12-12-2020

The Effect of Sociability on Socio-spatial Interaction and Learner Social Presence in Mixed-Reality Online Learning Environments: Using Head-mounted Wearable Items in Group Learning Activities

Aydin Farrokhi

Milena Head

Brian Detlor

The Effect of Sociability on Socio-spatial Interaction and Learner Social Presence in Mixed-Reality Online Learning Environments: Using Head-mounted Wearable Items in Group Learning Activities

"*Research in Progress*"

Aydin Farrokhi
McMaster University
aydin.farrokhi@mcmaster.ca

Milena Head
McMaster University
headm@mcmaster.ca

Brian Detlor
McMaster University
detlorb@mcmaster.ca

ABSTRACT

In online learning environments, little is known regarding the effect of head-mounted wearable devices on group learning behavioral outcomes, and the impact the mediated communication type has on socio-spatial interactivity and learner social presence. Interaction and presence are two important concepts that influence group activity. Drawing on social interaction, social presence, and the characteristics of mixed-reality environments, we develop and empirically test hypotheses on the effectiveness of three different types of digitally mediated mixed-reality learning environments.

Keywords

Virtual environments, behavioral outcomes, group activity, online learning, mixed-reality , socio-spatial interactivity, social presence.

INTRODUCTION

Many students opt for in-person learning engagement and interaction because they assume that computer-mediated environments will limit their ability to build interpersonal connections. They believe that most computer-mediated learning environments are designed for specific tasks and lack essential socio-emotional support for collaborative learning (Kreijns, Kirschner, Jochems, & van Buuren, 2007). However, this assumption might not hold any longer because technological advancements have introduced greater capabilities in transferring sensual cues and providing a broader range of control choices in mixed-reality environments. In mixed reality, perception of the real world is created in the mind of the learner by augmenting virtual objects, such as displayed information, three-dimensional (3D) figures, and simulation of phenomena in real instructional settings (Chen & Wang, 2018).

In Virtual Reality (VR) and Augmented Reality (AR), participants can interact with virtual objects such as markers, whiteboard, prototypes, and virtual others (Sonalkar, Mabogunje, Miller, Bailenson, & Leifer, 2020). Physical movements, including head and body movements, can be transferred through mixed-reality environments (Bailenson & Machi, 2018). In such conditions, online group activities can go beyond the purely cognitive. For example, mixed reality's immersive nature makes it easier to perform tasks such as role play in group settings than in 2D-mediated environments. However, recognizing other participants' virtual representative and interacting with them becomes crucial for successful social interaction in a mixed environment. One inspiring finding by Sonalkar et al. (2020) demonstrates that including virtual representation of others (avatars) in designing teamwork actually promotes the other team members' presence and improves members' self-efficacy.

We have conducted this research to answer the following research questions:

RQ1. What are the relationships between sociability, socio-spatial interactivity, learner presence, and social space in a mixed-reality online learning environment?

RQ2. How does the communication channel type, namely 3D augmented reality (using HoloLens), 3D virtual reality (using HTC Vive), and 2D computer-mediated environments (using Zoom), impact the group members' behavioral outcomes?

In this research, relative comparisons of sociability, socio-spatial interactivity, social presence, and group behavioral outcome of two innovative technology-mediated learning environments, namely augmented reality (AR) and virtual reality (VR), with a traditional web-conferencing-based learning environment will be conducted.

Online Education

Online learning is a platform enables outreach to a greater number of learners by making the learning materials available anywhere and anytime via the Internet (Chang, 2016). Several advantages were identified for the adoption and implementation of online learning educational models.

These included cost reduction, improved accessibility of education, uniformity of content, and improved quality of learning content (Perna et al., 2014). There are two delivery methods for online learning, synchronous and asynchronous. The difference between the two is the time lag required for performing learning tasks (Panigrahi, Srivastava, & Sharma, 2018).

Socio-Technical Dimension in Online Education

Sociability and its effect on learners' perception of online learning have been much discussed because many believed that computer-mediated communication was not rich enough to communicate effectively (Richardson, Maeda, & Swan, 2010). Students in online learning environments have complained about feeling isolated and disconnected from their peers and instructor. Further, many students expressed they were not prepared for learning in online environments. Given the circumstances, many online learners perceive online education as an inferior educational experience, which, in turn, has led to higher dropout rates among online learners (Liu, Gomez, & Yen, 2009; Richardson, Maeda, Lv, & Caskurlu, 2017).

Previous studies show that student engagement in learning activities has a positive impact on information retention (Miller, McNear, & Metz, 2013), confidence with learned material (Wilke, 2003), and heighten attention (Steinert & Snell, 1999). The effect of interactions on student engagement varies across settings (Nicholson, Nicholson, Shen, & Song, 2019).

AR and VR in Education

Augmented reality (AR) and virtual reality (VR) technologies are gaining attention in the education domain (Chen & Wang, 2018; Matsutomo, Miyauchi, Noguchi, & Yamashita, 2012).

In general, VR forms a mental representation of the environment where users can experience the virtual environment as a physical world. VR participants are transported to an artificial world that is created digitally. It requires various cognitive engagement to navigate, orient, appropriate, differentiate, and interact in this environment (McCreery, Vallett, & Clark, 2015). In AR technology, digital representation of objects are added into existing physical environments.

Mixed reality (MR) is neither total immersion nor complete synthesis. But, depending on the environment in which the participant is intended to feel part of, the mixed reality concept can relate to a broad spectrum of the virtual continuum (Milgram & Kishino, 1994). Integrating a different proportion of real and virtual objects in design results in a mix that can belong to an entirely real environment at one end of the spectrum, or a fully immersed virtual environment at the other (Milgram & Kishino, 1994). Depending on the intended use, mixed reality can address different needs.

LITERATURE AND HYPOTHESES DEVELOPMENT

Sociability

Sociability is defined as the perceived quality of the characteristics of a mediated learning environment that facilitate interaction (Weidlich & Bastiaens, 2017). Sociability has been viewed as a technical aspect of a computer-supported collaborative learning (CSCL) environment (Laffey, Lin, & Lin, 2006). In CSCL, technological properties determine the degree to which the sociability is afforded (Kreijns, Kirschner, & Vermeulen, 2013). To explain, Kreijns et al. (2013) compare a CSCL's sociability to the coffee machine in an office, where the coffee machine facilitates informal conversation. In some cases, these conversations are non-task related; yet, these social interactions can serve as a foundation for promoting group development. Therefore, the sociability afforded by mixed reality can be defined as the degree to which the medium can facilitate a sustainable social interaction among learners.

Socio-Spatial Interactivity

The interaction concept is defined as the amount and frequency of communication between a given learner and their peers (Weidlich & Bastiaens, 2017). To interact with and within a mediated environment, whether in a virtual space or physical environment, participants must gain a minimum familiarity with the space. Virtual spaces require their participants to develop a set of spatial abilities (McCreery, Schrader, & Krach, 2011). These abilities are manifested through a set of cognitive functions divided into four domains: spatial positioning, spatial realization, spatial appropriation, and interactive possibility (Webb, 2001). Initially, the concept of "interactive possibility" equated to the spatial interactivity and was described as the ability to interact with a broad range of system and environmental stimuli, participants, and non-participant characters (McCreery et al., 2011; Webb, 2001). McCreery et al. (2011) then divided Webb's interactive possibilities into two spatial interactivity and socio-spatial interactivity constructs. Spatial interactivity exclusively referred to interacting with artificial intelligence agents and non-player characteristics. In contrast, socio-spatial interactivity referred to the ability to employ social channels to perform prosocial activities such as initiating group activities. Similarly, in a mixed-reality world, where virtual objects can be free from physical boundaries, various cognitive processing is required to navigate and interact with virtual objects and space. Therefore, since the learning environment's sociability facilitates social interaction, we propose:

H1. Sociability is a predictor of how much social-spatial interactivity will take place.

Social Presence

Although the nature of mixed environments appears to provide the means required for social interactivity, other

studies also show that social presence influences the salience of participants' experiences in digitally mediated environments (McCreery et al., 2015; Short, Williams, & Christie, 1976). Oh, Bailenson, & Welch (2018) systematic review of social presence in virtual reality suggests that the social presence concept is best referred to as "the feeling of being there with a real person" in a virtual environment. It is a subjective experience that shapes one's belief in having access to other participants' thoughts and emotions (Biocca, 1999). A variety of behavioral outcomes are associated with social presence. For example, social presence influences purchase intention on shopping websites (Hassanein & Head, 2007) and improves virtual team performance (Miranda & Saunders, 2003). In online learning, social presence is associated with learners' satisfaction with their instructor and peers (COBB, 2011; Richardson & Swan, 2003), reduced need for structured courses and move towards intent-based learning systems (Horzum, 2015), and willingness to facilitate collaboration among other learners (Akcaoglu & Lee, 2018).

Virtual systems are designed to transfer social signals such as visual, audio, and haptic cues. System properties, the context, and the individual traits of participants all can influence the interactant's perceptions of social presence (Oh et al., 2018). In this sense, virtual environments are a novel communication medium wherein participants can co-exist and interact (Biocca & Levy, 2013). Therefore, we propose:

H2. The quality of socio-spatial interaction influences the degree to which a member feels present.

Social Space: Virtual Group Behavioral Outcomes

Group members come together in order to engage in solving problems that are mutually beneficial to the participants. A social space refers to the group's norms, values, beliefs, roles, and rules that structure the social relationships among the members (Kreijns et al., 2007). It represents the group's work relationship, cohesiveness, trust, and sense of community (Kreijns et al., 2013). These qualities define the context in which collaborative learning takes place. The experience of social presence influences individual's prosocial behavior (Kothgassner et al., 2017). Prosocial behaviors are actions that are intended to benefit others such as helping, cooperating, sharing, and comforting. In an experimental study, Kothgassner et al. (2017) showed that virtual social exclusion lowers the individuals self-esteem and feelings of belonging, and inhibits prosocial behaviors. Feeling excluded can lead to a range of withdrawal behaviors such as a decrease in happiness, uncertainty, and distance (van Bommel, van Prooijen, Elffers, & Van Lange, 2016).

H3. The degree to which social presence of members is perceived influences the behavioral outcomes in virtual groups.

Not all group behavioral outcomes are explained by social presence. From the interpersonal relationship point of view, the connection between two members can be weak or strong (Kreijns et al., 2013); however, members' shared goal or certain technological features of the mediated environment can facilitate prosocial group behavior. The ability to combine real-world and virtual elements, interact in real-time, and experience 3D mixed-reality environments can provide settings in which group tasks are achieved even with weak relationships.

H4. The extent to which socio-spatial interactivity facilitates the group task-related interactions influences the establishment of a social space.

The Role of Mediated Communication Types

Huang et al. (2019) compared the impact of AR and VR technologies on learning outcomes. They measured attention, spatial presence, enjoyment, and learning outcome to study the relationships between attention and learning outcomes in AR- and VR-mediated environments. The authors showed that when participants are in a VR environment, they attend more closely to visual information and feel more of a spatial presence than with AR. In contrast, participants paid more attention to auditory information in an AR-mediated environment than VR. In their study, spatial presence equated to "presence" in general terms and was defined as "the subjective experience of physically being in a virtual or mediated environment." Based on the perceptual load theory (Raveh & Lavie, 2015), human attentional capacity is limited and is shared across all sensory inputs. The high perceptual load caused by visual sensory in VR environments can reduce auditory detection sensitivity. The high level of visual experience in VR overloads the participant's visual perceptual load, thereby limiting the ability to pay attention to auditory-related information (Huang et al., 2019). Based on this argument, we hypothesize that:

H5 & H6. In the spectrum of mixed-reality domains, the level of immersion in mixed-reality environments (immersiveness) impacts on group learning activities.

The Model

We are building on the SIPS (Sociability, Social Interaction, Social Presence, Social Space) model proposed by Weidlich & Bastiaens (2017). This framework is an extension of Kreijns et al. (2007) and Kreijns et al. (2013) models that theorize and validate the relationships between sociability, social presence, social interaction, and social space in computer-supported collaborative learning environments. Weidlich and Bastiaens (2017) used a different method and examined socio-emotional components based on an ecological approach. Their study supported Kreijns et al. (2013) work that sociability is a predictor for social interaction, and social interaction predicts social presence in an online learning environment. Weidlich and Bastiaens (2017) used the threads collected through communication messaging boards and biweekly non-mandatory chats in a Moodle-based distant education model. Our framework emphasizes and tests the role of

sociability afforded via different mixed-reality types in an online learning environment. Therefore, the Sociability and Socio-spatial interactivity factors become two important factors in our model.

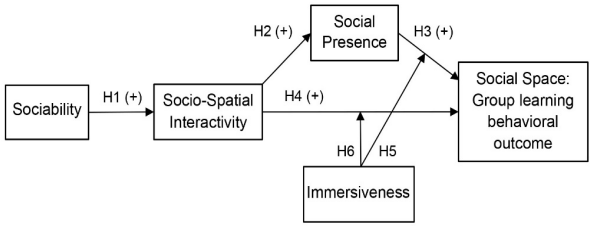

Figure 1. Theoretical Model: Integration of Our Hypothesized Relationships and SIPS Model

METHODOLOGY

Participants

The study examines group activity behavioral outcomes under time constraints. This condition has been common in booking group study rooms in universities and organizational group decision-making practice (Miranda & Saunders, 2003). Groups consist of five or six members, a typical number of students per study group in a classroom setup, and will be drawn from both undergraduate and graduate classes at a local Canadian university.

Procedure

Participants are randomly assigned to one of three groups. Each group is randomly assigned to one of three conditions following a Web-based 2D application/AR/VR within-subjects design. The experiment will be repeated three times. In the next round, the groups are assigned to one of three conditions randomly; however, we ensure that no group experiences the same mediated communication channel twice. Group members remain in the same group while performing their group assignments in all three experiments. Prior to the study, participants will receive about 10 minutes of training on using the technology to work through the assignments.

Following Kothgassner et al. (2017) procedure design, participants are asked to fill out survey questionnaires and answer an open-ended question about their group activity experience immediately after the experiment. The overall procedure will last 2.25 hours (3 x 45 min) per participant.

Measures

The sociability variable is adapted from the existing sociability scale developed by Kreijns et al. (2007). It is a self-reporting questionnaire that is developed to measure the perceived sociability of a mixed-reality environment.

The socio-spatial interactivity and social presence variables are drawn from previous behavioral protocols. To measure socio-spatial interaction within the virtual environment, we use the Behavioral Assessment Matrix instrument (McCreery et al., 2015). It is a partial interval recording sampling procedure. The social presence protocol is based on Social Presence Model. The model was developed and validated in an educational setting (Learning Management Systems) and later customized and validated by McCreery for application to a virtual environment.

We used the existing social space scale developed by Kreijns et al. (2007) to measure the social space's perceived quality. The scale consists of two dimensions representing positive group behaviors and negative group behaviors. This scale is validated, and the uniqueness of its items was tested by principal component analysis.

DISCUSSION AND CONCLUSION

Educators need to consider the differences among virtual learning environments that may provide the rationale for educated decision making about which virtual environment is most appropriate for their educational needs.

While VR is shown to be more immersive and engaging, AR is expected to be a more effective medium to establish a social space to convey online group activities. Therefore, in the spectrum of mixed-reality, augmented reality environment is more suited for group learning activities.

REFERENCES

1. Akcaoglu, M., & Lee, E. (2018). Using Facebook Groups to Support Social Presence In Online Learning. *Distance Education*, *39*(3), 334–352.
2. Bailenson, J., & Machi, V. (2018). Experience on Demand: What Virtual Reality Is, How It Works, and What It Can Do. *National Defense*, *102*(772), 4.
3. Biocca, F. (1999). The Cyborg's Dilemma: Progressive Embodiment in Virtual Environments. In *Human Interfaces, Human Factors in Information Technology* (Vol. 13, pp. 113–144).
4. Biocca, F., & Levy, M. R. (Eds.). (2013). *Communication in the Age of Virtual Reality*. United Kingdom, Europe: Routledge.
5. Chang, V. (2016). Review and discussion: E-learning for academia and industry. *International Journal of Information Management*, *36*(3), 476–485.
6. Chen, Y.-H., & Wang, C.-H. (2018). Learner Presence, Perception, and Learning Achievements in Augmented-Reality-Mediated Learning Environments. *Interactive Learning Environments*, *26*(5), 695–708.
7. COBB, S. C. (2011). Social Presence, Satisfaction, and Perceived Learning of RN-to-BSN Students in Web-Based Nursing Courses. *Nursing Education Perspectives*, *32*(2), 115–119.
8. Hassanein, K., & Head, M. (2007). Manipulating perceived social presence through the web interface and its impact on attitude towards online shopping. *International Journal of Human - Computer Studies*, *65*(8), 689–708.
9. Horzum, M. B. (2015). Interaction, Structure, Social Presence, and Satisfaction in Online Learning. *Eurasia Journal of Mathematics Science and Technology*

Education, *11*(3), 505–512.
10. Huang, K.-T., Ball, C., Francis, J., Ratan, R., Boumis, J., & Fordham, J. (2019). Augmented Versus Virtual Reality in Education: An Exploratory Study Examining Science Knowledge Retention When Using Augmented Reality/Virtual Reality Mobile Applications. *CyberPsychology, Behavior & Social Networking*, *22*(2), 105–110.
11. Kothgassner, O. D., Griesinger, M., Kettner, K., Wayan, K., Völkl-Kernstock, S., Hlavacs, H., … Felnhofer, A. (2017). Real-Life Prosocial Behavior Decreases After Being Socially Excluded by Avatars, Not Agents. *Computers in Human Behavior*, *70*, 261–269.
12. Kreijns, K., Kirschner, P. A., Jochems, W., & van Buuren, H. (2007). Measuring Perceived Sociability of Computer-Supported Collaborative Learning Environments. *Computers & Education*, *49*(2), 176–192.
13. Kreijns, K., Kirschner, P. A., & Vermeulen, M. (2013). Social Aspects of CSCL Environments: A Research Framework. *Educational Psychologist*, *48*(4), 229–242.
14. Laffey, J., Lin, G. Y., & Lin, Y. (2006). Assessing Social Ability in Online Learning Environments. *Journal of Interactive Learning Research*, *17*(2), 163–177.
15. Liu, S. Y., Gomez, J., & Yen, C.-J. (2009). Community college online course retention and final grade: Predictability of social presence. *Journal of Interactive Online Learning*, *8*(2).
16. Matsutomo, S., Miyauchi, T., Noguchi, S., & Yamashita, H. (2012). Real-Time Visualization System of Magnetic Field Utilizing Augmented Reality Technology for Education. *IEEE Transactions on Magnetics*, *48*(2), 531–534.
17. McCreery, M. P., Schrader, P. G., & Krach, S. K. (2011). Navigating Massively Multiplayer Online Games: Evaluating 21st Century Skills for Learning within Virtual Environments. *Journal of Educational Computing Research*, *44*(4), 473–493.
18. McCreery, M. P., Vallett, D. B., & Clark, C. (2015). Social Interaction in A Virtual Environment: Examining Socio-Spatial Interactivity And Social Presence Using Behavioral Analytics. *Computers in Human Behavior*, *51*(Part A), 203–206.
19. Milgram, P., & Kishino, F. (1994). Taxonomy of Mixed Reality Visual Displays. *IEICE Transactions on Information Systems*, *E77-D*(12), 1321–1329.
20. Miller, C. J., McNear, J., & Metz, M. J. (2013). A Comparison of Traditional and Engaging Lecture Methods in a Large, Professional-Level Course. *Advances in Physiology Education*, *37*(4), 347–355.
21. Miranda, S. M., & Saunders, C. S. (2003). The Social Construction of Meaning: An Alternative Perspective on Information Sharing. *Information Systems Research*, *14*(1), 87–106.
22. Nicholson, D., Nicholson, J., Shen, Y., & Song, P. (2019). Understanding Student Engagement and Learning Outcomes: The Role Of Learning Styles. In *Proceedings of the 2019 International Conference on Information Systems Education* (pp. 1–11).
23. Oh, C. S., Bailenson, J. N., & Welch, G. F. (2018). A Systematic Review of Social Presence: Definition, Antecedents, and Implications. *Frontiers in Robotics and AI*, *5*(114), 1–35.
24. Panigrahi, R., Srivastava, P. R., & Sharma, D. (2018). Online learning: Adoption, continuance, and learning outcome—A review of literature. *International Journal of Information Management*, *43*, 1–14.
25. Perna, L. W., Ruby, A., Boruch, R. F., Wang, N., Scull, J., Ahmad, S., & Evans, C. (2014). Moving Through MOOCs: Understanding the Progression of Users in Massive Open Online Courses. *EDUCATIONAL RESEARCHER*, *43*(9), 421–432.
26. Raveh, D., & Lavie, N. (2015). Load-Induced Inattentional Deafness. *Attention, Perception & Psychophysics*, *77*(2), 483–492.
27. Richardson, J. C., Maeda, Y., Lv, J., & Caskurlu, S. (2017). Social presence in relation to students' satisfaction and learning in the online environment: A meta-analysis. *Computers in Human Behavior*, *71*, 402–417.
28. Richardson, J. C., Maeda, Y., & Swan, K. (2010). Adding a web-based perspective to the self-assessment of knowledge: Compelling reasons to utilize affective measures of learning. *Academy of Management Learning & Education*, *9*(2), 329–334.
29. Richardson, J. C., & Swan, K. (2003). Examining Social Presence in Online Courses in Relation to Students' Perceived Learning and Satisfaction. *Journal of Asynchronous Learning Networks*, *7*(1), 68.
30. Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. John Wiley & Sons.
31. Sonalkar, N., Mabogunje, A., Miller, M., Bailenson, J., & Leifer, L. (2020). Augmenting Learning of Design Teamwork Using Immersive Virtual Reality. In C. Meinel & L. Leifer (Eds.), *Design Thinking Research: Investigating Design Team Performance* (pp. 67–76). Cham: Springer International Publishing.
32. Steinert, Y., & Snell, L. S. (1999). Interactive Lecturing: Strategies For Increasing Participation In Large Group Presentations. *Medical Teacher*, *21*(1), 37–42.
33. van Bommel, M., van Prooijen, J.-W., Elffers, H., & Van Lange, P. A. M. (2016). The Lonely Bystander: Ostracism Leads to Less Helping in Virtual Bystander Situations. *Social Influence*, *11*(3), 141–150.
34. Webb, S. (2001). Avatarculture: Narrative, Power and Identity in Virtual World Environments. *Information, Communication & Society*, *4*(4), 560–594.
35. Weidlich, J., & Bastiaens, T. J. (2017). Explaining Social Presence And The Quality Of Online Learning With The SIPS Model. *Computers in Human Behavior*, *72*, 479–487.
36. Wilke, R. R. (2003). The Effect of Active Learning on Student Characteristics in a Human Physiology Course for Nonmajors. *Advances in Physiology Education*, *27*(4), 207–223.