The experience with an AR garment
69 is very similar to holding a garment up to oneself in front of a mirror (Schwartz, 2011). AR

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3 70 applications in the apparel industry are usually developed for websites and mobile devices so that
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6 71 customers can virtually try on clothing and accessories (Carmigniani *et al.*, 2011; Pachoulakis
7
8 72 and Kapetanaki, 2012). Zugará, FittingBox, MemoryMirror, and Magic Mirror are some of the
9
10 73 developers that provide AR applications to fashion brands. In 2017, Gap collaborated with San
11
12 74 Francisco-based start-up Avametric and launched a digital dressing room with AR, where
13
14 75 shoppers can create their avatars and try garments on (Avametric, n.d.). In 2018, Amazon
15
16 76 patented a magic mirror that uses AR to superimpose garment images to users' reflections in the
17
18 77 mirror in real-time, which can help with an AR-enabled shopping experience on Amazon.com
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20 78 (Boyle, 2018).

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23
24 79 Although only a few apparel retailers have experimented with AR in their online stores,
25
26 80 more should consider using the potential of AR technologies to support consumers' online
27
28 81 shopping (Pantano *et al.*, 2017). Benefits of using AR include (a) providing shoppers with digital
29
30 82 help and increased likelihood of exploring more garments, (b) suggesting clothing based on user
31
32 83 preferences or fashion trends, (c) reducing the number of returned items, and (d) low technology
33
34 84 barriers (Chittrakorn, 2018). Challenges of using AR in online shopping are related to whether
35
36 85 these tools can assist shoppers with understanding product performance when making purchase
37
38 86 decisions (Pantano *et al.*, 2017).

87 *Conceptual framework*

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89 To explore how consumer perception of apparel products and behavioral intentions
90
91 would be impacted by AR in online apparel shopping, the Stimulus–Organism–Response (S–O–
92
93 R) model (Mehrabian and Russell, 1974) was selected. The model proposes that environmental
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95 stimuli are associated with behavioral responses, and that environmental stimuli (S) affect
96
97 organisms (O). Response (R) is the result of the internal (cognitive or emotional) process of the

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93 organism in the form of approach or avoidance behaviors (Eroglu et al., 2003; Fiore and Kim,
94 2007; Mehrabian and Russell, 1974; Prashar, Sai, and Parsad, 2017; Watson, Alexander, and
95 Salavati, 2018). The S-O-R was applied by numerous researchers to understand the influence of
96 new retail technologies on consumers' affective and behavioral responses when shopping online
97 (Eroglu et al., 2001; Fiore and Kim, 2007; Prashar et al., 2017; Watson, et al., 2018; Wu et al.,
98 2013) and is considered as a robust model (Watson et al., 2018). Past studies found that AR
99 creates rich sensory experiences and influences mental imagery, resulting in positive emotional
100 and behavioral responses (Park and Yoo, 2020; Watson et al., 2018). In the present study, the S-
101 O-R model was used as a foundation to examine hypotheses. The hypotheses were developed
102 based on the elements in the model: stimuli (i.e., AR and physical try-on), organism (i.e.,
103 telepresence as an internal state) and responses to the stimuli (i.e., attitudes towards the product
104 and purchase intentions)

Understanding Stimulus: Perception of apparel products in online AR environments

106 There are only a few studies investigated how garments and fashion accessories would
107 be perceived in online AR environments. In a study conducted by Chang *et al.* (2013), a real-
108 time 3D dynamic fitting room was developed by using AR and Microsoft Kinect, through which
109 sensors were used to automatically measure participants' sizes. Findings showed that sizes based
110 on the Kinect measurements were close to participants' claimed sizes, indicating the potential of
111 using AR for online apparel shopping. Verhagen *et al.* (2014) examined the differences among
112 three different eyeglass presentation formats (picture, 360-spin application, and AR try-on) on
113 the Ray-Ban website. They found that AR can make users feel significantly more "locally
114 present" as compared to seeing pictures or 360-spin formats of the products, suggesting that
115 retailers who sell products that consumers need to try on before buying can use AR technologies.

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3 116 Online shoppers tend to perceive that products they see on a website may not look, feel,
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5 117 or fit the same as the products they find in a brick-and-mortar store (Yu *et al.*, 2012). For apparel
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7 118 products, these perceptions manifest themselves as risks related to product performance based on
8
9 119 three main attributes: visual, tactile, and trial (Yu *et al.*, 2012). Therefore, it is important to
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11 120 measure whether apparel products received after using an AR application for online shopping are
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13 121 close to shoppers' expectations. Suh and Chang (2006) argued that online shopping
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15 122 environments lead to a discrepancy between online products (pre-purchase) and physical
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17 123 products (post-purchase) as consumers can not touch or try-on the online products. According to
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19 124 the authors, this would result in either finding physical products more satisfactory (i.e., positive
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21 125 disconfirmation), or the opposite (i.e., negative disconfirmation).

26 126 Previous AR studies examined size selections (Chang *et al.*, 2013), technology
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28 127 acceptance (Pantano *et al.*, 2017), telepresence (Verhagen *et al.*, 2014), interactivity and
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30 128 vividness (Yim *et al.*, 2017), and perceived tactile sensations (Overmars and Poels, 2015) in
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32 129 various AR settings. However, none of these studies specifically addressed if and how shoppers
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34 130 fit into the sizes selected by using an AR application, and if AR products' expected performance
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36 131 matches actual products' performance once the online order is received. Therefore, the present
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38 132 study's results would be beneficial for the researchers when examining AR in online shopping,
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40 133 and help retailers increase benefits and overcome challenges by providing them with
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42 134 experimental data. In light of these needs, the following hypothesis was examined:

47 135 H1: AR virtual try-on will provide a comparable representation of physical try-on in
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49 136 terms of (a) finding the right size, (b) evaluating fit, and (c) evaluating product performance.

51 137 *Organism: Telepresence*

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138 Research on IIT-supported environments shows that shoppers can see digital product
139 attributes through a variety of rich visual cues, using their gestures to control the environment
140 (Huang and Lui, 2014; Merle *et al.*, 2012). Because of this increased interaction, products are
141 experienced in “the mind’s eye,” which can potentially provide accurate sensory information
142 (e.g., touch, taste, and smell) based on real-world experiences with similar products (Schlosser,
143 2003). Telepresence is defined as a consumer’s sense of being present in a virtual environment,
144 such as an online store, where consumers could browse and shop as they would in a brick-and-
145 mortar location (Mollen and Wilson, 2010; Shih, 1998). Lim and Ayyagari (2018) described it as
146 “the perception of direct product experience simulated through a medium” (p.361). Telepresence
147 provides a good basis to understand consumers’ immersion and information processing in the
148 online AR context, as literature has found that telepresence is crucial for consumer immersion in
149 virtual environments (Steuer, 1992). Sense of telepresence is created by the quality and quantity
150 of simulated sensory information in the virtual space (Fiore *et al.*, 2005), particularly the
151 perceived interactivity and virtuality, both characteristics that set AR apart from more traditional
152 forms of online shopping (Javornik, 2016). Coming into contact with digital products in AR can
153 enrich product experiences. Additionally, consumers perceive AR products as tangible and
154 attractive (Verhagen *et al.*, 2014).

155 Response: Attitudes towards apparel products and purchase intentions

156 AR online shopping experiences can result in positive attitudes toward products and
157 increased purchase intentions (Verhagen *et al.*, 2014). Yim *et al.* (2017) found that AR-based
158 product presentations were superior to conventional web-based product presentations since they
159 offer higher immersion, media novelty, and media enjoyment, and increase attitude toward
160 medium and purchase intention. If a website utilizes AR, consumers become more curious about

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1
2
3 161 the products, tend to patronize the website, and eventually purchase the products (Beck and Crié,
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5 162 2018). Beck and Crié (2018) validated their findings by conducting tests with two products
6
7 163 (garments and eyeglasses) with both student and consumer samples. However, their study was an
8
9 164 online study and not set in a laboratory environment where participants could use the same
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11 165 system and try-on the physical garment and accessory. To our knowledge, no studies empirically
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13 166 compared consumers' attitudes towards the product and purchase intentions between AR and
14
15 167 real-world conditions. Therefore, we proposed the following hypothesis:
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19 168 H2: AR virtual try-on will have a comparable effect to physical try-on in terms of users'
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21 169 (a) attitudes towards the apparel product and (b) purchase intentions.
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23

24 170 A recent study by Kim *et al.* (2017) found that the use of AR is positively related to
25
26 171 enhanced telepresence, which in turn contributes to attitude toward the technology, and purchase
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28 172 intention of products. In the study, researchers suggested that in comparison to virtual reality
29
30 173 (VR)-based presentations (i.e., wearing sunglasses on a 3D virtual model), AR-based
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32 174 presentations (i.e., using a webcam to see themselves wearing sunglasses) were more likely to
33
34 175 stimulate presence, thus leading to stronger purchase intentions. Other researchers also supported
35
36 176 that telepresence increases attitudes towards products (Debbabi *et al.*, 2013) and purchase
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38 177 intentions (Song *et al.*, 2007; Watson *et al.*, 2018). When comparing a VR interface to 2D photos
39
40 178 and a video interface, Suh and Chang (2006) found that higher levels of telepresence (i.e.,
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42 179 manipulated as VR in their study) increased positive attitudes toward the product, which was a
43
44 180 computer desk. However, they did not find any direct association of purchase intentions with
45
46 181 telepresence. Similar to previous studies which examined a variety of products from accessories
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48 182 to make-up in both VR and AR settings (Park and Yoo, 2020; Yim *et al.*, 2017; Watson *et al.*,
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50 183 2018), telepresence in AR apparel virtual try-on may increase attitudes and purchase intentions
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184 toward the product. Thus, to understand the impact of telepresence on attitudes towards the
185 apparel product and purchase intentions, we proposed the hypothesis presented below:

186 H3: When using AR virtual try-on, individuals who have a higher telepresence will have
187 greater (a) attitudes towards the apparel product and (b) purchase intentions than those who have
188 a lower telepresence.

189 Methods

190 Data were collected with a one-factor (i.e., garment) within-subject quasi-experimental
191 study using repeated measures in two conditions: virtually trying-on condition using the AR
192 technology vs. physically trying-on condition. Within-subject design was selected because it
193 allowed researchers to remove subject-to-subject variation from the analysis of the relative
194 effects of different treatments (Seltman, 2015). It is important to “consider the context” when
195 deciding whether a between or within subject design should be selected (Charness, Gneezy and
196 Kuhn, 2012, p.2). Therefore, to be able to create conditions similar to the real-world, and not
197 conflict with the practice of online shopping (i.e., evaluating a garment on a website first and
198 ordering it for physical try-on), we let the participants try on the same dress in AR first and did
199 not reverse the order.

200 In this study, variance in participants’ body shapes and sizes is controlled with the within-
201 subject research design. Each participant was asked to try on the virtual dress using the AR
202 technology (Treatment 1); rate the perceived product performance, fit and size, attitudes and
203 purchase intentions towards the dress; and then physically try on the same dress (Treatment 2) in
204 a dressing room in the research lab after “ordering it online and receiving it via mail.” In a
205 similar vein, after viewing the product (a computer table) in an online store by using three
206 different viewing formats, Suh and Chang’s (2006) instructed their study participants to go to a

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207 separate room to view the physical product and compare it to the online product. After Treatment
208 2 in our study, participants answered the same set of questions that they did after Treatment 1.
209 The two treatments in this study design were fundamentally different, as Treatment 1 required
210 participants to evaluate the garment solely based on the visual images presented by the AR
211 technology, whereas Treatment 2 allowed participants to evaluate the garment by seeing,
212 touching, and wearing it. More details of the experiment procedure are discussed in the following
213 sections.

Participants

215 Female college students age 18 and above were targeted as participants as they use the
216 Internet for apparel shopping, are technology-savvy, and adopt new product visualization
217 technologies easily (Yu *et al.*, 2012). Compared to men, women examine garments in more detail
218 and tend to have more difficulty in selecting clothing items for themselves when shopping online
219 (Hansen and Jensen, 2008). After receiving approval from the Institutional Review Board (IRB),
220 undergraduate and graduate female participants were recruited via a large Midwestern
221 university's mass-emailing service. A total of 87 participants from a variety of majors voluntarily
222 participated in the study. Participants' mean age was 25.6 years old (SD = 6.08). The majority of
223 the participants were European-American (n = 65, 74.7%), followed by Asian/Asian-American
224 (n = 9, 10.3%), other (n = 6, 6.9%), Latino/Hispanic (n = 4, 4.6%), and African-American (n = 3,
225 3.4%). Most participants (89.7%) indicated that they had bought apparel online. To increase
226 participation, each participant was offered a \$5 gift card as incentive.

Stimulus

228 In this study, a dress was used to develop the treatments. For Treatment 1, the dress
229 image was used in the AR technology for virtual try-on; for Treatment 2, the real dress was used

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230 for physical try-on. Based on their pilot study finding using a convenience sample of 52 female
231 undergraduate students, Kim and Damhorst (2010) suggested dresses as the most frequently
232 purchased garment type among students. Huang and Liu (2014) also found that dresses were
233 among the top-three garments to be tried-on in AR; women spent the longest time on dresses
234 when using AR for virtual try-ons. Considering computer monitor limitations, full-length dresses
235 and pants are usually not easily seen with an online AR application. Also, full-length sleeves add
236 an extra variable to control the believability of the AR simulation.

237 In order to select the stimulus, six dress images of various knee-length, short-
238 sleeved/sleeveless dress styles were evaluated by five women in a pre-test. The pre-test
239 examined the garment style's attractiveness, fashionability, and likeability, using a 7-point
240 Likert-type scale adapted from Park (2009). The average ratings of the six dresses were as
241 follows: 4.47 (short-sleeved fitted dress), 3.53 (sleeveless fitted dress), 5.33 (short-sleeved
242 shift/A-line dress), 3.60 (sleeveless shift/A-line dress), 5.20 (sleeveless fit-and-flare dress), and
243 4.13 (short-sleeved fit-and-flare dress). Following suggestions from Kim and Lennon (2008) and
244 Park (2009), the short-sleeved fit-and-flare dress with a neutral rating was chosen to limit the
245 garment style's potential effect on the variables. The dress was purchased from a mass-retailer in
246 sizes from XS (0-2) to XL (16-18). To eliminate the confounding effect of brand name, brand
247 labels were removed from the dresses.

248 To create the dress image for Treatment 1, a photo of the dress in size medium was taken
249 on an appropriate dress form. The dress form and background components were then erased in
250 Adobe Photoshop. The final image was uploaded in PNG format to the AR developer's (Zugara)
251 server (Figure 1). In the online AR application, the computer's webcam captured participants'
252 body images, and the front-view of the stimulus was displayed on their body in 2D. Participants

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253 were able to adjust the size and placement of the AR dress by moving their hands in the air and
254 “clicking” the control buttons shown on the screen without needing a mouse or a keyboard. This
255 way, the computer screen became an interactive mirror without necessitating a high-tech kiosk
256 (Figure 1).

257 Insert Figure 1 here

258 Since Treatment 2 was the real dress for physical try-on and should remain exactly the
259 same as the Treatment 1 dress to avoid any variations other than the AR versus physical try-on
260 conditions, the researchers intentionally made no adjustment to the dress. The researchers
261 nonetheless made sure that all sizes of the dress were available in the lab for Treatment 2.

262 *Experimental procedures*

263 Participants were invited to our research laboratory and received instructions about the
264 task and the procedures. Informed consent forms were filled out at the beginning. Participants
265 were instructed to use an iMac on which the AR application website specifically developed for
266 this study was available. To virtually try on the AR dress (Treatment 1), participants stood 4-5
267 steps in front of the computer screen with a built-in video camera, so they could see their bodies
268 at least from head to calf. After the virtual try-on experience, participants were asked to complete
269 an online questionnaire on a separate laptop. The questionnaire measured fit and size perceptions
270 of the dress, product performance perceptions, **telepresence**, attitudes towards the dress, and
271 purchase intentions. The respondents also indicated the size of the dress that would fit them.
272 Next, participants physically tried on the real dress in the sizes they indicated previously
273 (Treatment 2), then answered a second online questionnaire regarding the real dress with the
274 same measurement instruments, **except telepresence**, as the previous questionnaire. We
275 implemented “time-off” in two ways to minimize potential confounding effects of the within-

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3 276 subjects design: (1) after the first questionnaire, participants went to the changing room to try on
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5 277 the real dress and (2) we added three open-ended questions about participant reflections on AR
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7 278 (not included to the present study) between the questionnaires to make it hard to remember
8
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10 279 repeated questions between Treatment 1 and Treatment 2.

280 *Survey instruments and data analysis procedures*

14 281 Items used to assess dress fit involving thirteen areas (e.g., neck, bust, waist) except
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16 282 buttocks were adapted from the fit scales developed by Song and Ashdown (2012) using a 5-
17
18 283 point scale that was anchored at *too loose/long/wide* (1), *excellent fit* (3), and *too*
19
20 284 *tight/short/narrow* (5). Product performance in regards to both treatments was measured with the
21
22 285 product performance risk scale adapted from Yu *et al.* (2012) using a 7-point Likert-type scale,
23
24 286 which was anchored at *not sure at all* (1) and *very sure* (7). A question, “*How sure are you about*
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26 287 *the apparel product’s attributes to perform satisfactorily to your needs?*”, was asked to measure
27
28 288 three dimensions (visual, tactile, and trial) at ten sub-dimensions (visual: style, fabric, color,
29
30 289 details, coordination with other items; tactile: touch and feel, weight of garment; and trial: fit,
31
32 290 comfort, and appearance on body) (Yu *et al.*, 2012). Telepresence was measured using the scale
33
34 291 adapted from Song *et al.*’s (2007) five-item, 7-point Likert-type scale, which was anchored at
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36 292 *strongly disagree* (1) and *strongly agree* (7). The items asked if the application “...lets me easily
37
38 293 *visualize what the real dress is like,*” “...gives me as much sensory information about the dresses
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40 294 *as I would experience in a store,*” “...creates a product experience similar to the one I would
41
42 295 *have when shopping in a store,*” “...allows me to interact with the dresses as I would in the
43
44 296 *store,*” and “...provides accurate sensory information about the dresses.”

51 297 Attitudes toward the AR and real dresses were evaluated using six items with a 7-point
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53 298 Likert-type scale from Holbrook and Batra (1987) and Bruner (1998) for the following question:
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299 “Please tell us about your overall thoughts and feelings about the dress: The dress is...” The
300 items were anchored at very dislikable (1)/very likeable (7), very unattractive (1)/very attractive
301 (7), very bad (1)/very good (7), very unfavorable (1)/very favorable (7), very unpleasant (1)/very
302 pleasant (7), very unappealing (1)/very appealing (7). Purchase intention was measured by a
303 scale originated from MacKenzie *et al.* (1986) and used by Yu *et al.* (2012): very improbable
304 (1)/very probable (7); very unlikely (1)/very likely (7); and very impossible (1)/very possible (7).
305 The instrument was pilot tested with five students. Some phrases in the instructions and the
306 questionnaire were further edited for clarity. Cronbach’s *alphas* of all scales were greater than
307 0.8. Table 1 shows the constructs, their items, and the reliability scores. To examine hypotheses,
308 paired-sample t-tests and multivariate analysis of variance (MANOVA) were conducted in SPSS
309 26.

310 Insert Table 1 about here

311 Results

312 Results for H1

313 *Finding the right size.* No statistical difference was found between the virtually tried-on AR
314 dress sizes ($M = 2.69$; $SD = 1.16$) and physically tried-on dress sizes ($M = 2.65$; $SD = 1.23$)
315 ($t(86) = -1.75$; $p = .41$). Therefore Hypothesis 1a was supported. Table 2 shows the distribution
316 of best-fitting dress sizes for AR (Treatment 1) and real (Treatment 2) dresses.

317 Insert Table 2 about here

318 *Evaluating Fit.* Before analyzing the overall fit of the dress using the product performance
319 construct, fit was evaluated in more detail by looking at thirteen locations on both AR and real
320 dresses. In general, all areas evaluated were perceived to be close to 3 (excellent fit). As shown
321 in Table 3, there were no significant differences in fit at four areas (neck, shoulder width, sleeve

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opening, and volume/fullness in skirt) between AR and real dresses. However, results showed significant differences between these two conditions in nine areas out of thirteen. Participants perceived looser fit around bust ($\Delta M = .28$, $SD = 1.00$, $t(84) = 2.58$, $p < .05$) and wider shoulder ($\Delta M = .22$, $SD = .93$, $t(86) = 2.18$, $p < .05$) when virtually trying on the AR dress. However, areas such as waist ($\Delta M = -.39$, $SD = .97$, $t(86) = -3.76$, $p < .001$), abdomen ($\Delta M = -.26$, $SD = .88$, $t(83) = -2.37$, $p < .01$), and hip ($\Delta M = -.43$, $SD = .83$, $t(85) = -4.79$, $p < .001$) were perceived tighter when using AR. When using AR, lengths were perceived to be longer at the following areas: sleeve ($\Delta M = .29$, $SD = .85$, $t(85) = 3.16$, $p < .01$), torso ($\Delta M = .26$, $SD = .92$, $t(86) = 2.68$, $p < .01$), skirt ($\Delta M = .37$, $SD = .94$, $t(86) = -3.64$, $p < .001$), and overall dress length ($\Delta M = .42$, $SD = .76$, $t(84) = 5.13$, $p < .001$). Therefore Hypothesis 1b was partially supported.

Insert Table 3 about here

Evaluating product performance. Out of ten attributes that investigated participants' perceived AR dress performance and real dress performance, nine items were found to be significantly different. Average ratings for the attributes related to tactile properties (i.e., touch and feel: $M = 2.55$, weight: $M = 2.81$) were lower than neutral (4) for the AR dress (see Table 1). When wearing the real dress, participants thought that nine dress attributes performed significantly better than when using AR: style ($\Delta M = .60$; $SD = 1.69$; $t(86) = 3.30$; $p < .01$), fabric ($\Delta M = 2.01$; $SD = 2.15$; $t(85) = 8.68$; $p < .001$), coordination with other items ($\Delta M = .48$; $SD = 1.45$; $t(85) = 3.04$; $p < .001$), details ($\Delta M = .96$; $SD = 1.64$; $t(86) = 5.50$; $p < .001$), touch and feel ($\Delta M = 3.34$; $SD = 2.17$; $t(86) = 14.32$; $p < .001$), weight ($\Delta M = 3.21$; $SD = 2.05$; $t(84) = 14.42$; $p < .001$), fit ($\Delta M = 1.16$; $SD = 1.85$; $t(85) = 5.82$; $p < .001$), comfort ($\Delta M = 2.53$; $SD = 2.17$; $t(84) = 10.75$; $p < .001$), and appearance on the body ($\Delta M = .46$; $SD = 2.09$; $t(85) = 2.06$; $p < .05$). Color (ΔM

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344 =.41; SD = 1.93; $t(85) = 1.12$; $p > .05$) was not significantly different between the two conditions
345 (Table 4). Therefore Hypothesis 1c was partially supported.

346 Insert Table 4 about here

347 Results for H2

348 A paired-sample t-test was conducted to test Hypotheses 2a (H2a) and 2b (H2b).

349 Attitudes towards both AR and real dress were favorable and above 5. Purchase intentions were
350 moderately positive in both conditions as well (Table 1). Participants had significantly more
351 favorable attitudes towards the real dress (M = 5.60, SD = 1.14) than the AR dress (M = 5.25,
352 SD = 1.00) ($\Delta M = .35$, SD = 1.15, $t(85) = 2.62$, $p < .05$). Participants indicated greater purchase
353 intentions during physical try-on (M = 4.74, SD = 1.71) as compared to AR try-on (M = 4.27, SD
354 = 1.70) ($\Delta M = .47$, SD = 1.94, $t(85) = 2.32$, $p < .05$). Thus, H2a and H2b were not supported.

355 Results for H3

356 In order to examine Hypothesis 3, participants were split into two groups based on the
357 mean value of telepresence (M=3.70). Participants who indicated telepresence 3.70 and higher
358 on average were assigned to the high telepresence group (n=39), whereas participants who had
359 telepresence level lower than 3.70 were placed in the low telepresence group (n=48). Results of
360 MANOVA showed that the high telepresence group tended to have more positive attitudes (M
361 $M_{\text{Low Telepresence}} = 5.04$ (SD = .14), $M_{\text{High Telepresence}} = 5.50$ (SD = .16)) and greater purchase intentions
362 to the apparel product when using AR ($M_{\text{Low Telepresence}} = 3.88$ (SD = .24), $M_{\text{High Telepresence}} = 4.77$
363 (SD = .27)) than the low telepresence group [$F_{(1, 83)} = 3.15$; $p < .05$, partial $\eta^2 = .071$]. Thus,
364 Hypothesis 3a and 3b were supported.

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Discussion

In this present study, we investigated if AR can help online apparel shoppers order the right size, obtain clues about fit and product performance by judging visual clues, and determine if virtually trying on an AR garment is the same as physically trying it on in regard to attitudes towards the garment and purchase intentions. Additionally, we examined how high and low telepresence levels of the participants in the AR condition impact their attitudes and purchase intentions. Understanding how online AR technologies affect consumers' perceptions of garments can help brands develop new ways to reduce consumers' regret caused by post-purchase expectation disconfirmation. In our study, the majority of the participants were able to select their sizes correctly and did not need to try on a different size once they "received" the garment "via mail" after "ordering it online." Narvar's (2017) survey shows that online apparel shoppers make bracket purchases, which means buying multiple versions of an item (size-, color- and style-wise) to see which they prefer, with the intention of returning the rest. In this regard, using AR would be very beneficial for retailers to implement as it gives shoppers more confidence in the sizes they want to try at home and reduces bracket purchases that increase re-shelving and shipping costs. Implications also include using this technology in a physical store environment to help shoppers quickly sort through styles to find what they like.

In regard to perceiving fit, our study found that participants were able to approximate how garment parts would fit (loose, tight, or right) when using an AR application. Therefore, our results imply that AR virtual try-on can give shoppers visual clues on the garment fit. However, the type of AR technology (3D overlay vs. 2D overlay), interactivity speed, and quality of the AR images impacts the level of visual information (realistic vs. graphic) that shoppers receive (Yim *et al.*, 2017). In our study, when compared to the real dress, fit of the AR dress was

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3 388 perceived to be significantly looser at the bust and tighter at the waist, abdomen, and hip. The
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5 389 discrepancies found around the waist, abdomen, and hip are considered plausible because the AR
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7 390 dress was a superimposed, static 2D image on the body, not stretching at these areas. Our finding
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9 391 on the fit perception at bust was unexpected. This result may have arisen from a possible
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11 392 difference between the bust measurements of the dress form, which was used to create the AR
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13 393 dress stimuli, and study participants. Moreover, lengths of sleeve, torso, skirt, and overall dress
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15 394 were perceived to be significantly longer in AR. Holding a garment up to oneself and assessing
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17 395 its length may be different than wearing it. After wearing the garment, the third dimension
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19 396 (depth) adjusts the garment length on the body and the garment becomes shorter than its flat
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21 397 form against the body.
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26 398 Although in our study only one type of stimulus (dress) was used, the findings may
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28 399 inform improvement of AR applications to help consumers evaluate fit. For example, garment
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30 400 pictures may be improved by taking several pictures of the same product depending on different
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32 401 body types or sizes (petite, regular, tall, and plus) to reduce the discrepancy. The images can be
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34 402 adapted to each user's body shape, to the extent that the materials' elasticity allows. While
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36 403 retailers do not have much control over how AR technology improves, the findings can help
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38 404 inform consumers of possible discrepancies, allowing for more accurate decisions regarding fit.
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42 405 Almost all of the product-performance-related items, except color, were perceived
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44 406 significantly different in two conditions. Attributes such as style, fabric, coordination with other
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46 407 items, details, touch and feel, weight, overall fit, comfort, and appearance on body were
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48 408 perceived to perform better for the real dress. The average ratings for tactile attributes (e.g.,
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50 409 touch and feel, comfort, and weight) were closer to the unsatisfactory side of the scale when
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52 410 using AR. In AR, users cannot account for tactile attributes such as touch and feel, comfort and
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3 411 weight. Nonetheless, results related to specific visual characteristics (i.e., style, detail, and
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5 412 coordination with other items), were above the neutral level when using AR, showing that AR
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7 413 visuals were satisfactory to help participants understand these attributes when shopping online.
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10 414 The findings showed that physical try-on condition affected consumers to have higher
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12 415 attitudes and purchase intentions compared to AR try-on condition. An explanation could be that
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14 416 consumers still prefer and make decisions based on the actual tactile experience they gained from
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16 417 physical try-on. However, it does not mean that AR is useless to consumers. As the findings
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18 418 from H1 indicated, AR does provide good visual information that can increase consumers'
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20 419 attitudes and purchase intentions. Furthermore, participants with higher telepresence level were
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22 420 found to have more positive attitudes towards the dress and greater purchase intentions when
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24 421 using AR as compared to the participants with low telepresence level. This finding adds to the
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26 422 existing literature (Debbabi et al. 2013; Kim et al, 2017; Suh and Chang, 2006) of how varying
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28 423 levels of telepresence affect attitudes towards the product and purchase intentions from the
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30 424 apparel field's point-of-view.
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425 **Conclusion**

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37 426 In the present study, the S-O-R model was used as a theoretical framework to investigate
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39 427 how AR products, most specifically a dress, and AR try-on would be perceived by consumers in
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41 428 comparison to physical interaction with the dress. For this purpose, we used an online shopping
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43 429 scenario that allowed our participants to experience the AR product, "order it" to see the physical
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45 430 dress, and decide if they want to keep it after physical try-on (i.e., purchase intention of the real
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47 431 dress). In addition to contributing to the academic field of AR product presentation in online
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49 432 shopping, our findings offer several implications for research and society/practice. Theoretical
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51 433 contributions of this research imply that although physical try-on plays an important role in
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3 434 apparel purchase decisions, AR stimulus can provide information that helps consumers make
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5 435 accurate decisions particularly regarding apparel sizes and visual characteristics when shopping
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7 436 online. Therefore AR can supplement, rather than replace, the physical try-on experience.
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10 437 Attitudes towards the dress and intentions to purchase the dress when using the AR technology
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12 438 were above the mid-point, and close to the attitudes and intentions measured in the physical try-
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14 439 on condition. Additionally, participants with higher telepresence levels were likely to have
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16 440 higher attitudes and purchase intentions as compared to the participants with low telepresence.
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18 441 These findings suggest that AR can be instrumental in introducing a certain style, building
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20 442 positive attitudes towards products, and driving sales when the consumers perceive a certain
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22 443 level of telepresence.
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26 444 Although adopting AR to provide more information about the product on an e-commerce
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28 445 environment would be an expensive investment (Plotkina and Saurel, 2019), our findings imply
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30 446 that retailers can benefit from using AR technology to increase consumer interest in their
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32 447 products. Retailers need to understand the potentials of AR technologies and work with
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34 448 technology developers to push the limits to enhance shopper experiences. As suggested by
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36 449 Pantano *et al.* (2017), fashion retailers who want to implement AR systems should be aware of
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38 450 the recent progresses as well as drawbacks in technology, taking part in the innovation process
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40 451 rather than passively adopting the offered technology. AR technology is an untapped area in
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42 452 apparel, and its potential in conveying reliable information when shopping online needs to be
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44 453 examined more closely.
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49 454 Some limitations of the present study must be addressed. First, the use of a student
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51 455 population reduces the generalizability of the study findings. Additionally, the vast majority of
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53 456 these women were in the XS-M category with very few women in the larger sizes. The product
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3 457 chosen for this experiment is another limitation. As Kim and Lennon (2008) indicated, when a
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5 458 single stimulus is used, the results cannot be generalized to other stimuli. Different garment types
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7 459 in varying silhouettes and fit must be considered for further study. Future studies should apply
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9 460 our methodology to other product categories and compare the results. Technology accounts for a
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11 461 third limitation. The AR garments were 2D and did not wrap around the body. Lu and Smith
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13 462 (2007) mentioned that AR system rendering should be improved to merge digital and real
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15 463 environments in a realistic way. This would improve vividness, i.e., “the ability of a technology
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17 464 to produce a sensorially rich mediated environment” (Steuer 1992, p. 80). As Suh and Chang
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19 465 (2006) suggested, focus should be on improving IIT interfaces to generate higher telepresence
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21 466 levels, so that consumers’ perceptions of products in online stores can be improved. Plotkina and
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23 467 Saurel (2019) argue that AR-based tools for trying on garments virtually are not “sufficiently
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25 468 technologically advanced” yet. Their study compared a mobile application with AR try-on to a
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27 469 mobile commerce interface that presented fashion models similar to the consumers. Plotkina and
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29 470 Saurel (2019) found that their female participants preferred traditional pictures. The present
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31 471 study used the AR provider’s server; therefore, fiber, fabric information, and price were not
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33 472 included on the website. Participants did not get clues on whether the fabric would stretch when
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35 473 wearing the dress, or if the dress was affordable. Written explanations would encompass the
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37 474 limitations and overcome picture-related misconceptions. As Kim and Lennon (2008) suggested,
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39 475 detailed verbal descriptions are important to enhance consumer understanding of the product and
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41 476 positively influence their purchase decisions. Additionally, collecting information from males
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43 477 would be a good idea, as they have different preferences and were reported to be less confident
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45 478 when selecting clothes without advice from a knowledgeable person (Hansen and Jensen, 2009;
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47 479 O’Cass, 2004). **The present study examined the influence of AR, which was developed by a**
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480 specific technology provider, on telepresence based on the S-O-R model. Future studies should
481 consider other providers as well as advancing AR functions, and using additional theoretical
482 models to compare the effects of different AR try-on conditions on telepresence.

483 Another limitation was the experimental design. Because a within-subject experimental
484 design was selected, with a possible carry-over effect, it is possible that attitudes and purchase
485 intentions were higher in the physical try-on condition due to the participants' learning of the
486 product, which might have been reinforced by experiencing the same product twice, first
487 virtually and second physically. Future research should look at conducting a between-subject
488 experiential design. Future studies should also investigate factors such as visual imagery on AR
489 fitting experience to better differentiate its competitive advantage as compared to virtual try-on
490 based on parametric models. Finally, future researchers should examine the perceived value of
491 AR fitting systems and their influence on consumer experience. Although AR fitting has
492 limitations on providing accurate fit information, based on our study, the unique interactive
493 features may contribute to consumers' perceived value of the shopping experience.

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Figure 1. Representation of the AR interface showing the controls and the dress stimulus

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Table 1.

The Descriptive Statistics of Survey Instruments

Constructs	AR dress			Real dress		
	n	M (SD)	α	n	M (SD)	α
Product performance						
Style	87	5.10 (1.39)	N/A	87	5.70 (1.37)	N/A
Fabric	86	3.73 (1.90)	N/A	86	5.74 (1.24)	N/A
Color	86	4.79 (1.50)	N/A	86	5.20 (1.59)	N/A
Coordination with other items	86	5.22 (1.50)	N/A	86	5.70 (1.23)	N/A
Details	87	4.37 (1.41)	N/A	87	5.33 (1.38)	N/A
Touch and feel	87	2.55 (1.84)	N/A	87	5.89 (1.09)	N/A
Weight of garment	85	2.81 (1.91)	N/A	85	6.02 (.99)	N/A
Overall Fit	86	4.20 (1.71)	N/A	86	5.36 (1.59)	N/A
Comfort	85	3.38 (2.01)	N/A	85	5.91 (1.14)	N/A
Appearance on the body	86	4.63 (1.66)	N/A	86	5.09 (1.71)	N/A
Telepresence	86	3.70 (1.25)	.88		N/A	
Attitude towards the dress	86	5.25 (1.00)	.94	86	5.60 (1.14)	.96
Purchase Intention	86	4.27 (1.70)	.96	86	4.74 (1.71)	.96

Notes. M = mean, SD = standard deviation, α = Cronbach's *alpha*

7-point Likert-type scales were used to measure the constructs/ items

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Table 2.

Distribution of AR (virtual try-on) and Real (physical try-on) Dress Sizes

		Which dress size fit you best?					
		XS	S	M	L	XL	XXL
What size do you think you should wear for this dress?	XS	11	0	0	0	0	0
	S	2	27	0	0	0	0
	M	0	4	24	4	0	0
	L	0	0	2	5	0	0
	XL	0	0	0	0	3	1
	XXL	0	0	0	0	0	3

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Table 3.

Fit Comparisons at Thirteen Areas

Fit location	Real dress fit M (SD)	AR dress fit M (SD)	ΔM (SD)	<i>df</i>	<i>t</i>	<i>AR dress fits...than real dress</i>
Neck	2.44 (.54)	2.48 (.65)	-.04 (.60)	85	-.54	-
Bust	2.76 (.68)	2.48 (.85)	.28 (1.00)	84	2.58*	Looser
Waist	3.02 (.65)	3.41 (1.00)	-.39 (.97)	86	-3.76***	Tighter
Abdomen	3.14 (.60)	3.40 (.78)	-.26 (.88)	83	-2.73**	Tighter
Hip	2.98 (.34)	3.41 (.77)	-.43 (.83)	85	-4.79***	Tighter
Armhole	3.34 (.61)	3.11 (.89)	.23 (1.05)	83	1.86	-
Shoulder width	2.95 (.61)	2.73 (.86)	.22 (.93)	86	2.18*	Wider
Sleeve opening	3.25 (.51)	3.06 (.76)	.19 (.88)	85	1.97	-
Volume/fullness in skirt	3.06 (.47)	3.06 (.56)	.00 (.68)	86	.00	-
Sleeve length	3.27 (.50)	2.98 (.76)	.29 (.85)	85	3.16**	Longer
Torso length	3.20 (.63)	2.94 (.85)	.26 (.92)	86	2.68**	Longer
Skirt length	3.17 (.77)	2.80 (.73)	.37 (.94)	86	3.64***	Longer
Overall dress length	3.14 (.64)	2.72 (.67)	.42 (.76)	84	5.13***	Longer

Notes. ΔM =Real dress fit-AR dress fit.

A 5-point scale, anchored at *too loose/long/wide* (1), *excellent fit* (3), and *too tight/short/narrow* (5), was used to measure the items.

* $p < .05$. ** $p < .01$. *** $p < .001$.

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Table 4.

Product Performance Comparison of Ten Apparel Attributes

	ΔM	SD	df	t
Style	.60	1.69	86	3.30**
Fabric	2.01	2.15	85	8.68***
Color	.41	1.93	85	1.12
Coordination with other items	.48	1.45	85	3.04**
Details	.96	1.64	86	5.50***
Touch and feel	3.34	2.17	86	14.32***
Weight of garment	3.21	2.05	84	14.42***
Overall Fit	1.16	1.85	85	5.82***
Comfort	2.53	2.17	84	10.75***
Appearance on the body	.46	2.09	85	2.06*

Note. ΔM =Real dress performance-AR dress performance

* $p < .05$. ** $p < .01$. *** $p < .001$.