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Abstract

Virtual reality (VR) displays present an immersive 3D virtual world that convey a sense of presence. These displays are rapidly increasing in fidelity, from traditional 2d desk monitors to head-mounted displays (HMD's) like the Oculus Rift. Research must investigate the relationship between this growing level of fidelity in displays and the virtual experiences they produce, especially as high-fidelity devices become more widespread. Evidence shows that the fidelity of VR displays can affect a variety of factors such as spatial awareness, communication, engagement, arousal, enjoyment, and presence. The current study investigated the potential relationship between the fidelity of VR displays and user's perceptions of others. Participants were randomly assigned to view a virtual avatar deliver a speech on either a high-fidelity HMD VR display or on low-fidelity desktop VR display (traditional 2D monitor). Self-reported perceptions of the presenter's credibility, motivation ability, social and task attractiveness, social presence, and dominance were then compared between the two groups to determine any affects. Fidelity did not impact perceptual evaluations in any significant way. Implications with respect to minimal cues and presence are discussed, as well as limitations and suggestions for future research.

Literature Review

Head-mounted Displays (HMD) such as the Oculus Rift and HTC Vive present advantages over older types of displays, such as traditional desktop monitors. Both devices display virtual environments, which are immersive, interactable 3D environments that are generated by computers (Sanchez-Vives & Slater, 2005), but HMDs display them with greater

fidelity. Fidelity, sometimes called “immersion,” is a system’s capability to deliver a convincing and realistic virtual environment (Buttussi & Chittaro, 2018; Ragan et. al., 2015; S.C. Simon & Greitemeyer, 2019), and there are various factors that differentiate an HMD’s fidelity from that of its lower-fidelity counterparts. Among these factors are the device’s screen resolution, field of view, stereoscopy, headtracking, and input devices, all of which contribute to an experience of the virtual environment that is in many ways truer to life than traditional desktop monitors. Improved fidelity also contributes to an enjoyment advantage for HMDs over desktop monitors (Macquarrie & Steed, 2017; Tussyadiah & Wang, 2018), which likely contributes to the trend of growth in the VR market with VR headset usage doubling in the year 2018 alone (Heaney, 2019). It follows that with the enjoyment advantage of higher fidelity devices, fidelity will continue to improve. Research must investigate the relationship between this growing level of fidelity in displays and the virtual experiences they produce.

In the literature, fidelity has been shown to impact many factors including spatial awareness (Macquarrie & Steed, 2017), communication (Greenwald, Wang, Funk, & Maes, 2017; Smith & Neff, 2018), engagement (Buttussi & Chittaro, 2018), arousal (Simon & Greitemeyer, 2019), and enjoyment (Macquarrie & Steed, 2017; Tussyadiah & Wang, 2018). Most importantly to the current study, device fidelity increases a participant’s sense of presence in a virtual environment (Buttussi & Chittaro, 2018; Simon & Greitemeyer, 2019), which is a participant’s subjective sense of being in a virtual environment rather than the current physical location (Sanchez-Vives & Slater, 2005). Because of this relationship, it can also be said that fidelity impacts behavior since as presence increases, a participant increasingly behaves in the virtual environment as if in an equivalent real environment. This is the case with postural sway (Prothero, Parker, Furness, & Wells, 1995; Freeman, Avons, Meddis, Pearson, & Ijsselsteijn,

2000), after-effects (Welch, 1997), and ducking in response to a flying object (Sanchez-Vives & Slater, 2005). Thus, it follows that as fidelity increases, behavior in the virtual environment becomes increasingly true to life. A limitation to this view however is that not all elements of fidelity contribute to presence (and therefore, behavior) equally. Consider the element of a virtual environment's photorealism which has been demonstrated to not significantly impact presence (Welch, 1997; Zimmons & Panter, 2003). The concept of minimal cues refers to the minimal elements necessary to produce presence (Sanchez-Vives & Slater, 2005), so if the minimal cues are satisfied with a low-fidelity desktop monitor, then additional elements of fidelity, such as the stereoscopy or headtracking of an HMD, would not contribute to behavior in any significant way. Regardless, fidelity's wide range of effects make it an important influence on a virtual experience.

An area of fidelity research that requires further investigation is the effects of fidelity on perception. There are studies that investigate the factors that affect perception of oneself in virtual environments (Yee & Bailenson, 2007; Yee & Bailenson, 2007; Yee, Bailenson, & Ducheneaut, 2009) and on tourism locations (Tussyadiah & Wang 2018), but there are fewer studies that investigate the factors that affect perception of others. Some examples include effects on perception of dominance, (Pazhoohi et. Al., 2018) and perception that others are out to get you (Freeman, et. al., 2014), but typically these relationships are not compared between high and low fidelity devices. The current study therefore investigates the effects of fidelity on perception of others' credibility, dominance, social attraction, task attraction, ability to motivate, and social presence. To assess any effects, perceptions were compared between a low-fidelity group viewing on a desktop monitor and a high-fidelity group viewing on an HMD.

We hypothesized that the HMD for the high-fidelity group would produce more true-to-life perceptions than the desktop monitor. This is because as fidelity increases, a participant increasingly behaves in the virtual environment as if in an equivalent real environment by mechanism of increased presence. The opposing view would hypothesize that the minimal cues would be sufficiently satisfied in the desktop monitor condition so that the addition of fidelity-enhancing elements, such as the HMD's stereoscopy or head tracking, would not contribute in any significant way to presence and the associated behavior change.

Method

Participants

Participants of the study were comprised of a convenience sample of 41 undergraduate students. 27 were female (65.85%) and 14 male (34.15%). Students were recruited from a beginning communications course at Western Michigan University. They received credit for their participation to satisfy a course requirement.

Procedures

Participants signed up through an online system that described the activities of the study as viewing a virtual presenter. They were directed to the virtual reality lab on campus where they would take a seat at a computer and were randomly assigned to either the HMD condition or the PC monitor condition to view the virtual presentation scene. There were 23 participants in the VR condition group, and 18 participants in the PC monitor condition group. Afterwards, participants completed a series of surveys that have demonstrated to be effective for measuring perceptions in the literature (Edwards, Edwards, Stoll, Lin, & Massey, 2019). The surveys

consisted of (a) McCroskey and Teven (1999) Measure of Source Credibility, (b) McCroskey and McCain (1974) measure of interpersonal attraction, (c) Christophel (1990) Student Motivation Scale, (d) a modified version of Walther and Bazarova (2008) social presence scale, a new addition, (e) Burgoon and Judee (1998) interpersonal dominance scale, and (f) a brief demographic survey.

The virtual presentation scene was identical for both conditions. It featured a classroom scene from the perspective of a second-row desk. Participants could interact with the scene by changing their camera view, either by moving the mouse for the pc condition or by moving their head for the HMD condition. No other avatars were in the room except for a virtual presenter at the front. The presenter was an avatar animated via motion capture to deliver a pre-recorded 3-minute speech on the wine industry. The content of the speech was unimportant for the study and only served as a stimulus. A script of the speech is in the appendix.

Dependent Variables

The 18-item credibility measure (Teven & McCroskey, 1999) consists of three semantic differential subscales related to competence (6 items, e.g., Intelligent/Unintelligent), character (6 items, e.g., Trustworthy/Untrustworthy), and caring (6 items, e.g., Concerned with others/Not concerned with others). The measure achieved a reliability coefficient of .928 (Item M=5.13, Item SD=.913).

McCroskey and McCain's (1974) subscale measures task and social attractiveness. Both subscales are 5-item measures with social attractiveness addressing questions such as "We could establish a personal friendship with each other" and task "This voice would be a poor problem solver". Achieved a reliability coefficient of .840 (Item M=2.92, Item SD=.922) for social

attractiveness and .824 for task attractiveness (Item M=3.67, Item SD=.684).

The fifth measure was a 10-item measure of student motivation on a 7 point Likert scale (Christophel, 1990). It achieved a reliability score of .952 (Item M=4.62, Item SD=1347)

The sixth measure was 6-items related to social presence on a sematic differential scale (together…alone; disconnected…connected). It achieved a reliability score of .925 (Item M=3.98, Item SD =1.6)

The seventh and final measure was 32-items measuring interpersonal dominance (i.e. authority), addressing questions such as “This person is very expressive during conversations” and “This person is often the center of attention” (Burgoon & Judee, 1998). [it was used in robotic telepresence study] It achieved a reliability score of .925 (Item M=4.09, Item SD=.354).

Results

Using independent samples T-tests, the 6 dependent variables of credibility, social and task attraction, social presence, student motivation, and dominance were compared between the two display conditions. Participants consistently ranked the HMD condition higher than the PC monitor condition for each of the dependent variables, however, none of these differences were large enough to be significant.

Variable	PC Monitor	HMD	
	M (SD)	M (SD)	p
Credibility	4.95 (.915)	5.28 (.905)	.260
Social Attraction	3.53 (1.53)	4.33 (1.60)	.111
Task Attraction	3.56 (.734)	3.76 (.644)	.357
Motivation	4.24 (1.60)	4.91 (1.32)	.145
Social Presence	3.53 (1.53)	4.33 (1.60)	.111
Dominance	4.06 (.36)	4.11 (.36)	.699

What follows is a discussion of the meaning of the results, the limitations of the study, as well as suggested future research.

Discussion

The hypothesis that the HMD for the high-fidelity group would produce more true-to-life perceptions than the desktop monitor was not supported. Rather, the fact that the HMD's stereoscopy or head tracking did not contribute to perceptual evaluations seems to indicate that

minimal cues were sufficiently satisfied in the desktop monitor condition. There are several other ways to interpret the results, however. It could be that perceptual evaluations of others' qualities is not a "behavior" like postural sway or after effects. As a result, the tendency to behave in virtual environments as if in equivalent real environments as fidelity increases would not apply to perceptual evaluations. Further research could investigate what types of behavior fidelity affects. Additionally, it is possible that questionnaires failed to measure perceptions in a way that could be compared between conditions. Usoh, Catena, Arman, & Slater criticized questionnaires as a measure of presence for "cross-environment" comparisons such as HMDs to desktop monitors (2000). Since the current study investigated the effects of increasing fidelity as a proxy to presence, it is possible that the measurements for perceptual evaluations would likewise be inaccurate.

Of all the dependent variables measured, the differences between the HMD and PC monitor conditions for dominance were the least significant findings with a p value of .699, well above the .05 mark. Research from Pazhoohi et. Al. found support that interpersonal distance is also associated with height and dominance (2018). An alteration to the current study could investigate these findings further by positioning the participant in the virtual space at a seat directly in front of the presenter so that the presenter would invade the participant's comfortable interpersonal distance. Thus, differences between the two display conditions may be more apparent.

One limitation to the study is a flaw in its execution. Due to limited resources, the student co-researcher who facilitated the experiment for participants also delivered the speech used to animate the avatar. The flaw was identified too late in the process to remedy, and the result is that an uncertain number of participants recognized the identity of the virtual presenter as their

facilitator, which may have influenced their perceptions of the presenter. The student facilitator attempted to speak in a quiet voice in the lab to minimize similarities between himself and the presenter, but the problem was exacerbated by the fact that a few participants knew the student facilitator prior to the study and had heard him public speak. Future research should avoid the flaw in execution present in the current study. Despite its flaws, the findings of the current study suggest that previous studies of perceptual evaluations in virtual environments will remain no less relevant as the fidelity of displays improve in the future.

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Appendix

Avatar Wine Speech

The wine industry presents an exciting opportunity for an entrepreneur. It accounts for $5.4 billion of economic impact in the state of Michigan and continues to grow. The opportunity is not without its challenges, however. The wine industry is notoriously difficult to enter. There is enormous complexity when it comes to the exact science of producing the wine, purchasing the right kind of land, maintaining the soil, and so on, but just looking at a list of a winery's typical suppliers helps to capture the grand scope of this complexity.

For example under "cooperage," which is a barrel-maker's business, a winery must deal with suppliers who work in the sanitizing and washing of barrels, build barrel racks, and sell refurbished barrels. Under packaging, there are suppliers who provide label and decorating services, corks, boxes, seals, & wax, label printing, bottle providers, and packaging machinery. Under technology, some suppliers help with off & on-premise sales data to help a winery make strategic decisions. There are pricing analysis applications, accounting, payroll, customer relationship management software, and more. Under vineyard equipment, an entrepreneur can expect to work with pest control services, fencing, irrigation, seeders, and testing.

But what if you don't have the land, the growing and brewing expertise, or the money. Could you still create a winery without dealing with all of these suppliers and other complexities? The answer is yes! You could create a "virtual winery." The 2017 Economic Impact Study of the Michigan Wine Industry defines a virtual winery as "a company that owns, promotes, and/or sells their own brand of wine but has a contract winery produce the wine." In other words, a business person can create a company legally recognized as a winery that doesn't produce its

own wine! Instead, an existing winery would produce the wine, and the company can focus on process of creating and selling their new custom brand of wine.

There are several steps for a business person to create a virtual winery. First, the person must establish the legal entity that will own and sell the wine. Second, the legal entity must establish a contract with the partner winery to set expectations between parties and protect the business relationship. Third, the company must obtain the various wholesaler's licenses & permits necessary to sell the wine to retailers. The fourth and final step is to choose a wine brand name and label and protect them with trademarks. This will give the product a unique identity and make it identifiable to consumers in the marketplace.

What's more is that virtual wineries are surprisingly uncommon in the state of Michigan compared to the rest of the United States. While virtual wineries account for 17.5% of wineries nationwide, only 5% of wineries in Michigan are virtual wineries. This could represent a unique opportunity to start your virtual winery today!