Immersive medical augmented reality that evokes presence and affect

Abstract

The matching relationships between media immersiveness/immersion and presence has received a lot of research attention. With this area of investigation, ample evidence exists to support the hypotheses that show the connection between media immersiveness/immersion and presence, and considerable studies have been carried out to explore the impact of presence. However, important questions about the nature of presence remain unanswered. The aim of this study, thus, is to address this issue both conceptually and empirically. For the empirical investigation of this connection, mixed method was used. As its results, presence was attributed to a systematic effect of media immersiveness. However, the results also showed the statistical significance was reached in most influences of immersive tendency and physician empathy on presence, which were initially controlled as concomitant variables. Further, these variables cancelled out the effect of media immersiveness. Presence is maximally correlated with transportation in its characteristics of high concentration and lost sense of real-world environment. During the interview, medical students illustrated environmental/contextual factors that facilitate perceptual process and emotional process of presence.

Introduction

When healthcare professionals perceive and appraise patients' invisible symptoms by using immersive media technologies, how do they respond? This is the question which is relevant to current situations since an increasing number of healthcare professionals have been exposed to the number of medical augmented reality for patient treatment or rehabilitation and medical surgery or physician training/education (Azuma, 1997; Carmigniani & Furht, 2011; Chen, Day, Tang, &

John, 2017; Hollerer & Feiner, 2004; Peddie, 2017; Peters, 2018). In the areas of patient treatment and rehabilitation, medical augmented reality has been used to augment the impaired functionality of visually impaired people, immobile people, or patients with chronic intractable phantom limb pain by augmenting sensory information and virtual labels (Hollerer & Feiner, 2004; Peddie, 2017; Peters, 2018). In the areas of medical surgery or physician training, surgical data inside patients' internal view is rendered with the view of patients' body structures through the real-time basis. Or, for the physicians who visit their patients are exposed to augmented virtual labels that show the medical history of patients' injuries. A general principle of this medical augmented reality in the context of medical training or education is to augment physicians' views with patients' data. Particularly, medical training or education not only has included medical knowledge acquisition, but also embraced communication skills with patients. In the medical pedagogy, it is important for medical teacher to consider the psychological processing of medical students when they are exposed to patients' suffered moments. For this reason, a more thorough understanding of the psychological processing of augmented reality as the pedagogical tool is required to know the effect of augmented reality on healthcare professionals' learning outcomes.

In this study, presence is suggested as a psychological diameter to evaluate the pedagogical effect of immersive medical augmented reality. Immersive augmented reality is defined objectively and subjectively. Also, two different natures of presence were examined with theoretically and conceptually within two frameworks of media effect and media psychology and measured empirically with its relations to immersive traits of augmented reality, environmental/contextual relationships, and canonical relationships with transportation using mixed method of experimental study and interview study.

Literature review

Presence

Presence has been defined as multidisciplinary concepts. For this reason, scholars in fields of media, information, engineering, computer science, and even art have defined presence differently. Some scholars define it as a more psychological processing occurring during the media exposure. Other scholars pursue it psychological states that happen accordingly to physical characteristics of media technologies. In particular, Schumie (2001) organized six theories that are applicable to the study of nature of presence according to presence as a non-mediation, exclusive (tele-)presence opposed to presence in the real world, presence by involvement, ecological view, estimation theory that combines ecological view and rationalistic view, embodied presence defined with embodied cognition framework. This study adopted three scholarly efforts of five to illuminate the natures of presence suggested by Lombard & Jones (2015): define relevant terminologies, operationalize presence-related characteristics of media technologies, contents, contexts, and users, and enhance the ways to measure it.

With these steps, this study examined the matching relationship between media immersiveness and presence while exploring covariates such as contexts, and users' characteristics or behaviors. Presence scholars have examined this by operationalizing immersion as objective qualities of media technologies and presence as matching response to a given level of these qualities (Biocca, 1992; Slater, 2003; Steuer, 1992). Biocca (1992) suggested output devices that connect computer to human senses by suggesting optimally matched parameters that induce perceptual illusion in each sensory channel. Slater (2003) also suggested presence as a natural response to the given level of immersion by adding the specific condition. According to him, this occurs when there are two mutually exclusive, and competitive systems: one typically real world and the other that renders a given immersive system. Steuer (1992) also

suggested that the condition where telepresence occurs naturally renders virtual environment presented solely via the medium that competes for user's attention. Similar concepts of presence are shown in Sheridan's concepts of telepresence and virtual presence (1992) that refers to "a sense of being physically present" in the mediated environment that is generated by the computer. Lombard and Jones (2015), for this reason, categorized objective form of presence and subjective form of presence (perceptions, feelings, sense, state) of individuals.

In other words, this study explores the presence as a phenomenal moment that maximize user's response to a given level of media qualities that can be measured objectively and reported subjectively. This can be interpreted as the effect naturally aroused/induced by densely designed technological artefact or psychological moment that involves user's allocation of attentional resources when technological parameters were assembled to arouse maximal presence of visual illusion of non-mediation. For this reason, presence is defined as perceptual illusion of non-mediation that involves continuous cognitive and affective responses (Lombard & Ditton, 1997; Lombard & Jones, 2015). For this study, perceptual illusion of non-mediation was defined limitedly as illusion in the visual domain and media stimuli were limited as visual symptoms, whose reasons will be explained in the following section.

Media immersiveness/immersion and presence

For this study, the notion of augmented reality underlying this study is based on the received view of augmented reality (Azuma, 1997; Billnghurst, Kato & Poupyrev, 2001; Hollerer & Feiner, 2004; Milgram, Takemura, Utsumi, & Kishino, 1995). Milgram et al. (1995) defined it within the reality-virtuality continuum. Azuma (1997) introduced three maximal properties of augmented reality as the combination of real-world components and virtual components, geometric registration of them, and technologically facilitated interactivity.

Billinghurst et al. (2001) introduced the collaboration to previous definition so that tangible collaboration was enabled. Hollerer and Feiner (2004) adds mobility to it so that augmented reality does not constrain users' movement to the limited equipped place.

Immersive medical augmented reality is conceptualized for this study to simulate the patients' symptoms for healthcare professionals who are interested in symptoms and their influence on impairment, disability, and activity restrictions of patients. For example, the students in neurology or medical rehabilitation might be interested in symptoms and their influence on functional impairment to restore patients' performance ability. Immersive augmented reality can be defined as augmented reality that simulates presence experience so that users perceive symptoms and their behaviors from others' perspectives. In immersive augmented reality, presence is naturally experienced accordingly to the media immersiveness/immersion as objective quality. Two concepts were conceptually operationalized for this simulation: media immersiveness and presence. They were operationalized based on presence terminologies that were supported by several presence scholars (Biocca, 1992; Lombard & Jones, 2015; Slater, 2003).

To conceptualize immersive medical augmented reality, media form characteristics of augmented reality devices such as display, input, tracking, and mobility should be considered (Azuma, 1997; Carmingniani & Furht, 2011; Hollerer & Feiner, 2004). Display devices are used to allow users to perceive the presence of virtual objects in their mixed environment. Input devices are used to convey the information of users' interaction or movement into the mediated environment/simulation. Tracking devices are applied to facilitate the information exchange process between users and technology. Mobility devices expand the range of augmented reality experiences beyond its equipped area. Among these devices, display devices are assembled for

the purpose of this study that facilitate the medical students' understanding of patients' symptoms and their influence on impaired functionality (Leonardi et al., 2009). According to Carmingniani and Furht (2011), typical types of augmented reality display devices are three: handheld display, HMD, and spatial display. Among these devices, handheld display and HMD were used to simulate immersive augmented reality for medical students' perception of migraine symptoms and patients' dysfunctionality. Display devices were chosen for presence experience based on one visual phenomena: visual capture. This occurs since users' experience is predominantly influenced by visual sense (Azuma, 1997; Biocca, 1992).

Several conditions exist to satisfy the conditions of immersive medical augmented reality. First, the form characteristics of medical augmented reality were considered (Chen et al., 2017; Lombard & Ditton, 1997; Peters, 2018). A medical augmented reality displays data of patients' biological structures to augment physician's view and assist their workflows by tracking the constantly updated status of changing data through the real time basis (Peters, 2018). In other words, display, registration, and tracking suggested by Azuma (1997) were applied to help physicians' workflow. Additionally, for the purpose of this study, media immersiveness or immersion was added to allow medical to perceive patients' symptoms and impaired functionality from their positions. Second, as its content characteristics, patients' data are based on patients' report of symptoms. In this study, migraine visual symptoms, such as photosensitivity, visual snow, and aura, were simulated with apps that displayed these patients' invisible symptoms.

Immersive tendency, physician empathy, and presence

Since the goal of present study is to gain a better understanding of presence of patients' symptoms as media effect directly evoked by immersive medical augmented reality, medical

students' tendencies that mediate this process are controlled. These tendencies include immersive tendency and physician empathy. Immersive tendency is defined as individuals' traits or capacities to involve in presence differently (Hou et al., 2012; Lombard & Ditton, 1997; Weibel & Wissmath, 2011; Weibel et al., 2010; Witmer & Singer, 2003). Physician empathy consists of physicians' cognitive understanding about patients' feelings and situations that involve users' tendencies to experience patients' symptoms and feelings differently (Hojat, 2016; Hojat, 2007; Hojat, Gonnella, Nasca, Mangione, Vergone, & Magee, 2002; Hojat, Gonnella, Nasca, Mangione, Veloski, & Magee, 2001). These two tendencies were controlled to see presence directly experienced by immersive medical augmented reality.

Environmental factors and presence

Since users perceive see the actual environment through augmented reality simulation, the influence of surrounding objects, events, and information on users' presence response to immersive medical augmented reality should be considered to explore the natures of presence. In this regard, media environment can be conceptualized into media environment displayed on media screen and actual environment where users are exposed to those media (Lombard et al., 2000; Lombard, Ditton, Grabe, & Reich, 1997). A former type of media environment is perceived as a virtual environment while the latter type is experienced as actual environment. For this reason, M. Lombard said that users perceive media environment objectively and subjectively (personal communication, July 2018). Based on these theoretical conceptualizations, this study established one primary hypothesis and two research questions.

Hypothesis 1. There will be a significant effect of media immersiveness on presence and transportation when controlling for physician empathy and immersive tendency.

Research question 1. What are the mediated/unmediated characteristics of the media environment or media context that influence the sense of presence or transportation?

Methods

Mixed methods of experiment and interview

Mixed method was designed to explore the true nature of presence evoked by immersive medical augmented reality. In this study, presence is defined as perceptual illusion of non-mediation that involves continuous cognitive and affective responses to a given level of media qualities that can be measured objectively and reported subjectively. Because of this, mixed method can be suggested as one way to maximize the possibilities of experimental psychology which deals with both qualitative psychology and quantitative psychology for a "true representation of what's going on" (Todd, Nerlich, and McKeown, 2004).

Experimental apparatus

As previously mentioned, media immersiveness or immersion was operationalized with the field of view (presence) to assemble immersive medical augmented reality that evokes medical students' presence. Since migraine symptoms are defined biomedically as biological disorders and psychosocially as illness experiences (Kleinman, 1988), its simulations were assembled by using two augmented reality displays: a see-through handheld display as a low immersive condition and an immersive see-through HMD as a high immersive condition (Carmigniani & Furht, 2011; Milgram et al., 1994). In other words, media immersiveness was manipulated with the wide field of view of HMD (Lombard & Ditton, 1997; Loomis et al., 1999), where students perceive virtual symptoms and their own behaviors. Specifically, migraine symptoms such as light sensitivity, white spots, and aura were overlaid onto users' view with

mobile augmented reality app called Migraine Simulator and created in 2017 by E. S. Janikowscy, and simulated with Samsung Galaxy Note 8 only for a see-through handheld display, and both Samsung Galaxy Note 8 and Samsung Gear VR 2018 for an immersive see-through HMD. Students across conditions were asked to 1) perceive the migraine symptoms fully, 2) imagine as if they were patients, and 3) walk while carrying out handheld augmented reality or wearing HMD.

Results

Twenty-seven medical students participated in the experiment. They took the survey right after it. Twenty-three (85%) of them voluntarily participated in the follow-up interviews right after it, two or three days after it, or one week after it. In this study, current scales of Temple Presence Inventory (TPI), immersive tendency (ITQ), Jefferson Scale of Physician Empathy (JSPE), and the transportation scale short form (TS-SF) were used. The survey items were randomized to avoid participants' socially desirable tendencies (Steenkamp, Jone & Baumgartner, 2010).

Data preparation

Factor scores as new data were prepared by imputing missing values, examining multivariate outliers, reliability, and validity (Azur, Stuart, Framgakis, & Leaf, 2011). Multiple imputation was done through the statistical program to replace missing values with imputed variables by creating multiple datasets and using multiple regressions for those imputed variables as dependent variables and all other variables as independent variables until predictions from regressions replaced all of the missing values (Azur et al., 2011). Multivariate outliers and normality were checked by using Mahalanobis distance (Boslaugh & Watters, 2008).

Hilkenmeier et al. (2020) adopted Fornell-Larcker criterion and suggest Cronbach's alpha as a sufficient alternative for average variance extracted (AVE) and a correlation matrix between composite scores to examine discriminant validity of composite scores as another test for the discriminant validity of each factor. Factor scores were computed with the regression method for the independent variables and the Bartlett method for the dependent variables (Devlieger & Rosseel, 2019; Skrondal & Laake, 2001). Their reliability and validity were assessed with Cronbach's alpha and intercorrelations among them (Hilkenmeier et al., 2020).

As its results, a set of immersive tendency as focus had a low reliability coefficient (Cronbach's alpha=.511*)* compared to other set of measurement variables (Refer to Table 1). Its Mahalanobis distance showed that its range of distance from the center is wide (Refer to Table 1). Furthermore, it was highly correlated with other set of immersive tendency as involvement (Refer to Table 2). Thus, the set might be reliable, but not valid.

Table 1.

Reliability and multivariate outliers

Concepts	Index	Cronbach's alpha	Mahalanobis distance
Immersive tendency	Focus	.511	1.21-117.649
	Involvement	.720	1.816-12.242
Physician empathy	Perspective taking	.819	2.136-20.616
	Compassionate care	.648	1.176-18.661
	Standing in patients' shoes	.779	0.091-9.008
Presence	Realism	.905	0.827-16.363
	Immersion	.810	0.433-14.565
	Spatial presence	.643	0.069-11.364
	Social richness	.723	0.944-12.919

Additionally, correlations among factor scores showed correlational patterns among presence and transportation (Refer to Table 2). Presence as immersion was positively correlated with spatial presence (r=.436, p<.05), social richness (r=.715, p<.01), and transportation (r=.686, p<.01). Spatial presence was positively correlated with presence as social richness. Also, there were positively significant associations between presence as social richness and transportation.

Table 2.

Correlations among factor scores

	1	2	3	4	5	6	7	8	9
1.Focus	--								
2.Involvement	.485**	--							
3.Perspective taking	-.228	.113	--						
4.Compassionate care	-.156	-.234	-.348	--					
5.Standing in patients' shoes	.142	-.192	-.354	.144	--				
6.Realism	-.056	.228	.116	-.318	-.198	--			
7.Immersion	.264	.218	-.236	-.091	-.120	.016	--		
8.Spatial presence	.261	.130	-.108	-.008	-.321	.188	.436*	--	
9.Social richness	.101	.144	-.043	-.190	.078	.110	.715**	.420**	--
10.Transportation	.169	.261	-.176	.065	-.004	.046	.686**	.256	.756**

Results

Hypothesis 1: immersive augmented reality and presence

For this hypothesis, three methods were employed: first, binomial sign test was used to know if presence using binary variables can be attributed to a systematic effect; second,

ANCOVA was applied to analyze the portion of variance in presence explained by media immersiveness or immersion excluding exogenous variables of physician empathy or immersive tendency that are assumed to be correlated with presence in this study.

First, since the data was not normally distributed, underlying assumptions of parametric test were not met. For this reason, binomial sign test was used to know whether repeated outcome between two binary conditions can be attributed to the systematic effect (Abdi, 2007; Boslaugh & Watters, 2008)). In this study, a binomial distribution models the survey items as trials in which a repeated binary outcome is counted. Each binary outcome corresponds to two alternatives: when HMD groups experience a higher level of presence than handheld display groups or when HMD groups experience a lower level of presence than handheld display groups. The systematic probability of obtaining this repeated binary outcome in this study is 0.013 ($p<.05$) and it can be concluded that there is a significant difference in presence response between HMD users and handheld display users. Mean rank measures were chosen to compare difference between tendencies of two groups since they have different sample size. According to Boslaugh and Watters (2008), mean rank was calculated by 1) raking thirteen handheld display users and fourteen HMD users from top to bottom, 2) assigning the rank "1" for the lowest score of presence, "27" for its highest score and "average rank" when same ranks occur for more than twice, and 3) adding all the ranks together for each group. HMD group tended to experience a higher level of presence than handheld display users in statistically significant ways.

Table 5.

Binomial sign test of presence

Variables	Conditions	N	Mean ranks	Sig. (2-tailed)
Realism (certainty)	High immersive	14	15.50	0.0129

	Low immersive	13	12.38
Realism (plausibility)	High immersive	14	14.25
	Low immersive	13	13.73
Realism (credibility)	High immersive	14	15.11
	Low immersive	13	12.81
Perceptual realism	High immersive	14	14.86
	Low immersive	13	13.08
Immersion (engagement)	High immersive	14	15.11
	Low immersive	13	12.81
Immersion (involvement)	High immersive	14	16.68
	Low immersive	13	11.12
Immersion (absorption)	High immersive	14	15.75
	Low immersive	13	12.12
Immersion (embodiment)	High immersive	14	13.32
	Low immersive	13	14.73
Spatial presence (self-here)	High immersive	14	16.29
	Low immersive	13	11.54
Spatial presence (other-there)	High immersive	14	14.96
	Low immersive	13	12.96
Social richness (personal)	High immersive	14	15.71
	Low immersive	13	12.15
Social richness (lively)	High immersive	14	16.50
	Low immersive	13	11.31
Social richness (emotional)	High immersive	14	12.89
	Low immersive	13	15.19
Social richness (immediate)	High immersive	14	15.21
	Low immersive	13	12.69

Note. *This is the chance of observing either 12 or more successes, or 2 or fewer successes, in 14 trials

Second, ANOCOVA, at the level of latent variables, was used to know whether there is a main effect of media immersiveness or immersion on presence that cancelled out other covariates, such as immersive tendency and physician empathy. Based on the results of test of homogeneity with Levene's test, items of presence that meet underlying assumptions of ANOVA, presence as immersion with F (6, 20)=.116, p=.736 and the presence as social richness with F (6,20)=.410, p=.528, were used for the analyses. As its results, statistically significant difference of presence as immersion between two augmented reality display groups were observed with probability of p=.053 by removing the effects of physician empathy or immersive tendency.

Table 6.

ANOVA testing differences in immersion (DV) for media immersiveness (IV) with covariates (focus, involvement, perspective taking, compassionate care, and standing in patients' shoes)

Predictors	Sum of squares	Df	Mean square	F	P	partial η^2	partial η^2 90% CI (LL, UL)
(Intercept)	.007	1	.007	.007	.936	.000	
Focus	.426	1	.426	.423	.523	.021	
Involvement	.400	1	.400	.397	.536	.019	
Perspective taking	2.913	1	2.913	2.894	.104	.126	
Compassionate care	.204	1	.204	.203	.657	.010	(.010, .175)
Standing in patients' shoes	1.028	1	1.028	1.021	.324	.049	
Media immersiveness	4.275	1	4.275	4.248	.053	.175	
Error	20.128	20	1.006				

Third, ANCOVA was used at the level of observed variables to analyze the portion of presence as immersion that suppressed the effects of physician empathy and immersive tendency to examine this effect of media immersiveness by considering the measurement errors. As its results, media immersiveness did not have significant effects on presence as immersion. Rather, the effect of physician empathy as perspective taking, such as emotional status of patients and family ("An important component of the relationship with my patients is my understanding of the emotional status of the patients and their families") and the effect of reversely coded compassionate care as intense emotional relationships ("I do not allow myself to be touched by intense emotional relationships between my patients and their family members") were not cancelled out on presence as immersion, such as engagement ("To what extent did you feel mentally immersed in the experience?). Also, another effects of covariates of immersive tendency as focus, such as activity involvement ("Do you ever become so involved in doing something that you lose all track of time?) was not suppressed on presence as immersion, such as absorption ("How completely were your senses engaged?).

Table 7.

ANCOVA testing differences in presence as immersion (DVs) with covariates of immersive tendency and physician empathy

Dependent variables		Treatment, extraneous variables	Mean squares	F	P	Partial η
Latent	Observed					
Presence as immersion	Engagement	Media immersiveness	1.270	.754	.394	.029
		Media immersiveness	3.570	2.613	.119	.098
		Physician empathy (Emotional status of patients and family)	9.348	6.842	.015	.222
		Media immersiveness	.686	.469	.500	.019

	Physician empathy (Intense emotional relationships)	7.032	4.807	.038	.167
Absorption	Media immersiveness	2.201	1.396	.249	.053
	Media immersiveness	.753	.546	.467	.022
	Immersive tendency (Activity involvement)	6.328	4.589	.043	.161

Research question 1: environmental factors and presence

In this study, interview questions were additionally designed to explore the mediated or unmediated environmental factors that facilitate the presence as psychological phenomena in the augmented reality learning environment based on the rules suggested by the APA Publication manual (7^{th} ed). As previously mentioned, experimental stimuli combined two different augmented reality display devices: immersive virtual environment display and see-through display (Hollerer & Feiner, 2004; Lombard et al., 2000; Lombard et al., 1997; Loomis et al., 1999; Milgram et al., 1994). According to Loomis et al. (1999) and Hollerer and Feiner (2004), when HMD set is used to simulate augmented reality, it combines affordances of immersive virtual environment display and see through displays, which allows medical students to have action possibilities to be immersed in presence as virtual sensation facilitated by technology while perceiving the real environment through it. Also, in-depth interview revealed medical students' motivation to be fully attentive to patients' symptoms through real-life behaviors in more natural settings.

Immersive virtual environment and presence. 70% of participants were fully attentive to patients' symptoms from professional stance when participants' perceptions were fully surrounded by perceptual illusion of virtual sensation. This was provided when experimental

environment was controlled from external stimuli except the environmental factors that optimally represent symptoms, such as light. Participant O said that the well-manipulated study room helped him attend to the simulated visual symptoms.

> Oh, I would say, I feel. Also, the room being quieter allow me to get into it more having to experience this (Participant O).

Participant V also said that well-controlled study room enabled him to focus on simulated visual symptoms as opposed to the external stimuli of natural environment.

> (I) guess, in this room, since it is pretty quiet and isolated, there is no outside stimuli to take away from it. So, you (can) get more focused on that. Versus if we were doing this out in the hallway when people talking, everything else would be a lot more difficult to be more immersed. Yeah, focus on it (Participant V).

However, participants' perception of these two competing stimuli became attenuated when they were perceptually surrounded by HMD sets. Participant J said that tactile stimuli to grab the mobile phone and visual stimuli from actual environment interrupted her full sense of presence while HMD sets afforded her chances to fully focus on visual symptoms.

> With the phone, I was just too aware that I was holding a phone and since I could still see around the phone where my vision was normal. It was not as immersive that way. And, again, with the headset, since I could not see anything but the screen, it was more immersive, and I did not have to focus on holding anything right (Participant J).

Participant Q said that absence of sensory cues that connect his perception to mediated experiences enhanced his sense of presence by helping him to use the HMD field of view as if it were his actual vision.

> Is this a video or is this my actual vision? It is more tilted towards my actual vision because all the cues I have of videos were not there. I was lack in all of these cues whereas, when I have the phone, having a phone is one cue, having the phone from a distance, that is another cue, and seeing this move on the screen that is the third cue. With the headset on, I was not holding anything. So, that is one of the cues that are associate with the video that was eliminated. It was not a distance that it was my actual vision would be. So, there was not anything between that. There was not anything between what I would see it and myself. So that was another cue that was eliminated. And yes, I actually felt pretty real (Participant Q).

Furthermore, inclusion of expected patients' real-life behaviors in natural setting such as imagination and walking rather inhibited the full sense of presence. For example, participant K commented that his perceptual differentiation between immersion felt inside the virtual sensation and his awareness about the actual environment deterred his full sense of presence in symptoms.

> I felt like, I was immersed in this virtual space, but I was fully aware of being here and like I said there is a disconnect between the visual of what I was seeing and what I was feeling around me. So, it did not feel like it was real. I felt immersed in this kind of synthetic world though (Participant K).

Participant P also said that his involvement in walking behaviors interrupted his sense of presence by differentiating his visual processing to be attentive the symptoms with another perceptual needs to perceive the room to navigate it.

> It was immersive. It was a little bit clumsy because I think the room is so small. That is why my attention was so divided. I could not walk around freely. It was like, I had to focus on not running into the wall or following. you know, so I think if it was a little bit easier to move around, you might be able to be more immersed because you do not have to worry about it falling over (Participant P).

Immersive mixed environment seen through the display and presence. 74% participants' feelings of immersion were extended to their actual environment seen through the display by imagination and behaviors. For example, participant C tried his mundane activities and perceived them until he felt immersed in patients' symptoms.

> I tried to apply my every, daily living activities as much as I could with the setting. I was trying to see how person with migraine feel. By doing that, I got more and more immersed. I forgot and I tried to forget that I was having the set. It did not happen right away, but after ten or fifteen minutes, I started less thinking about it as a set and on my head. I was having the symptoms. Also, I was trying to imagine having a headache and all this. So, I also tried to work on to add to and see how far I can get closer to a person with migraines (Participant C).

Participant L also tried her daily activities and perceived them until she was immersed in patients' symptoms. Furthermore, her imagination, visual memory, and retrieval came into

play in this process. In other words, her currently incoming visual stimuli and internal representation allowed her to feel immersed in patients' symptoms.

> So, I was just trying to imagine, if that was, if I woke up today and that was, How, what happened when I got into this room, just really trying to. That is why I opened my pill bottle because I have to take a pill every day. Would I be able to do that? You know, I was trying to do things that I would regularly do. I could write my name, read the news, and so I think, trying to make it as realistic for myself as possible, but also with the mindset of like, OK, I woke up this morning and this is what happened. And now, here we are. And, you know, what is this going to be like? I think that is what made me completely immerse. And then, I mean this app itself was, I think, very well made in that. It still felt like I was, you know, totally my normal in this environment (Participant L).

Participant S commented her internal motivation to extend understanding of symptoms into patients' real-life difficulties in more natural setting.

> I think, just the fact that we are in like a small room and, it is not like, I am going everyday life. It is not like we are outside like in a normal scenario and I am walking around and experiencing the symptoms. So, I feel like, that is obviously very difficult to do especially with the current weather. But, if I was like walking around outside, or something like that, then I would get a better understanding of what it is like in actual real life and not just in like a test setting (Participant S).

Discussion

As a part of project that examines the influence of augmented reality and presence on empathetic response of physicians, the process of presence directly evoked by technology was a current focus of this paper based on the matching relationship between media immersiveness or immersion and presence in augmented reality. Several theoretical implications were found during this process.

First, the results of this study showed effects of a wide field of view on presence. As the results of binomial sign tests showed, there were systematic differences in presence between high immersive conditions of HMD user group and low immersive conditions of handheld display user group ($p=.013$). In its following analysis of covariance, these differences were also shown as significant effects of different levels of media immersiveness on presence as immersion that

cancelled out the influences of physician empathy or immersive tendency with probability of 0.53. Though the probability was not acceptable as a statistically significant level, it was interpreted as significant since it showed possibilities of more robust results that lead to statistically reliable significance based on a larger sample size. In the follow-up analysis, however, other psychological factors were found as covariates that were not cancelled out in this process. This showed that there are psychological factors that influence the sense of presence more than media immersiveness when considering measurement errors.

Second, in the follow-up interview, medical students' affect, memory retrieval, and imagination came into play as unexpected incoming stimuli in this process of presence. However, medical students commented their potential effect differently. When they focused the accurate perception of symptom, they thought that these stimuli as competitive one that might deter their full sense of presence in the symptoms. In contrast to this, when they wanted to be emotionally attentive to dysfunctionality as difficulties, they used these stimuli to be fully immersed in symptoms. These results might suggest possible complementary reasons why presence evoked by HMD sets were attenuated when considering covariates in the quantitative study.

Third, as several scholars mentioned about the effect of immersive virtual environment on presence from the perspective of virtual reality (Loomis et al., 1999; Slater, 2003; Steuer, 1992), there are needs to think about the effects of perceptual allocation of attentional resources led by two different displays, environment, perceived stimuli and behaviors, and evoked memory, feeling, and imagination in presence from the perspective of augmented reality. In contrast to virtual reality environment which renders virtual environment scenes distinctively from its external stimuli, this augmented reality displays simulated by HMD sets and mobile

handheld display enabled users to be exposed to both the real environment and virtual environment that involves users' cognitive and affective response differently in this process. Thus, this offers questions on how affective components influence in this perceptual process of presence.

References

Abdi, H (2007). Binomial distribution: binomial and sign tests. In *Encyclopedia of measurement and statistics* (1). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.77.3055&rep=rep1&type=pdf

Azuma, R. (1997). A survey of augmented reality. *Presence: Teleoperators & Virtual Environments, 6*(4), 355-385. 10.1162/pres.1997.6.4.355

Azur, M. J., Stuart, E. A., Frangakis, C., & Leaf, P. J. (2011). Multiple imputation by chained equations: what is it and how does it work?. *International journal of methods in psychiatric research*, *20*(1), 40-49. 10.1002/mpr.329

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The magic book-moving seamlessly between reality and virtuality. *IEEE Computer Graphics and applications*, *21*(3), 6-8.

Biocca, F. (1992). Virtual reality technology: A tutorial. *Journal of Communication*, *42*(4), 23-72. 10.1111/j.1460-2466.1992.tb00811.x

Boslaugh, S., & Watters, P. A. (2008). *Statistics in a nutshell: A desktop quick reference*. CA, Sebastopol: O'Reilly.

Carmigniani, J., & Furht, B. (2011). Augmented reality: Overview. In B. Furht (Eds.), *Handbook of augmented reality*. Boca Raton, FL: Taylor & Francis Group. 10.1007/978-1-4614-0064-6

Chen, L., Day, T. W., Tang, W., & John, N. W. (2017, October). Recent developments and future challenges in medical mixed reality. In *2017 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)* (pp. 123-135). IEEE.

Devlieger, I., & Rosseel, Y. (2019). Multilevel factor score regression. *Multivariate Behavioral Research*, 1-25. 10.1080/00273171.2019.1661817

Hilkenmeier, F., Bohndick, C., Bohndick, T., & Hilkenmeier, J. (2020). Assessing distinctiveness in multidimensional instruments without access to raw data: A manifest Fornell-Larcker criterion. *Frontiers in Psychology*. 11. 10.3389/fpsyg.2020.00223

Hojat, M. (2007). *Empathy in patient care: Antecedents, development, measurement, and outcomes*. New York, NY: Springer Science & Business Media. 10.1007/0-387-33608-7

Hojat, M. (2016). *Empathy in health professions education and patient care*. New York, NY: Springer. 10.1007/978-3-319-27625-0

Hojat, M., Gonnella, J. S., Nasca, T. J., Mangione, S., Vergare, M., & Magee, M. (2002). Physician empathy: definition, components, measurement, and relationship to gender and specialty. *American Journal of Psychiatry, 159*(9), 1563-1569. 10.1176/appi.ajp.159.9.1563

Hojat, M., Mangione, S., Nasca, T. J., Cohen, M. J., Gonnella, J. S., Erdmann, J. B., ... & Magee, M. (2001). The Jefferson Scale of Physician Empathy: development and preliminary psychometric data. *Educational and psychological measurement, 61*(2), 349-365. 10.1177/00131640121971158

Hollerer, T. H., & Feiner, S. K. (2004). Mobile augmented reality. In H. Karimi & A. Hammad (Eds.), *Teleinformatics: Location based computing and services*. New York, NY: CRC Press.

Hou, J., Nam, Y., Peng, W., & Lee, K. M. (2012). Effects of screen size, viewing angle, and players' immersion tendencies on game experience. *Computers in Human Behavior, 28*(2), 617-623.

Kleinman, A. (1988). *The illness narratives: Suffering, healing, and the human condition*. Basic books: A Member of the Perseus Books Group. 10.1016/j.chb.2011.11.007

Lombard, M., & Ditton, T. (1997). At the Heart of It All: The Concept of Presence. *Journal of Computer-Mediated Communication, 3*(2). Retrieved from https://onlinelibrary-wiley-com.libproxy.temple.edu/doi/full/10.1111/j.1083-6101.1997.tb00072.x

Lombard, M., & Jones, M. T. (2015). Defining presence. In M. Lombard, F. Biocca, J. Freeman, W. Ijsselsteijn, & R. J. Schaevitz (Eds.), *Immersed in media: Telepresence theory, measurement & technology*. New York, NY: Springer Publishing Company. 10.1007/978-3-319-10190-3

Lombard, M., Reich, R. D., Grabe, M. E., Bracken, C., & Ditton, T. B. (2000). Presence and television: The role of screen size. *Human Communication Research, 26*, 75–98. 10.1111/j.1468-2958.2000.tb00750.x

Loomis, J. M., Blascovich, J. J., & Beall, A. C. (1999). Immersive virtual environment technology as a basic research tool in psychology. *Behavior Research Methods, Instruments, & Computers, 31*(4), 557-564. 10.3758/bf03200735

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995, December). Augmented reality: A class of displays on the reality-virtuality continuum. In *Telemanipulator and telepresence technologies* (Vol. 2351, pp. 282-293). International Society for Optics and Photonics. 10.3929/ethz-a-010002635

Peddie, J. (2017). *Augmented reality: Where we will all live*. Tiburon, CA: Springer.

Peters, T. M. (2018). Overview of mixed and augmented reality in medicine. In T. M. Peters, C. A. Linte, Z. Yaniv, J. Williams (Eds.), *Mixed and Augmented Reality in Medicine* (pp. 1-11). New York, NY: Taylor & Francis Group. 10.5811/westjem.2017.10.35026

Schuemie, M. J., Van Der Straaten, P., Krijn, M., & Van Der Mast, C. A. (2001). Research on presence in virtual reality: A survey. *CyberPsychology & Behavior*, *4*(2), 183-201. 10.1089/109493101300117884

Skrondal, A., & Laake, P. (2001). Regression among factor scores. *Psychometrika*, *66*(4), 563-575. 10.1007/bf02296196

Slater, M. (2003). A note on presence terminology. *Presence Connect*, *3*(3), 1-5. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.800.3452&rep=rep1&type=pdf

Steenkamp, J. B. E., De Jong, M. G., & Baumgartner, H. (2010). Socially desirable response tendencies in survey research. *Journal of Marketing Research*, *47*(2), 199-214. 10.1509/jmkr.47.2.199

Steuer, J., 1992. Defining virtual reality: Dimensions determining telepresence. *Journal of Communication 42*(4), 73–93. 10.1111/j.1460-2466.1992.tb00812.x

Todd, Z., Nerlich, B., McKeown, S. (2004). Introduction. In Z. Todd, B. Nerlich, S. Mckeown, & D. D. Clarke (Eds.), *Mixing methods in psychology: The integration of qualitative and quantitative methods in theory and practice*. New York, NY: Psychology Press. 10.4324/9780203645727

Weibel, D., & Wissmath, B. (2011). Immersion in computer games: The role of spatial presence and flow. *International Journal of Computer Games Technology, 6.* 10.1155/2011/282345

Weibel, D., Wissmath, B., & Mast, F. W. (2010). Immersion in mediated environments: The role of personality traits. *Cyberpsychology, Behavior, and Social Networking, 13*(3), 251-256. 10.1089/cyber.2009.0171

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence, 7*(3), 225-240. 10.1162/105474698565686