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Marker versus Markerless Augmented Reality. Which Has More Impact on Users?

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ABSTRACT

Augmented Reality (AR) platforms are being used for an extensive array of applications. One of the critical moments of online shopping is the choice of product. Ideally, consumers should be able to try the product before pressing on "add to cart" button. The experimental design discussed in the article compares two different optical tracking systems of AR—a marker-based AR (MB) and a markerless AR (ML) for two types of interfaces: tangible and multimodal based on gesture recognition, respectively. Both AR technologies allow the consumer to virtually visualize sport shoes' features. Although the interface systems affect the facial/body expression of participants, the self-reported arousal does not change. In contrast with the literature, the usability of the MB (tangible) AR is considered better than the ML (gesture-based recognition) AR option. The probability of recommending the displayed brand is higher under ML (gesture-based recognition) AR than the MB (tangible) AR. Some covariates and factors such as positive/negative emotional traits, tendency to adopt innovation, and familiarity with the brand interfere with the impact of both AR technologies on the dependent variables.

1. Introduction

The consumer is gazing at a TV set watching himself/herself in his/her dining room while he/she is jumping, walking backward and forward, smiling, and having fun. He/she is just observing her/his body and the sports shoes characteristics he/she selects in a mirror-like scenario on the screen. Instantly, the person can control and change the displayed features of the sport shoes as many times as he/she wants. After the purchaser chooses the brand, but before selecting "add to cart" and then pressing the "buy" button, other product details should be taken into account. Such is the case with the color and size. Under the Augmented Reality (AR) system, due to an embedded 3D digital space combining real and virtual images, the consumer can be graphically represented "inside" the screen. His/her body image is transferred to the computer screen, which then works as a mirror allowing him/her to visualize and manipulate the shoes, move around, and use her/his hands freely as an input device directly controlling the available options. The viewers can choose and adjust the colors and the size immediately, without any effort.

The applications of AR technologies have been increasing in different areas: media (Choi, Lim, & Jeong, 2016), office productivity (Ryu and Park, 2016), therapies against phobias (Juan & Calatrava, 2011), pedagogical outcomes and learning/academic performance (Akçayir, Akçayir, Pektaş, & Ocak, 2016; Zarraonandia, Aedo, Díaz, & Montero Montes, 2014), and accuracy of human–robot interaction in signaling way mapping (Coovert, Lee, Shindev, & Sun, 2014). In addition to the utilitarian/practical outcomes, the effectiveness of AR technologies also encompasses the ability to induce psychological reactions in users. Whether the focus is on how to automatically index, code, retrieve mood, emotional content from multimedia productions, or to assess users' reactions when interacting with those tools, human–computer interaction is always under scrutiny. With regard to the former procedures, current research comprises happiness-inducing social media (Kim, Park, & Jo, 2014), video affective content analysis (Xu et al., 2014), automatic music mood annotation (Laurier et al., 2010), microblog sentiment analysis (Cao, Ji, Lin, & Li, 2016), and multi-emotion coexistence tagging (Wang, Zhu, Wu, & Ji, 2014). The latter stream of research has been devoted to evaluating the six basic emotions during a multimedia experiment by online surveys (Arafsha, Alam, & El Saddik, 2015), the measurement (using EEG) of the effect of videos on arousal (Wang et al., 2014), and both the influence on attitudes of virtual forms (Sakamoto, Nakajima, & Alexandrova, 2015) and the affective elicitation of videos (Gamboa, Silva, & Fred, 2014) by experiment design protocol.

In our study, we use two different optical tracking systems of AR technology: a marker-based AR (MB) and a markerless AR (ML); for two types of interfaces: tangible (Billinghurst & Poupyrev, 2008) and multimodal based on gesture recognition (Wu, Wang, & Zhang, 2016), respectively. Our research goal is to compare the two AR technologies in relation to the excitement they provoke, their usability, the interactive experience they provide, and the brand recommendation

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likelihood. A very critical moment is simulated in the experimental design setting: the purchase intention. Purchase intention is considered a function of cognitive and affective evaluations (Fishbein & Ajzen, 1975) and serves as a link between consumers' attitudes toward products and their adoption. Purchase intention is preceded by a general product evaluation and an emotional reaction reflecting consumers' attitude toward an object. After consumers have virtually interacted with the sports shoes, what is the impact of the two distinct AR systems on the aforementioned dependent variables?

2. Overview of AR technology

In the past few years the development of AR, as part of Virtual Reality research, has expanded at a quickening pace. Reproducing the real world in a virtual reality system has proven difficult due to the enormous number of elements needed to complete a homogeneous view of an equally realistic scene. Simulated environments were either too basic as in the case of gaming or too expensive and difficult to produce, as in the case of flight simulator systems (Koussoulakou, Patias, & Sechidis, 2001). An AR system is used to create a compound scene, immersing the user in a real setting and adding computer-generated virtual elements. The primary aim was to design a system whereby a simultaneous blend of the real and the virtual could be accomplished, preferably in a nonintrusive way (Park & Park, 2010).

To achieve augmentation of a scene, various forms can be employed. However, the use of AR is not limited merely to its visual side. Research on AR systems for audio (Lyons, Gandy, & Starner, 2000; Rozier, Karahalios, & Donath, 2000) haptics (Hayward, Astley, Cruz-Hernandez, Grant, & Robles-De-La-Torre, 2004; Salisbury, Conti, & Barbagli, 2004), taste, and even smell (Nakamura & Miyashita, 2011) has been done, evidencing the enormous interest in the field. However, the most researched area with practical applications is vision, while the other sensory receptors are less studied and are beyond the scope of this article.

In a visual AR experience based on optical tracking techniques, we can use the following displays: handheld (e.g., mobile devices, optical see-through glasses), head mounted displays (video-see through glasses, holographic projector, Anaglyph glasses, alternate frame sequencing, and polarization displays), and spatial projection (e.g., LCD display or autostereoscopic display) (Carmigniani et al., 2011; DiVerdi & Hollerer, 2007; Papagiannakis, Singh, & Magnenat-Thalmann, 2008). The output from those displays comes in the form of images, while the information users receive is displayed as text, virtual objects, textures, or highlighting. Table 1 summarizes the development fields of AR systems.

In order for an AR system to operate efficiently, the relationship between the real and computer-generated objects, together with specific hardware, must be designated precisely. The objective of AR applications is to represent the virtual images to the user in such a way as to be believable and as close to reality as possible. To achieve a flawless immersion for the user, several aspects of a system are of significant importance. Building compelling AR environments requires enabling technologies such as displays, tracking, registration, and calibration (e.g., Azuma et al., 2001; Shen, Ong, & Nee, 2011). One of the most important requirements for AR systems is tracking. Visual tracking attempts to calculate the trajectory of an object in the image plane as it moves around a scene through features detected in a video stream. In the past, one of most used solutions to overcome this issue was by utilizing fiducials, or artificial markers placed in the scene. The geometric or color properties of these markers make them easy to extract and identify in a video frame. However, AR technology has evolved, providing improved solutions for ML tracking. Hence, the increasing number of patents being published, and the improvements that Software Development Kit such as Vuforia have been facing, as well as the release of ARKit, by Apple (Chowdhary, Blumenfeld, & Garland, 2017; Jiang & Gu, 2017; Peng & Zhai, 2017). In ML AR, the

Table 1. AR systems grouped in terms of output and input devices.

	Category	Description	Device	Output	AR information
Augmented reality	**Vision**	**Handheld**	Mobile device	Image	Text
		HMD	Optical see-through glasses		Virtual Objects
		Spatial	Projector		Highlighting
			LCD Display		
			Autostereoscopic Display		
		HMD	Video see-through glasses	3D Image	3D Text/
		Wearable	Holographic projector		Virtual objects/
		HMD+	Alternate Frame Sequencing Display & Glasses		Textures
		Spatial	Polarization Display & Glasses		3D Highlighting
			Anaglyphic glasses + default display		
	Audio	Spatial	Speakers	Surround sound	Direction of sound
					Translations
					Additional sound
					Improved sound
		HMD	Headphones	Stereophonic sound	Translations
					Additional sound
		Handheld	Earphones		Improved sound
	Touch	Spatial	Haptic device	Motions	Additional motion
		Handheld	Vibrating mobile device	Vibration	Haptic feedback
			Game controller		
	Smell	HMD	Gustatory display	Smell	Fragrance
	Taste	HMD		Taste	Flavor

implementation of the tracking system relies on natural features instead of fiducial markers.

In the past decade, tracking systems struggled to provide range, accuracy, robustness, latency, ergonomic comfort, and user-friendly calibration (Livingston, 2005); therefore, the emphasis was pushed to the user experience regarding an overall evaluation of systems. However, despite the advances met in the technical aspects, the topics of usability and users' experience, especially on mobile solutions, are still up to date (Ko, Chang, & Ji, 2013; Poushneh & Vasquez-Parraga, 2017). The consumption of products and services generates experiences with emotional tones (Holbrook & Hirschman, 1982) and varied intensity levels. The values of products or services are not exclusively economic or utilitarian; they also convey pleasurable experiences (Schmitt, 1999). Such experiences can be surprising (LaSalle & Britton, 2003), memorable (Pine II & Gilmore, 1999), or holistic, integrating individual sensations and cognitive activity (Schmitt, 1999).

The performance quality of a system affects the user's emotional experience. Therefore, our research is designed to compare tangible (MB) and gesture-based (ML) interfaces through appropriate construct measures such as arousal, usability, the likelihood of recommending the brand, and observation/coding of the users' body language and facial expressions.

3. Theoretical background and hypothesis

3.1 Tracking systems and interfaces

One of the most important requirements for AR systems is the accuracy of the tracking system (Craig, 2013).

Computer vision-based visual tracking attempts to calculate the trajectory of an object in the image plane as it moves around a scene, through features detected in a video stream. A computer calculates the camera's pose in relation to known features seen in the real world such as position, area, or shape of an item (Herling & Broll, 2011). In many video see-through AR systems, a video camera is already present in the system. Extracting a pose from a video frame requires software to create consistency between the elements in the image and the known 3D locations in the world. Feature extraction and improved tracking systems can be achieved using software packages such as OpenCV, and other AR tool sets such as Vuforia and Unity, Augment, Infinity AR, Intel RealSense, among others (Nixon & Aguado, 2012; Peddie, 2017). However, despite the effort of the previously mentioned solutions, there are still some limitations regarding the support needed for interacting and processing virtual elements (S. L. Kim et al., 2014). According to the current state of the art regarding AR tracking systems, there are, among others, the following tracking systems: marker-based (MB), markerless (ML), and extensible tracking (Kim, Lee, Wang, & Kim, 2015; Pucihar & Coulton, 2013). In our study we focus on the first two tracking systems.

MB AR relies on the placement of fiducial markers (such as barcode, QR code, to name a few) on the real world (Katiyar, Kalra, & Garg, 2015) which are captured by a camera thus creating an AR experience. From the system requirement point of view, this solution is implemented more easily than the ML, especially in terms of recognition and registration (Hirokazu & Billinghurst, 1999). The geometric or color properties of these markers make them easy to extract and identify in a video frame (Katiyar et al., 2015).

ML AR does not depend on fiducial markers; however, the systems rely on natural features for the execution of tracking (Papagiannakis et al., 2008). Since tracking systems struggle to provide range, accuracy, robustness, latency, ergonomic comfort, and user-friendly calibration (Herling & Broll, 2011; Livingston, 2005; Schmalstieg & Hollerer, 2016), the overall evaluation of systems is contingent on the user experience.

There are four main types of interfaces: tangible, collaborative, hybrid, and multimodal (Carmigniani et al., 2011). However, other authors consider another type of interface, the natural interface, where the user can interact with AR using gestures (Mark Billinghurst, Clark, & Lee, 2014; Lee & Hollerer, 2007).

Interacting with a QR code printed on a card—that is, marker-based AR—can be considered similar to interacting with a tangible interface (Billinghurst & Poupyrev, 2008). Using gestures to interact with the virtual environment is understood as a natural interface, where there is no fiducial marker—that is, markerless AR.

Past research has focused on the analysis of the impact of AR on subjects, especially using the technology acceptance model (TAM) (e.g., Rese, Baier, Geyer-Schulz, & Schreiber, 2016). Despite studies exploring either or both tracking systems—interfaces and associated displays—there is a shortage in literature in examining human reaction to different technological and psychological aspects of the AR experience, other than adopting the TAM measurement.

To the best of our knowledge, the specificities of AR interfaces systems and the comparison of their effect on psychological reactions and on facial expressions of users has not been studied.

3.2. Arousal

Arousal is essential in all mental functions, contributing to attention, perception, memory, emotion, and problem-solving. A generally accepted definition of arousal has not yet been agreed upon, but a classical one is still outlined as "a condition conceived to vary in a continuum from a low point in sleep to a high point in extreme effort or intense excitement" (Duffy, 1962, p. 5). Arousal is associated with both a physiological response (e.g., an automatic reaction to a stimulus) and cognitive processes (e.g., judgment), and it is described as a nonspecific component of motivation which reflects intensity rather than direction of motivation (Humphreys & Revelle, 1984) or the valence of affect (Whissell, Fournier, Pelland, Weir, & Makarec, 1986). It is possible that heightened arousal will lead to an increase in motivation in a range of behavior, as directed by the environmental context (Antelman & Caggiula, 1980; Brehm & Self, 1989). Multimedia technologies—audio, video, games, and social networking—induce various emotional states, some of which provoke immediate excitement (Wang et al., 2014) while others engender a more gradual arousal (Arafsha et al., 2015). Hopp and Gangadharbatla (2016), using exclusively an MB tracking system, explored the impact of AR on consumers' attitudes toward technology and toward the brand. They concluded that at an early stage of exposure to an AR stimulus, arousal plays a significant role in stimulating the exploration, thus contributing to the development of positive attitudes. The ML AR platform favors more instantaneous reaction and direct interaction than MB AR.

H1. ML (gesture-based) AR induces higher arousal than MB (tangible) AR.

3.3. Body and face indicators of emotional reactions

Frowning

People recognize stereotypical and universal facial displays of sadness such as frowning and downcast eyes in the absence of verbal communication (Bavelas & Chovil, 2006). Frowning draws the eyebrows together and wrinkles the forehead, especially in worry or concentration. There are a number of emotions that include frowning: several studies use frowning to measure anger as well as sadness (Blairy, Herrera, & Hess, 1999; Hess & Blairy, 2001). Lowering the eyebrows is often a sensitive indicator of disagreement, doubt, or uncertainty (Givens, 2002). It has been argued that increased frowning activity is associated with higher cognitive load (Hietanen, Surakka, & Linnankoski, 1998; Van Boxtel & Jessurum, 1993). There are also indications that frowning increases the perception of effort (Larsen, Kasimatis, & Frey, 1992; Stepper & Strack, 1993) and puzzlement (Burgoon, J. K., Buller, D. B. & Woodall, 1989). This suggests that in addition to frowning activity reflecting negative emotional response, it may be naturally related to tasks that require changes in attention. Moreover, frowns may be expressed due to deep thought and may be best seen as reactions to stimuli (Dimberg, Thunberg, & Grunedal, 2002; Moody, McIntosh, Mann, & Weisser, 2007).

Posture and gestures

Typically, nonverbal communication is associated with body language, or kinesics. Nonverbally, kinesis codes involve bodily actions that communicate signals without using touch or physical contact with another person (Burgoon et al., 1989). Ekman and Friesen (1968) define nonverbal acts as "a movement within any single body area" and "across multiple body areas", or through gestures. Those are movements designed to communicate a certain meaning and may be expressed using the hands, arms, or body. Furthermore, movements of the head may be used to convey thoughts or emotions. For example, body posture can be used to determine a participant's degree of attention or involvement, the difference in status between communicators, and the level of fondness a person has for the other communicator (Knapp, Hall, & Horgan, 2014). In an early experimental study, James (1932) identified four main postural categories: (1) forward body inclination ("attentiveness"); (2) drawing back or turning away ("negative," "refusing"); (3) expansion ("proud," "conceited," "arrogant"); and (4) forward-leaning trunk, with bowed head, drooping shoulders, and sunken chest ("depressed," "downcast," "dejected"). Behaviors such as foot tapping or face touching generally do not carry information about the expressers' appraisals, intentions, concerns, or dispositions, although they may be interpreted as signaling nervousness or irritation with emotional meaning (Hess & Fischer, 2014).

The identification and recognition of posture, movement, proxemics (or the use of space), and human behavior is also the subject of gesture recognition techniques. Gesture recognition enables humans to communicate with a computer and interact naturally without the aid of any mechanical devices, such as mouse or keyboard. In gaming for example, in terms of direction of movement, moving forward toward a device translates into an easier manner of play (Koštomaj & Boh, 2009).

Surprise

Surprise is the briefest of all the emotions, lasting only a few seconds, and possibly transforming into fear, amusement, relief, anger, disgust, or no emotion at all (Ekman, 2003). This theory is supported in the literature, and surprise is considered to be a neutral and ephemeral emotion (Meyer, Reisenzein, & Schützwohl, 1997; Rainer Reisenzein, 2000; Schützwohl, 1998). Surprise is subjective in nature (e.g., personal feeling), physiological (e.g., changes in the respiration rates), and behaviorally expressive (e.g., raised eyebrows and opened eyes, interruption of ongoing activities, focusing of attention on the stimulus triggering the surprise reaction) (e.g., Meyer et al., 1997; R Reisenzein, Meyer, & Schutzwohl, 1996; Vanhamme & Snelders, 2003). Surprise cannot be anticipated; by definition it is an unexpected event (Ekman & Friesen, 2003; Scherer, 1984). Surprise occurs when there is a mismatch between prior and posterior beliefs. Russell (1980) defined surprise as an emotional high state in activation and neutral in valence (e.g. neither unpleasant nor pleasant). Surprise (as well as puzzlement or uncertainty) may be accompanied by grimaces of so-called jaw-drop, where in the expressing of interest or excitement "the brows lift or lower slightly, the eyes open wide and fixate, and the lips may be parted" (Izard, 1971, p. 242). Since surprise is frequently elicited by products in terms of consumer experience (Desmet, 2002; Richins, 1997), it can be beneficial, because it allows customers to experience or learn something new.

Smile

Both the frequency and the intensity (i.e., magnitude of muscle contraction) of facial expressions are critical to what the face reveals. The smile is the most complex of the facial expressions. Ekman (2003) identified 18 types of smiles and argued that there might be as many as 50. The smile is characterized by the upward turn of the corners of the lips through contraction of the *zygomaticus major muscle* (Ekman & Friesen, 1978). Kraut and Johnston (1979) defined a closed smile as the one with corners of the mouth turned up, lips [sealed] and teeth together, while the open smile consisted of the corners of the mouth turned up with lips parted to show the teeth. Smiles differ according to morphological and dynamic characteristics (Ambadar, Cohn, & Reed, 2009;

Ekman & Friesen, 2003; Keltner, 1995). Morphological characteristics include opening the mouth with the cheeks rising, lips pressed, contraction of zygomatic major muscle, symmetry of the lip corners, and amplitude of the smile (morphological characteristics), while the duration and velocity of the onset and offset of the smile belong to dynamic characteristics.

The smile can be a powerful indicator of a person's present emotional experience (Ekman, Levenson, & Friesen, 1983; Tracy & Robins, 2004). Smiles are most often perceived as communicating "happiness" or "joy" (Frank & Stennett, 2001; Messinger, Fogel, & Dickson, 2001), although there is evidence that happy people might not necessarily smile at happy times, but rather when they interact with others (Fernández-Dols & Ruiz-Belda, 1995; Kraut & Johnston, 1979). Smiling can be quite a complex signal, due to people's ability to fake it. Ekman's (2003) research, however, confirmed that it is feasible to differentiate between fake (no enjoyment) and sincere smiles (enjoyment). To distinguish a genuine smile from a fake one, one must observe the eyebrows and check that the eye cover folds have been pulled down by the muscle orbiting the eye (Ekman, 2003).

Concentration/focus

Humans receive a constant abundance of information. Keeping the so-called "focus of attention" means filtering out the important information and leaving the less important information unprocessed (Parkhurst, Law, & Niebur, 2002). A person who is focused on a task usually has his/her eyes fixed on it, experiences reduced blinking, has slightly raised eyebrows, and head either erect or pushed forward. Focusing is facilitated by the senses. However, inner perception, such as the perception of feelings, emotions, and thinking, plays an important role. Those feelings may be evoked by visual stimuli. The interval between the presentation of a stimulus and the generation of a response is measured by reaction time (Cashmore, 2008). Reaction time is used to assess cognitive (e.g., attention, resource allocation) and affective processing (Annie & Basil, 1998; Reinmann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010). Simple reaction time is used to measure processing speed, alertness, and selective attention (Prieler, 2011). Attention, the behavioral and cognitive process of selectively fixating on a discrete aspect of information, encompasses a broad spectrum of abilities, referred to by researchers in addressing questions of focus or concentration (Weinberg & Gould, 2011).(Weinberg & Gould, 2011). Concentration, high energy, and pleasurable engagement result in a high positive effect, or an immediate psychological response in connection with a stimulus (Snyder, Lopez, & Pedrotti, 2011). Conversely, a low positive affect is associated with lethargy and sadness. Maintaining attention is a measure of how concentration is directed toward a stimulus without losing focus.

Impatience

Impatience refers to when users become increasingly dissatisfied (Reich & Chaintreau, 2009). System complexity, errors, lack of knowledge, or time delays may lead to emotions such as confusion, frustration, and failure (Baecker, Booth, Jovicic, McGrenere, & Moore, 2000). In usability testing, when users cannot control a system entirely, even though they want to, they may show impatience. Behaviors such as foot tapping or face touching generally do not carry such information about expressers' appraisals, intentions, concerns, or dispositions, unless they are interpreted as signaling nervousness or irritation with an emotional meaning. Users expect to have a system response easily and display impatience when that system does not measure up to their expectations. Engagement as well as good usability may convert them from a visitor to a customer (Nielsen, 2004)

H2. ML (gesture-based) AR generates greater bodily/facial reactions than MB (tangible) AR.

3.4. Interactive experience

Humans can interpret a visual scene in a matter of milliseconds (Miller, 1994). If the visual scene is pleasant and the content is interesting, users will enjoy the experience more, as opposed to undergoing hardship or feeling bored. Research has revealed that fun has an effect on the perception of time, which often seems shortened when one is having an enjoyable experience. In an experiment by Sackett, Meyvis, Nelson, Converse, and Sackett (2010), a group of participants were exposed to a boring task and told that it had lasted half an hour—which it really had. This group thought it was more enjoyable than another group who had been doing exactly the same task but hadn't been told about how much time had passed. Evaluation of an interface is especially important in the pretesting stages of any digital tool. In general, higher interactivity has a positive effect on the assessment of an experience (Cheng, Blankson, Wang, & Chen, 2009; Lavie & Tractinsky, 2004; Westbrook & Oliver, 1991).

H3. ML (gesture-based) AR stimulates higher interactive experience than MB (tangible) AR.

3.5. Usability

Usability, also referred to as "ease of use", is an inseparable part of any designed interactive user experience and incorporates user navigation, information search, and actual site interaction (Goto, K. & Cotler, 2004; Wood, 1998). One prevalent definition explains that "usability means that people who use the product can do so quickly and easily to accomplish their own tasks" (Dumas & Redish, 1999, p. 4). Furthermore, Nielsen (2004) states that ease of use is the first priority of interface design. He defines usability in terms of five characteristics, namely (1) learnability, (2) efficiency, (3) memorability, (4) errors, and (5) satisfaction (Nielsen, 1993, p. 26). Learnability refers to the initial ease of accomplishing basic tasks. Efficiency and memorability are concerned with the speed of performing tasks after first use and after a period of time, respectively. Errors give information on how easily users can recover actual errors they make and satisfaction is concerned with design pleasantness.

Similarly, Rosson and Carroll (2002) identify three perspectives that contribute to the general concept of usability, such as (a) human performance, time, and errors, (b) human cognition, mental models of plans and actions, and (c) collaboration, group dynamics and workplace context (p. 10).

Rese and colleagues explored the acceptance of AR apps using a modified version of the TAM. They compared two MB and two ML AR apps. They found that the latter outperform the MB apps (Rese et al., 2016). An AR interactive application allowing consumers to use freehand gestures will be more beneficial and attractive to user experience than an alternative requiring the user to handhold a marker to activate the interface system (Wu et al., 2016).

H4. ML (gesture-based recognition) AR is associated with a better usability than MB (tangible) AR.

3.6. Intention to recommend the brand

Recommendation expresses a social commitment which is only possible when the consumer is convinced that the experience with the brand in that context has conveyed enough value for her/him to share and endorse it. Javornik (2016) studied the media characteristics provided by AR (i.e., perceived augmentation, interactivity, and flow as a mediator) comparing the impact that such technology had on consumers, in cognitive (e.g., nr. of thoughts), emotional (attitude toward the band and the site/app), and behavioral terms (purchase, recommendation, and revisit intention), by conducting two ML AR experiments (one using tablets, and the other using a computer and a webcam). She found that flow, as a mediator of perceived augmentation, leads to a higher revisit and recommendation intention, and lower the number of brand-related thoughts. An interactive experience with a more technologically advanced perceived device may foster the likelihood of recommending (Cheng et al., 2009; Jin & Su, 2009; Cheng et al., 2015).

H5. ML (gesture-based recognition) produces a greater intention to recommend the brand than MB (tangible) AR.

3.7. Consumer's profile mediation

Apart from the aforementioned dependent variables, there are other variables—moderators—which potentially interfere with the way that interface systems affect the dependent variables. A previous connection with a category (sports shoes) or target brand produces a recency effect (Moreland & Zajonc, 1982). The degree of familiarity with any type of advertising or product (sports shoes) website may provoke surprise or less involvement when consumers are invited to interact with online shopping platforms (Verhellen, Dens, & De Pelsmacker, 2016). Innovativeness refers to consumers' judgment(s) and willingness to try new things (Goldsmith & Foxall, 2003). That personality feature is related to many other psychological and contextual factors which mold the consumer's reaction in an unpredictable manner (Bartels & Reinders, 2011; Vandecasteele & Geuens, 2010). Affect intensity is defined as "stable individual differences in the strength with which individuals experience their emotions" and is considered to be a significant predictor of mood experience (Larsen & Diener, 1987, p. 2). The way a person experiences emotion is not dependent on the nature of the activator, but on how he/she cognitively processes them (Bosse, Jonker, & Treur, 2008). In that regard, we have not only to assess the intensity but also the valence of the affect. The same object or situation may trigger distinct reactions contingent on a person's personality profile.

Therefore, we formulate two research questions:

RQ1. Does the website visit and brand awareness of the target category/brand moderate the varying effect of two interface systems on the dependent variables?

RQ2. To what extent do innovativeness and emotional intensity affect the level and direction of each interface system on the dependent variable?

4. Method

To study the impact of two interface systems (gesture-based [ML] vs. tangible [MB]) on emotional expression, self-reported emotion, usability, and intention to recommend, we carried out a laboratory between-subjects experiment with those technological platforms. The experimental procedures protocol is similar to other interface comparative studies (e.g., Swan II, Kuparinen, Rapson, & Sandor, 2017).

4.1. Procedures and stimulus material

All AR applications work on similar theoretical principles. The only distinction among them lies in two operational aspects: the position/orientation detection and the template matching approach (Procházka & Koubek, 2011). Markers or tangible (MB) interface require additional effort from the end user to provide an intuitive and engaging brand experience. A markerless or gesture-based (ML) approach might be more beneficial. Intuitive interaction allows a user to manipulate virtual objects based on unconscious application of prior knowledge (Hurtienne & Blessing, 2007). Numerous interaction methods have been developed in the field of AR, and new types of motion sensing input devices such as Microsoft Kinect facilitate free hand interaction. A Kinect device provides a full-body 3D motion capture, facial recognition, and even voice recognition capabilities. For the platform development, the position of the hands and their gestures were identified without requiring users to use additional devices (Kamel Boulos et al., 2011). The purpose was to allow participants to view the 3D object in the same way they would view a physical one. For the MB treatment, the system consisted of a widescreen monitor and a video camera, while for the ML approach a Microsoft Kinect device and a Unity3D game engine were used. The video camera live-streamed the scene while the user observed the augmented scene on the monitor.

The experiment was designed to follow a three-step process. The facility used for the purpose of testing was a university computer lab, and involved two groups of participants consecutively. To begin with, each group of students was given instructions on how to proceed with the system. The first step involved filling out a computer-based questionnaire, after which participants were asked to interact with the system without restriction. Nothing more than common sense was required to interact with the two systems. Participants had full control over interacting with the system; however, a limit of 3 min per person was given. That time length was enough not only for allowing a full interaction/experience with the AR context as well as to develop a clear cognitive representation of that experience. Concerning the facial expression, once human reactions are quite instantaneously, the first 30 seconds of trial represent enough time to capture the most frequent type of emotion. After that time, the consumers' emotional reactions become quite repetitive or inexpressive since they start to get used (habituation) to that stimuli (Ambadar et al., 2009; Ekman & Friesen, 2003; Keltner, 1995). The final step involved answering a second, post-experiential computer-based questionnaire.

The user interacted with two distinct interfaces: (1) the six buttons, which only required one hand to hover and (2) a rotator, activated by moving a hand from down to up position or from left to right (see Figures 1 and 2). It was important to maintain uniformity between the two interfaces, making them as similar as possible. The standard features of the systems were: (1) three interactive screen buttons for them to be able to express their color preference, (2) two arrows to allow the user to choose the shoe size, (3) an "ADD TO CART" purchase button, (4) a "BUY" button, and (5) a "CLEAR" button. Marker-based AR (MB) required a black and white fiducial image (QR code) to be pointed at and recognized by the application. The printed symbol served as a spatial reference to place the subject in the scenario, enabling the possibility of following and rotating correspondingly. For the execution of the second interface (an ML one), the user was able to position his/her hand over it for detection for 2 s while the buttons started to glow, with the glow spreading around it increasingly until a 2D flat background with a live, real time streaming of the Kinect-captured video was activated. To reactivate the same interface, the hand was removed and placed over the selected interface once again. A sticker on the lab floor assisted the subjects' positioning in front of the system. All participants in both conditions were video recorded in order to collect information on their facial expressions and gesture movements. Table 2 summarizes the differences between ML (gesture-based recognition) AR and MB (tangible) AR systems. In both interfaces, participants were given the opportunity to customize the shoe they intended to visualize. They had three color options: orchid pink, lime green, and royal blue, and they could choose their shoe size to proceed the order. By allowing them to customize the color

Figure 1. Markerless or gesture-based (ML) system.

Figure 2. AR marker-based or tangible (MB) system and the used fiducial.

Table 2. Characterization of the two types of AR interfaces.

AR marker-based or tangible (MB)	Markerless or gesture-based (ML)
• Uses fiducial markers; • Corresponding image descriptors are provided beforehand; • No need of accelerometer or compass; • Recognition library may be able to compute the pose matrix (rotation & translation) of the detected image, relative to the camera of the device; • Cheap detection algorithm; • Robust against lighting changes; • Doesn't work if partially overlapped; • The fiducial marker image is black and white with square form for easy detection.	• No need for fiducial markers; • Does not need any pre-knowledge of a user's environment to overlay 3D content into a scene and hold it to a fixed point in space; • Recognizes images that are not provided to the application beforehand; • Recognition algorithm running in an application should identify patterns, colors, or other features that may exist in camera frames.

and the size, it was given them plenty opportunities to interact with the system within the 3 min limit time, providing the collection of the needed data, regarding both user experience and purchase intention.

A pretest (n = 98, 62% male, 20 ± 1.3 years old) was undertaken to assess whether the online shopping environment design was realistic and to select the most appropriate sports shoe for the chosen target. The results were useful for adjustments in wording and question order. The selection of the Converse shoe brand as the stimulus in this lab experiment was considered appropriate, since it is a real brand with some appeal to the chosen segment. Furthermore, the Converse brand is not as heavily advertised as other brands (Nike or Adidas), and is therefore seen as more emotionally neutral.

4.2. Participants and sample characteristics

The participants were volunteers recruited from the University of Porto. Fifty subjects per treatment were organized in two homogenous experimental groups (e.g., age, instructional level, native language). Age 21.48 ± 3.12 and 76% of males.

4.3. Measures

Emotional response

The "arousal" dimension was obtained from the original construct of Mehrabian and Russell (1974). Its reliability was considered good (α = .855). A list of items used in this construct is given in the Appendix.

Usability

We extract this dimension from the construct developed by Lavie and Tractinsky (2004). However, taking into account the specificity of the stimuli—interface systems—two additional items (response speed and ease of control) are included (α = .804). A list of the usability construct items is given in the Appendix.

Interactive experience

Most of the available constructs measure the general emotional status quo of the user or his/her evaluative reactions against a particular object. To the best of our knowledge, no assessment has yet been published of the interface systems similar to the ones applied in our study. Therefore, we were inspired by the measures of three investigations (Cheng et al., 2009; Lavie & Tractinsky, 2004; Westbrook & Oliver, 1991). The eight construct items we used in the questionnaire were: interesting, annoying, entertaining, boring, gratifying, pleasant, confusing, and disappointing (5-point Likert scale). Factor analysis extracted two dimensions, statistically explaining 68.9% of the total variance with a KMO value of .853 and Barlett's test of sphericity. The final two emotional reactions to stimuli factors are labeled "fun" (Cronbach's α = .817) and "boring" (α = .762), showing good reliability (Hair, Black, Babin, & Anderson, 2014) (details are available in the Appendix).

Recommendation intention

The measurement of the likelihood of recommending is substantiated by the question: "Probability to recommend the brand" (1 = none to 7 = very high).

Observations

Since "coding means attaching a set of descriptive labels/categories" to the objects (Rose, 2012, p. 90), the quality of the data generated by that process relies both on the objectivity of the structure of categories and on the observer's work (Kolbe & Burnett, 1991). Apart from the quality of the judgment-based data, an appropriate operational definition of the coding categories is required (Perreault & Leigh, 1989). Two independent coders observed the same videos and coded the corresponding facial expressions and body movements of each participant using a prespecified coding scheme. The Krippendorff Alpha reliability measure (Hayes & Krippendorff, 2007) of the judgments for 35% of the data commonly coded ranged from 0.81 to 0.97. The mean value was 0.89. Those values indicated a satisfactory level of intercoder reliability. The disagreements concerning codified behaviors were later subjected to further analysis, and after discussion of the result among coders a new recoding took place which proved mutually acceptable.

- Frowning – incidence (yes/no) and frequency (nr. of times it occurred);
- Smiling – occurrence (yes/no), frequency (nr. of times it occurred), and intensity (two levels);
- Surprise – incidence (yes/no) and frequency (nr. of times it occurred);
- Concentration/focus – incidence (yes/no) and intensity (three levels);
- Leaning close to the screen – incidence (yes/no) and frequency (nr. of times it occurred).

Consumer profile

We included two types of background characteristics in our model, known as personality traits and behavioral aspects, which may influence the way that two distinct stimuli have an effect on dependent measures: fixed factors and covariates. The fixed factors are represented by three nonmetric variables: "Which brand of sports shoes do you know?" (binary, Converse = yes) intended to capture any familiarity with the Converse brand; "When did you purchase your last pair of sports shoes?" aimed to measure the degree of immediacy contacting with the category (four time-span options); Have you already visited a website for sports shoes? (binary). The covariates are the following metric variables: (1) The Emotional Intensity (Bachorowski & Braaten, 1994) construct gives rise to two dimensions: "Positive emotion inclination" (α = .820) and "Negative emotion tendency" (α = .8214). (2) Innovativeness (Goldsmith & Hofacker, 1991). From that original construct we selected one factor, labeled "Oversight regarding the purchase of new products" (4 items) (α = .741).

5. Results

Several multivariate statistical techniques were used in this research: ANOVA, 2-way ANOVA, ANCOVA, MANCOVA, cross tabulation, and factorial analysis. Depending on the specificities of each technique, the corresponding statistical assumptions they should satisfy were assured, and if violated [the] adequate corrections were made or an alternative test was given. Overall, normality, linearity, homoscedasticity, and equality of variances–covariance matrices were previously verified (Hair et al., 2014). Most of the dependent variables were unidimensional measures formerly defined in the literature except for the case of the interactive experience construct, which gave rise to two dimensions: fun and boring.

5.1. Manipulation check

Following good practices established in behavioral research, we conducted a manipulation check (e.g., Perdue & Summers, 1986; Bonate, 2000; Lana, 2009). In order to check whether the participants had perceived the two interface systems—independent variables subjected to manipulation—we asked them to evaluate the interactive dimension of their experience by rating "the relative ease of use" (5-point scale) variable. One-way ANOVA is employed to see whether the average values differed significantly among treatments $F(1, 95) = 6.828$, $p < .01$). The mean differences between ML and MB groups are always statistically significant ($p < .05$). The test also provided evidence for the construct validity of the manipulation (Cozby & Bates, 2012).

5.2. Data analysis

Emotional response

Whether a self-reported (arousal) measure or based on observation and codification of bodily/facial reactions or expressions, we expected that ML treatment would stimulate the participants more than the MB condition. The ANOVA tests showed no statistical differences between the two experimental conditions concerning the arousal dimension ($F(1, 95) = 0.125$; $p = .724$). None of the fixed factors (Two-way ANOVA) or the covariates (ANCOVA) interfered or changed the effect of the interface system on arousal. Consequently, H1 is rejected.

Three of the five measures of the observed facial expressions reactions indicated significantly different responses when each group of participants was interacting with the distinct interface systems: surprise [$\chi^2(1) = 3.630$, $p = .045$], smile $\chi^2(1) = 7.687$, $p = .021$], and intensity of focus [$\chi^2(1) = 7.367$, $p = .057$]. A greater proportion of participants expressed surprise under the ML (64.7%) than MB (35.3%). If we filter out those participants who did not visit a sports shoes website or only include those who bought a pair of sports shoes less than three months previously, the surprise effect increases (from 64.7% to 68.2% and from 64.7% to 91.7%, respectively).

The ML experience tends to increase the proportion (and frequency) of those who smile. Under the ML condition only 8% did not smile, compared with 29.8% during MB treatment. Among those who smiled at least once, 61.1% occurred in the ML experience. Less contact with the website stimulated smiling in the ML condition since 62.5% smiled and had not visited a website, versus 54.1% who smiled and had already visited a website. However, the recency of purchase also favored the reinforcement of the smile reaction among those who witnessed the ML. In the smiling group 87.5% were interacting with ML against 12.5% with MB. The type of interface only affected the intensity of focus within two specific subgroups. The participants who had already visited the website showed significantly superior percentages in the ML condition (63.2%) than under the MB treatment (36.8%). A similar pattern occurred among those who were more familiar with the brand (ML: 61.5% vs. MB: 38.5% in the brand familiarity situation and an equal 50% proportion in the "no brand awareness" situation). Therefore, H2 is supported.

Interactive experience

Since both dimensions of the Interactive experience construct are highly correlated (Pearson cor. = .654; $p = .000$), the multivariate analysis of variance is carried out. Although MANOVA tests perform the multivariate tests acceptably (Box's $M = 5.175$; Wilk's $L = 0.948$ ($p = .083$); $\eta^2 = .052$), only the "Fun" dependent variable shows individual between-subjects statistically significant main effects ($F(1, 95) = 3.293$; $p = .073$; $\eta^2 = .034$) in contrast with the other variable outcome: "Boring" ($F(1, 95) = 0.083$; $p = .774$; $\eta^2 = .034$). MANCOVA assesses the potential influence of covariates on dependent variables. When the "positive emotion" covariate is added to the model, the joint effect on the interactive experience variables becomes nonsignificant, which may indicate a likely mediation of that covariate (Pituch & Stevens, 2016). A further analysis carried out through the ANCOVA test ($F(1, 95) = 5.939$; $p = .017$; $\eta^2 = .060$) proved that "positive emotion" contributed to enhancing the effect of AR on the "Fun" dimension ($m = 4.02$; $sd = .069$) ($p = .006$) versus MB ($m = 3.86$; $sd = .071$). Concerning the fixed factors, "having visited sports shoes websites" also positively affected to what extent the ML experience is evaluated distinctly regarding MB when measured by the dependent variable "Fun". In the two-way ANOVA test, the main effects of the experimental treatments are significant ($F(1, 95) = 2.937$; $p = .037$; $\eta^2 = .087$). Therefore, H3 is supported.

Usability

Due to the technological characteristics of ML AR, it is more effortless and apparently more intuitive to use ML than MB. In the ANOVA test, as the homogeneity of variances assumption is violated (Levene's statistic = 6.109; $p = .015$), the main effects of the treatments are indicated by Brown-Forsyth robust tests of equality of means ($F(1, 95) = 11.088$; $p = .001$). The corresponding values in the ML condition ($m = 3.39$; $sd = .826$) and MB ($m = 3.88$; $sd = .632$) show that the usability gradually decreases from the most sophisticated ML to MB.

The negative emotion trait acted as a significant covariate in the participants' usability evaluation under ML and MB treatments. The tests of between-subjects effects, ANCOVA, are significant ($F(1, 95) = 5.796$; $p = .018$; $\eta^2 = .059$). The negative emotion trait reinforces the influence of technological stimuli on the dependent variable by $\beta = -.491$ ($sd = .144$; $p = .001$ for MB vis-à-vis ML). The lack of familiarity with the brand also reinforces the gap between the usability measure of two conditions ($F(1, 95) = 9.384$; $p = .001$). The pairwise comparisons show that usability values in the ML condition ($m = 3.31$; $sd = .842$) are smaller than in the MB ($m = 3.95$; $sd = .497$). A similar pattern occurred among those participants who have never visited the website: ($F(1, 95) = 10.829$; $p = .001$). Once again, the usability is greater under the MB treatment ($m = 4.03$; $sd = .734$) than the ML treatment ($m = 3.44$; $sd = .845$).

As these outcomes are the opposite of what the theory indicated, H4 is rejected.

Recommending the brand

The intention to recommend is statistically different in each experimental treatment—ANOVA ($F(1, 95) = 6.417$; $p = .013$). The probability is greater during the ML interface experience ($m = 4.48$; $sd = 1.940$) than during MB ($m = 3.55$; $sd = 1.639$). Innovativeness is a personal profile which influences the effect of the interface system on the probability of recommending the brand: the ANCOVA test ($F(1, 95) = 3.639$; $p = .016$; $\eta^2 = .105$). Being more predisposed to adopt innovation increased the differences between the relative impact of the two modalities of the interface on the intention to recommend by $\beta = -.960$ ($sd = .362$; $p = .009$ for ML vis-à-vis MB). The distance in probability of recommending between the two interface systems is amplified among those consumers who have never visited websites for sports shoes ML ($m = 4.39$; $sd = 2.033$) versus MB ($m = 3.12$; $sd = 1.764$)—2-way ANOVA ($F(1,95) = 6.882$; $p = .010$; $\eta^2 = .069$). Therefore, H5 is supported.

Table 3. Summary of hypotheses testing.

Hypotheses	Statistical output	Outcome
H1. ML (gesture-based) AR induces higher arousal than MB (tangible) AR.	($F(1, 95) = 0.125$; $p = .724$)	Rejected
H2. ML (gesture-based) AR generates greater bodily/facial reactions than MB	Surprise [$\chi^2(1) = 3.630$, $p = .045$]; Smile [$\chi^2(1) = 7.687$, $p = .021$]; Intensity of focus [$\chi^2(1) = 7.367$, $p = .057$]	Supported
H3. ML (gesture-based) AR stimulates higher interactive experience than MB (tangible) AR.	"Fun" ($F(1, 95) = 3.293$; $p = .073$; $\eta^2 = .034$); "Boring" ($F(1, 95) = 0.083$; $p = .774$; $\eta^2 = .034$)	Supported
H4. ML (gesture-based) AR is associated with a better usability than MB (tangible) AR.	($F(1, 95) = 11.088$; $p = .001$ ML < MB	Rejected
H5. AR produces a greater intention to recommend the brand than MB (tangible) AR.	($F(1, 95) = 6.417$; $p = .013$)	Supported

6. Conclusions

Apart from the utilitarian and practical features of the online shopping experience, the emotional feature is relevant. The participants did not report statistically significant differences between the ML treatment and MB (Table 3 summarizes the results). The reported feelings represent a cognitive elaboration of emotional sensation; thus, they reason out a specific verbalization of that experience (Damásio, 2000). However, the facial and body expression observations show significant differences between the two interface systems. Regardless of the verbalization, participants' moods were distinct.

The facial/bodily reaction was reinforced among those participants who had a previous relationship with the brand/category/website. Apparently, they were having fun during the interactive process and that disposition tended to increase among those with a higher positive emotional trait and who had previously visited the website. The evaluation of usefulness and control over the technology undermined the more sophisticated modality. In that respect, users found the MB condition more attractive than the ML. This evaluation deepens among consumers who have more negative patent emotional traits and those who lack familiarity with both the brand and the website. The speed learning process is instrumental for enhancing the users' feel good sensation with a new technology (Jou, Tennyson, Wang, & Huang, 2016; Mayes & Fowler, 1999). The managerial implications are straightforward, since any investment in terms of communication and sales strategy aims to facilitate and persuade interaction with the product/brand. If the adoption of AR technology is able to overcome that interaction it may contribute to return on that investment. Finally, the ML solution offers more stimulation to consumers to recommend the brand than the MB interface. That tendency is amplified for those who are more prone to adopt innovation and are unfamiliar with the sports shoes website.

No scientific investigation is free from limitations, some of which can be tackled in future research by investigating the use of different types of products and brands, a more balanced gender composition, and more diversified age and educational background groups. The use of biometric measures (for example, heart rate or skin conductance) would complement emotional self-reporting and body/facial observation variables. The existing software/devices of facial expression and/or human bodily activity recognition, as well as the automatic analysis algorithms, are innovative alternative solutions (Boughrara, Chtourou, Ben Amar, & Chen, 2016) to the human observations and manual coding procedures. Both approaches merit some degree of criticism. The methods of human observation and manual coding have a long tradition in several social sciences. Hence, the coding scheme and validation procedures are well tested and widely applied (e.g., Ekman, 2003). However, that method is susceptible to human error and some cultural biases if the observer/coder and the participant do not belong to the same ethnic group. Conversely, the accuracy of the automatic recognition/coding is good for repeated and static images, as long as they match previous scripts defined and tested by humans. The reliability of automated/electronic techniques is still under examination, particularly when it involves moving bodies plus faces and several blended emotions (Basit, 2003; Uddin & Kim, 2016).

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Appendix

Items of the dependent variables

Usability (Lavie & Tractinsky, 2004)	Arousal (Mehrabian & Russell, 1974)
1. Ease of use 2. Intuitive navigation 3. Response speed 4. Organization 5. Ease of control	1. Wide-awake/Sleepy 2. Super active/Passive 3. Enthusiastic/Apathetic 4. Jittery/Dull 5. Unaroused/Aroused
Interactive experience (Cheng et al., 2009; Lavie & Tractinsky, 2004; Westbrook & Oliver, 1991)	
Fun	Boring
1. Interesting 2. Entertainment 3. Gratifying 4. Pleasant	1. Annoying 2. Boring 3. Disappointing 4. Confusing

Items of the covariates

Emotional intensity (Bachorowski & Braaten, 1994)	
Positive emotion inclination	Negative emotion inclination
1. Someone compliments me. I feel: (1 = It has little effect on me…5 = Ecstatic-on top of the world)	1. Something frustrates me. I feel: (1 = It has little effect on me … 5 = So extremely tense and frustrated that my muscles knot up)
2. I am happy. I feel: (1 = It has little effect on me…5 = Euphoric-so happy 1 could burst)	2. I say or do something I should not have done. I feel:(1 = It has little effect on me … 5 = Extremely guilty)
3. Someone I am very attracted to asks me out for coffee. 1 feel:(1 = Ecstatic-on top of the world…5 = It has little effect on me)	3. When someone criticizes me. I feel: (1 = It has little effect on me … 5 = So extremely upset I could cry)
4. I achieve a personal best in my favorite sport. I feel: (1 = It has little effect on me…5 = Ecstatic-on top of the world)	4. People do things to annoy me. I feel: (1 = It has little effect on me … 5 = So extremely annoyed I feel like hitting them)
5. I receive positive feedback from a favorite professor. I feel: (1 = Thrilled-so happy I could burst …5 = It has little effect on me)	5. I have an embarrassing experience. I feel: (1 = It has little effect on me … 5 = So embarrassed I want to die)
6. Something wonderful happens to me. I feel:(1 = Extremely joyful–exuberant…5 = It has little effect on me)	6. Someone I know is rude to me. I feel: (1 = It has little effect on me … 5 = It has little effect on me)
Innovativeness (Goldsmith & Hofacker, 1991)	
1. In general, I am among the last in my circle of friends to buy a new product when it appears on the market. 2. If I heard that a new product was available on the market, I would not be interested enough to buy it. 3. In general, I am the last in my circle of friends to know of a launch of a new product. 4. Compared to my friends, I own a few of the latest new products.	