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Augmented architectural space system for the creation of casual connections with people

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Abstract. In recent years, the increasing social isolation has become a major problem in Japan because of the growing trend toward nuclear families. In addition, further social isolation is concerned caused by a decrease on face-to-face communication opportunities due to the outbreak of the COVID-19 infection. Therefore, it is necessary to create connections among people. On the other hand, opportunities for people to communicate online have increased rapidly. However, various information obtained the face-to-face is missing online, which degrades the quality of communication and causes physical and mental fatigue to users. To solve these problems, this study aims to minimize the gap that exists between online and the face-to-face, and to propose an Augmented Architectural Space that creates casual connections between people within their living space. By comparing the results of impression evaluation experiments using questionnaires for the face-to-face environment, the video conferencing system environment, and the proposed system environment, we demonstrate the usefulness of the proposed Augmented Architectural Space system for creating casual connections between people.

Introduction

In recent years, people's social isolation has become an issue in Japan, as the growing trend toward nuclear families, the increase in the number of single-person households, and changes in residential patterns have weakened the sense of neighborhood and community ties. According to the Ministry of Health, Labour and Welfare, 15.3% of the Japanese population reported that they have "no" or "very little" interaction with "friends, colleagues, and other people" outside of their family, the highest percentage among the 20 OECD member countries [1]. Previous research refer to the high impact of social isolation on risk of death[2], and social isolation can lead to increase in isolated deaths, disuse disease, shut in, and suicides[3]. Compounding this situation, the recent COVID-19 epidemic has reduced the number of face-to-face encounters with people, exacerbating the social isolation situation. In order to improve these problems, a way to create casual connections between people under the constraints of face-to-face activities is urgently needed.

The COVID-19 epidemic has forced activities that were usually conducted outside the home to be conducted inside the home, and video conferencing systems have rapidly become popular. Not only are they useful in the fields of education [4], healthcare [5], and business [6], but they have also become an important tool for communicating with family and friends who live far away, and can help prevent social isolation. In particular, due to Zoom's features of being free, simple, and easy-to-use, the number of users per day rapidly increased from about 10 million in December 2019 to about 200 million in March 2020, and about 300 million in April 2020[7]. It is predicted that the lifestyle of using video conferencing systems will continue into the post-covid era because of the reduced commuting time, more efficient use of time, and reduced travel costs.

While video conferencing systems are rapidly gaining popularity due to their many advantages, the term “Zoom fatigue” has become popular. “Zoom fatigue” (synonym: video conferencing fatigue) is defined as the physical and mental exhaustion caused by intensive and inappropriate use of video conferencing systems [8] and is caused by the gap that exists between face-to-face and online. There are seven main causes of this fatigue. (1) stress due to communication delays, (2) increased cognitive and communicative effort due to lack of body language, (3) increased anxiety and cognitive effort due to lack of eye contact and not knowing where to look, (4) unnatural interaction with multiple faces (close range,etc.), (5) stress to induce self-evaluation by looking at one’s own appearance[9], (6) stress from multitasking during video conferencing, and (7) stress on the whole body due to difficulty in moving around [8][10][11]. (1) to (3) can be summarized as “lack of information” and (4) to (6) as “too much information”. These causes create a gap between face-to-face and online, causing people to experience physical and mental fatigue. By dissolving these causes of fatigue and minimizing the gap between face-to-face and online communication, we think we can create a sense of casual connection between people who live far away from each other that is more similar to face-to-face communication.

The elements shared in communication include information, action, and space. In face-to-face communication, all these elements can be shared. On the other hand, we have always shared some of these elements to communicate remotely and create a sense of connection with people who live far away from each other. For example, we are familiar with telephone calls and e-mails, which create a sense of connection by sharing information with others using text and voice. SyncDecor [12] and Meeting Pot [13] are communication tools that focus on sharing something with others. These are tools that create a sense of connection by sharing each other’s actions. Furthermore, video conferencing systems, which have spread rapidly in recent years, can perform both information and actions sharing because they allow people to see each other’s faces. On the other hand, there is currently little remote communication that incorporates the spatial elements that are inevitably shared in face-to-face communication. While existing video conferencing systems and videophone systems can share space around each other as visual information because the background space of the communication target is cut off, there are cases where disclosure of private information is not desired from the viewpoint of privacy protection, and virtual backgrounds and filters have been used in recent years. In addition, there is a large gap in the amount of information between the space in which one is and the space in which the other party is, obtained from limited visual information, and this inequality is not appropriate for space sharing. Now that opportunities for face-to-face communication are limited, there is a possibility of creating more casual connections if space can be shared in a new way in telecommunication.

Therefore, this study aims to minimize the gap that exists between face-to-face and online communication, and to try space sharing that has not been considered in remote communication so far by proposing an Augmented Architectural Space that creates casual connections between people within their living space. For the reasons mentioned above, this study attempted to propose a system that allows people to feel connected through the same shared space by sharing a third space, rather than just sharing the private space where each other is. By comparing with the existing video conferencing system and the face-to-face communication, we evaluated the usefulness of the proposed system and clarified the optimal form of a combined real and virtual space that can create a sense of connection between people.

Proposed system

Among the causes of creating the gap between face-to-face and online mentioned above, the spatial system we propose approaches four of them: (2) increased cognitive and communicative effort due to lack of body language, (3) increased anxiety and cognitive effort due to lack of eye contact and

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not knowing where to look, (4) unnatural interaction with multiple faces (close range, etc.) and (5) stress to induce self-evaluation by looking at one's own appearance. Figure 1 shows the proposed system environment.

The proposed system is intended for use by two people living apart and consists mainly of a large screen, a display, and a web camera. A real-time spatial image common to both students is projected on the large screen, and silhouettes of both students are projected on top of the spatial image. Students are seated facing the large screen. The video and audio images of each student, captured by a web camera installed on a desk beside them, are projected in real time on a display installed on the side of the communication partner.

Next, explain the intention of each device. The silhouette images of both students projected on the large screen attempt to solve (2) above. By projecting a silhouette image of the whole body in front of the student's eyes, the presence [14] and body language of the other party, which are difficult to convey online, can be expressed without violating privacy. In addition, by projecting not only the silhouette of the other party but also one's own silhouette on the same spatial image, we thought it would induce a sense of being in the same space as the other party. We attempted to solve (3) by having the students seated facing a large screen and having their partner's profile projected on a display installed on the side. Unlike conventional video conferencing systems, the proposed system is designed to prevent excessive eye contact by positioning the student's side-by-side with the other party, not facing each other, so that the students can recognize that they are being watched and that their attention is being directed from the direction of the other party's face. The side-by-side positional relationship in a face-to-face situation is called a sociopetal relationship, which promotes the most interaction. By projecting the other party at life-size on the side display, we are attempting to solve (4). Based on the concept of personal space, the psychological area surrounding the human body, and in order to establish an appropriate virtual distance for the relationship between students, we prevented communication at unnatural close range by matching the size of the head in the face-to-face state with the size of the other party's head projected on the display. And, unlike conventional video conferencing systems, the proposed system attempts to solve (5) by not projecting the image of oneself except as a silhouette. Also, in the face-to-face space, people share the same space equally and are always unconsciously influenced by surrounding information such as wind and passersby. In order to solve the situation of a video conferencing system, where all external information is shut out, and to create the situation in the face-to-face space online, we attempted to create a situation similar to face-to-face communication by sharing a common space in real time.

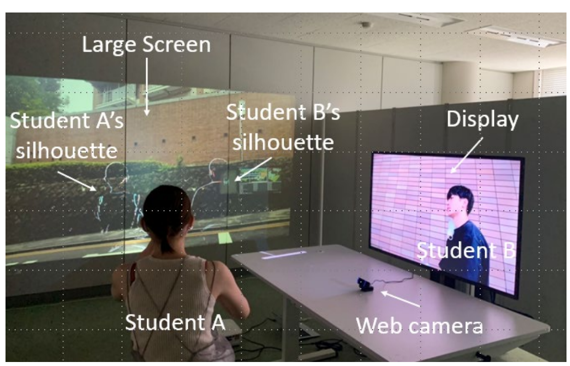

Fig. 1 the proposed system environment

Experimental and Evaluation methods

The experiment was conducted on 8 students (M:4 F:4) in their 20s in pairs. After 3 minutes of (a) the face-to-face communication, the students entered two rooms where the proposed system was installed, one by one, and communicated freely with each other for 3 minutes each in two environments: (b) the existing video conferencing system environment and (c) the proposed system environment. After each communication in (a) the face-to-face environment, (b) the video conferencing system environment, and (3) the proposed system environment, the students were asked to answer a questionnaire using Google Form. The total time for communication and questionnaire response was about 30 minutes.

In this study, in order to measure individuals' impressions of the target environment and to clarify the semantic structure and image of the target environment, we employed a method in which (A) words with relative meanings were paired to form a single item, and students were asked to answer each item on a 5-point scale. They were also asked to answer on a 5-point scale the questions about (B) fatigue and (C) missing elements online. Factor analysis was conducted for the items with (A) paired words with relative meanings in order to get the characteristics of the proposed system, and t-tests were conducted for the questions about (B) fatigue and (C) missing elements in order to show the usefulness of the proposed system.

Statistical analysis

The factor analysis and t-tests indicated above were conducted using IBM's SPSS 28 statistical analysis software.

For items that (A) paired words with relative meanings, based on the data collected, standardized data were entered into SPSS for each item, 24 data for 8 students multiplied by 3 patterns, and analyzed. The items to be analyzed were adjusted, and the factor analysis was repeated until each item loaded relatively high on only one factor. The principal axis was used to extract the factors, and the Promax rotation method was employed. In order to examine whether the collected date are valid for factor analysis, we confirmed the KMO measure of sampling adequacy. In addition, in order to determine whether the items constituting the factors were consistent, we calculated Cronbach's coefficient alpha using SPSS and confirmed the internal consistency of the factors. Cronbach's coefficient alpha of 0.8 or higher was considered sufficient for internal consistency. After that, the factor score coefficient was calculated by factor analysis with SPSS again, the factor score coefficient was multiplied by the standardized mean value for each item, and the factor score was calculated by summing all items. The factor score was used to confirm how each factor affected (a) the face-to-face environment, (b) the video conferencing system environment, and (c) the proposed system environment.

For the questions on (B) fatigue and (C) missing factors, we also input 24 standardized data for each item into SPSS and analyzed them. Here, before conducting the t-test, a test of normality of the data was conducted to confirm that all items followed a normal distribution. By checking the significance probability, we confirmed whether there was a significant difference between (b) the video conferencing system environment and (c) the proposed system environment in the mean value of each item.

Result

Factor analysis results for the evaluation environment

A graphical representation of the questionnaire results for items that paired words with relative meanings is shown in Figure 2. Here, the variables were standardized so that the mean was 0 and the standard deviation was 1, since the standard of evaluation may differ due to individual differences such as student's preferences.

As a result of repeated factor analysis on the collected data, four items, "fun - boring," "relax - tension," "comfortable - uncomfortable," and "bright - dark atmosphere," were removed from the data and analyzed.

Since the KMO measure of sampling adequacy is 0.851, which is greater than 0.50, it can be concluded that there is validity to conduct a factor analysis.

When the number of factors is examined from the perspective of eigenvalues, the first factor is 8.94, the second factor is 1.39, the third factor is 1.15, and the fourth and subsequent factors are less than 1, so it can be determined that the Kaiser criterion can be determined up to the third factor. Also, the cumulative contribution ratio up to the third factor is 88.2%, which is more than 50%, it can be determined that the number of factors should be three.

The variance value of the sum of squares of loadings after Promax rotation indicates that Factor 1 explains 67.7% of the total, Factor 2 9.28% of the total, Factor 3 7.28% of the total, and the three factors together explain 84.2% of the total. Here, Factor 1 consisted of six items: “casual”, “easy to talk”, “calm”, “convenient”, “relief” and “friendly”, and the items related to the comfort of the space and the other party showed a high load. Therefore, the first factor was named “comfortableness”. The second factor consisted of four items, “spacious”, “open”, “highly space shared”, and “no pressure”, and the items related to openness toward space showed a high load. Therefore, the second factor was named “openness”. The third factor consisted of three items, “immersive”, “close to existence” and “highly connected” and the items related to the connection with the other party and the space with others showed a high load. Therefore, we named the third factor “sense of connection”. From the above, it was found that the evaluation environment in this experiment can be explained by three indices: “comfortableness”, “openness” and “sense of connection”.

Regarding the correlation of the three extracted factors, a correlation of 0.688 was found between the first and second factors, 0.657 between the first and third factors, and 0.531 between the second and third factors, indicating that there is a very strong correlation between “comfortableness”, “openness” and “sense of connection” with each other.

Next, for the Cronbach’s coefficient alpha, all factors took values of 0.8 or higher, so it can be said that there is sufficient internal consistency for all factors.

Using the three factors determined above, we will discuss the three evaluation environment patterns in terms of factor score. The results of factor score for each evaluation environment are shown in Figure 3.

Figure 3 shows that the proposed system scored higher than the video conferencing system in all three factors of “comfortableness”, “openness” and “sense of connection”. For “comfortableness”, the proposed system scored higher than the video conferencing system because it created a natural communication environment similar to a face-to-face environment by expressing body language through silhouette projection and by expressing appropriate conditions such as distance through a life-size display. The proposed system also scored higher than the video conferencing system for “openness”. When the method of magnitude estimation was used to evaluate the size of the space, the mean values of 100 for (A) the face-to-face environment, 32.8 for (B) the video conferencing system environment, and 77.5 for (C) the proposed system environment were calculated, showing that the proposed system scored higher than the video conferencing system in terms of numerical values. It is thought that these results were obtained because the real-time sharing of a common space allowed the students to feel the expansion of the communication space through another space, rather than only the separate space they could see in each other’s video conferencing system. The reason for the smaller value than the face-to-face space is thought to be due to the lack of reality of the common real-time space. The proposed system scored higher than the video conferencing system in terms of “sense of connection” not only because the silhouette projection expressed body language and presence, and the projection of the other party’s profile on the display induced a side-by-side feeling, but also because the projection of oneself and the other party sitting next to each other in one common space created a sense of physically being in the same space.

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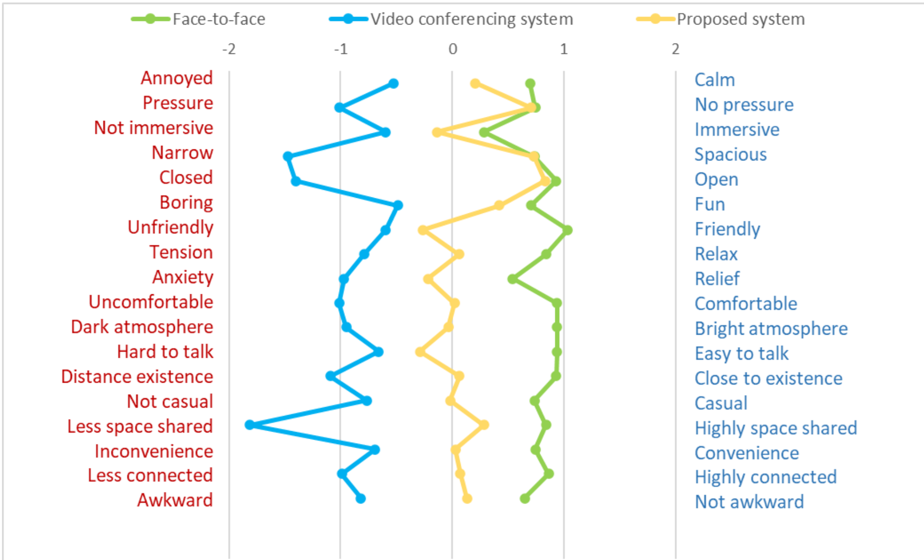

Fig. 2 Questionnaire standardized mean results graph

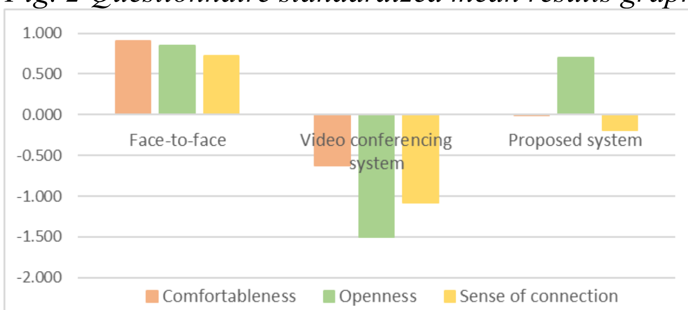

Fig. 3 Factor score for each evaluation environment

T-test results in fatigue

A graphical representation of the questionnaire comparison results for fatigue in the face-to-face, video conferencing system, and proposed system environments is shown in Figure 4. All results are standardized.

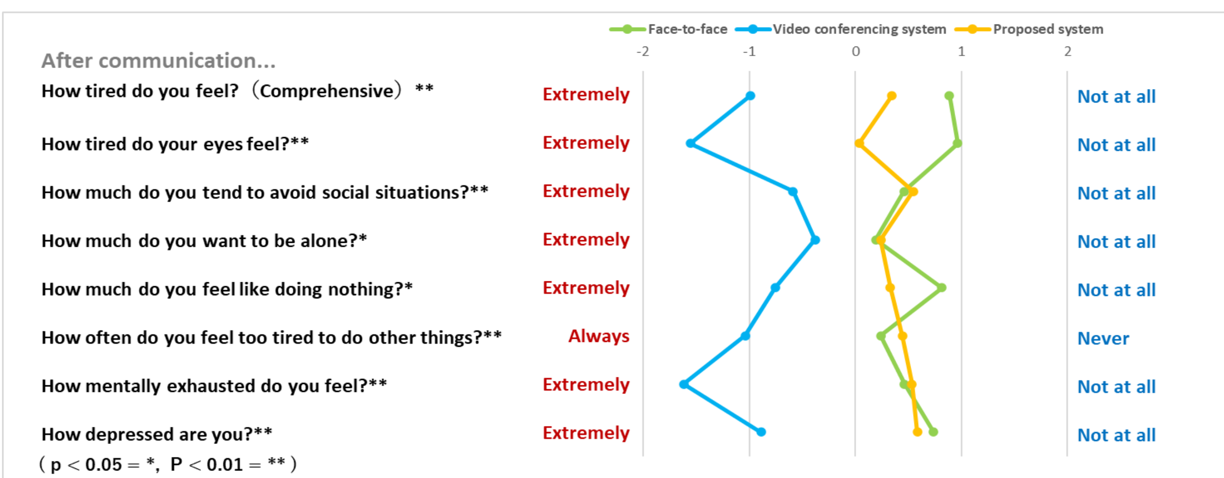

Fig. 4 Questionnaire standardized mean results graph for fatigue

From Figure 4, it can be visually seen that the proposed system is less fatiguing than the existing video conferencing system for all questionnaire items. Here, we compared the mean values of each questionnaire item between the two subjects in the video conferencing system environment and the proposed system environment, and quantitatively clarified whether there was a significant difference by t-test. As a result of the t-test, items with a significance probability of less than 0.05 are marked with *, and items with a significance probability of less than 0.01 are marked with ** at the right end of each questionnaire item in Figure 4. Figure 4 shows that there were significant differences between the mean values in the video conferencing system environment and the mean values in the proposed system environment for all items of the questionnaire items about fatigue. This indicates that the proposed system causes less physical and mental fatigue after use than the existing video conferencing system. In other words, the proposed system was shown to be useful in dissolving Zoom fatigue.

T-test results for missing elements online

A graphical representation of the questionnaire comparison results for missing elements online in the video conferencing system and proposed system environments is shown in Figure 5. All results are standardized.

From Figure 5, it can be visually seen that the proposed system shows more useful results in terms of the sense of connection with the other party than the existing video conferencing system in all items except eye contact. Here, we conducted a t-test in the same way as for the questionnaire about (B) fatigue, and examined whether there was a significant difference between the mean values of the two environments. From Figure 5, among the questionnaire items about the missing elements online, a significant difference was found between the mean values in the video conferencing system environment and the mean values in the proposed system environment for the sense of distance from the other party, awareness of oneself, gestures of the other party, proximity of the other party, gap with the face-to-face space, and sense of being monitored. On the other hand, no significant differences were found for the two items of where the other party is looking and the sense of eye contact. This indicates that the projection of silhouettes of both students complements body language such as gestures and hand gestures, and has the effect of making the presence of the other party feel closer, that the life-size display placed on the side allows a natural distance from the other party and avoids the feeling of being watched by not being in front of the other party, and that the projection of one's own image only in silhouette allows one to avoid awareness and evaluation of oneself. By compensating for these missing elements online with the proposed system, the gap that exists between the face-to-face space and online is minimized and more natural communication is possible. On the other hand, the camera that captures the image displayed on the life-size display was installed in a position that project the student from below, which caused the student to look above his/her own eyes, resulting in an unnatural sensation of looking at the other party. Although line of sight is still an issue, compared to the video conferencing system, it was shown that the proposed system was able to create an environment closer to the face-to-face.

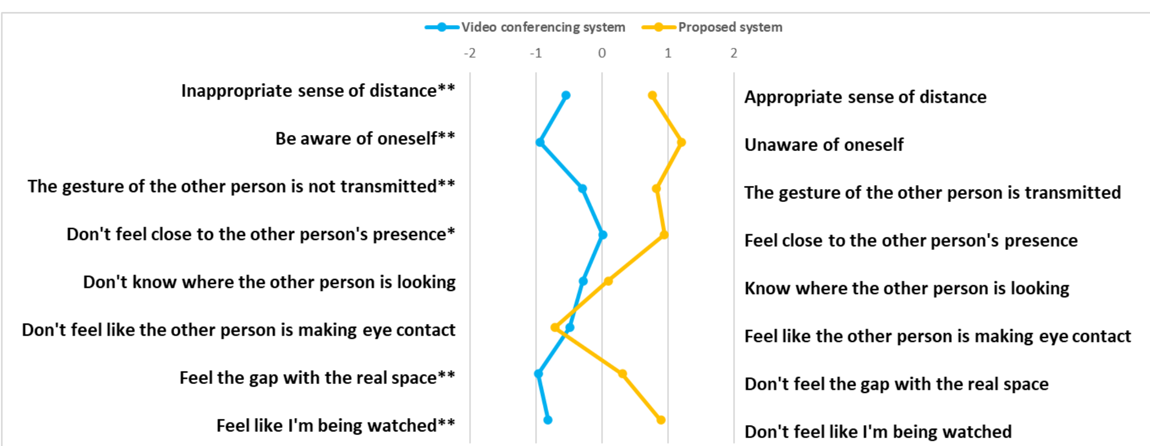

Fig. 5 Questionnaire standardized mean results graph for missing elements online

Conclusion

In this study, we conducted an impression evaluation experiment to clarify what kind of impression people have of an Augmented Architectural Space system created to create a space where they can easily connect with people who live far away from them, and what the factors are that make people feel this way. In addition, by comparing the proposed system with the video conferencing system, which has the same value in terms of "creating human connections" within a living space in an online environment, we clarified the usefulness of the proposed system.

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