A-Vibe: Exploring the Impact of Animal-form Avatars on Students' Connectedness and Social Presence through Delivering Honest Signals in Live Online Classes

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ABSTRACT

The outbreak of the coronavirus pandemic has made online video conferencing a common delivery method of education around the world. Research has shown that students in online learning environments often experience isolation and alienation, which can be improved by increasing their social presence. In this study, A-Vibe as a non-real-time animal-form avatar system has been created to work to translate the user's current honest state into a customised animal form, thus contributing to social presence and connectedness in the online learning environment. The experiment has been conducted with twenty-four participants to explore and evaluate the connectedness and social presence in three conditions: (1) real-life face-to-face, (2) only A-Vibe and (3) A-Vibe with the live video via videoconferencing mediated tool. Overall, the obtained results of this study provide important insights and ideas on the impact of introducing animal-form avatars on students' connectedness and social presence in the live online classes.

KEYWORDS

Avatar, Live online class, Honest signal, Connectedness, Social presence

1 INTRODUCTION

The outbreak of the coronavirus pandemic has made online video conferencing a common delivery method of education around the world (Serhan, 2020). The rapid use of e-learning platforms, such as Microsoft Teams or Zoom, has made students more aware of the usefulness and advantages of online learning (Al-Fraihat et al., 2020). However, it also poses many challenges for students in the online education environment, for example, the loss of structure and routine, as well as changes in social connections with peers and teachers (Poquet, et al., 2022).

The occurrence of online learning instruction results in students missing out on opportunities to interact or share their backgrounds with the teacher and other students (Dingle et al., 1999). In America, almost two-thirds of the 22,516 undergraduate students and over 7,000 graduate students reported that the greatest obstacle they dealt with due to the transition to online education was the lack of peer interaction and communication (Soria et al., 2020).

Compared with physical face-to-face interaction, communicating through video conferencing mediated tools is an artificial experience (Hauber et al., 2005). The physical separation creates a barrier to communication (Sorensen & Baylen, 1999) as these mediated systems lack "media richness" and support for both verbal and non-verbal communication (Burgoon et al., 1996).

According to research done by Rovai (2007), the isolation and detachment felt in online learning environments can be improved by increasing social presence, the level to which one is perceived as "real" in mediated communication (Gunawardena & Zittle, 1997). Rourke et al. (2001a) further identified the development of social presence (i.e., the perceived interaction with others) as one of the keystones of the development of online learning communities. Consequently, the ability of the learner to establish a satisfactory level of social presence is of great importance in the online learning environment (Caspi & Blau, 2008). To date, the empirical evidence on the extent to which learners are connected to others in their learning communities is limited (Schroeder et al., 2016). Further research on connectedness and presence in online learning environments is necessary.

In this study, A-Vibe, a non-real-time animal-form avatar system, has been created and introduced to video conferencing communication. It works to translate the student's current honest state into a vivid, customised animal form, thus attempting to amplify subtle physical and non-verbal signals. In the study, honest state/signal is defined as emotion estimation as the output of an artificial intelligence program, which has been achieved in combination with the manually selected mood animations and the results of human observations during the experiment. The experiment has been conducted with twenty-four participants to explore and evaluate the connectedness and social presence using A-Vibe in the live online classes. Surveys were conducted to obtain both quantitative and qualitative data.

The primary objective of this study is to investigate the impact of animal-form avatars in the live online classes environment on students' connectedness and social presence by delivering honest

signals. As such, the following research question is proposed: What are the impacts of introducing animal-form avatars that can transmit honest signals to live online classes on students' connectedness and social presence?

2 RELATED WORK

2.1 Online Education

Online education in the higher education environment has been growing exponentially (Martin et al., 2019). The COVID-19 pandemic has contributed, intentionally or unintentionally, to this situation (Talwar et al., 2021), while according to the research from García-Peñalvo et al. (2020), online education may not be a complete substitute for the face-to-face mode. Learners have to interact with other learners, experts, etc. in the online education environment (Figure 1) (Brown, 2018). This introduces one of the challenges of online education is the lack of real-time interaction with peers and teachers, which is likely to affect the basic psychological needs of students (Chen & Jang, 2010; Hsu et al., 2019). Research shows that computer-mediated communication can create a time-space shift that reduces communication, weakens social connections, and increases isolation and depression (Caplan, 2003; Caplan & High, 2006).

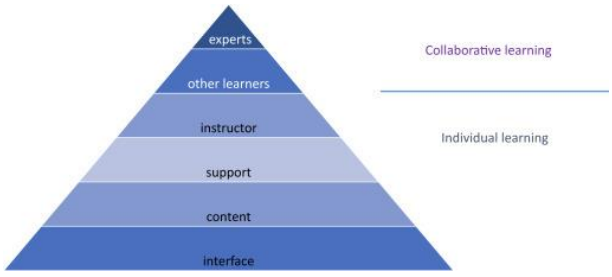

Figure 1: The interaction of learners with other online elements in a collaborative online course (Brown, 2018).

Synchronization tools are widely used in online education. Software that allows real-time online video connections is constantly developing (Burton & Kitchen, 2011), allowing teachers and students to conduct live online classes. Live online classes allow simultaneous sharing of text, audio, images, screens, etc. in the form of e.g. "live classroom, live virtual classroom/classes, online classes/courses, and live virtual classes" (Aslan, 2021). This study focuses on the situation of live online classes in online education.

2.2 Social Presence

Social presence was first introduced by Short et al. (1976) and was defined as "the degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships (p. 65)". Short et al. (1976) pointed out that computer-mediated communication "filters out" important audio and visual cues from face-to-face communication, resulting in less ability to develop a high level of social presence. According to this view, the social presence in an online learning environment is less than that in a traditional face-to-face classroom. Short et al. (1976) also stated that intimacy and immediacy are the two core components of social presence, which are closely related (Oh et al., 2018) and are determined by verbal and non-verbal signals (Gunawardena & Zittle, 1997) such as facial expressions, eye contact and gestures. The extent to which the medium conveys information about those cues contributes to the degree of social presence of the communication medium (Cobb, 2009).

Garrison et al. (1999) have extended the traditional definition of social presence to "the ability of participants in a community of inquiry to project themselves socially and emotionally, through the medium of communication being used (p. 94)", as the second core element of the "Community of inquiry" model. This social presence can be developed and fostered as individuals in the mediated environment are able to "make up" for lost social cues (Swan, 2003), e.g. expressing moods by using emoticons and displaying humour can affect the perception of social presence (Rourke et al., 2001b; Swan, 2003).

Importantly, social presence is the result of interactions among social participants (i.e. students-students, student-instructors) in an online learning environment (Gunawardena, 1995; Gunawardena, 2017; Orcutt & Dringus, 2017; Oyarzun et al., 2018). The study by Liu et al. (2009) further presented that social presence is vital to maintaining a high degree of online social interaction as a significant predictor of course retention in the online education environment.

2.2.1 Networked Minds measure. Biocca et al. (2001) defined mediated social presence as "the moment-by-moment awareness of the co-presence of another sentient being accompanied by a sense of engagement with the other… As a global, moment-by-moment sense of the other, Social Presence is an outcome of cognitive stimulations (i.e. inferences) of the other's cognitive, emotional, and behavioral dispositions (p. 2)". Based on a comprehensive literature review, three essential dimensions of social presence have been defined by Biocca et al. (2001), which are "Co-Presence", "Psychological Involvement" and "Behavioral Engagement", and the empirically determined factors have been named, see Figure 2.

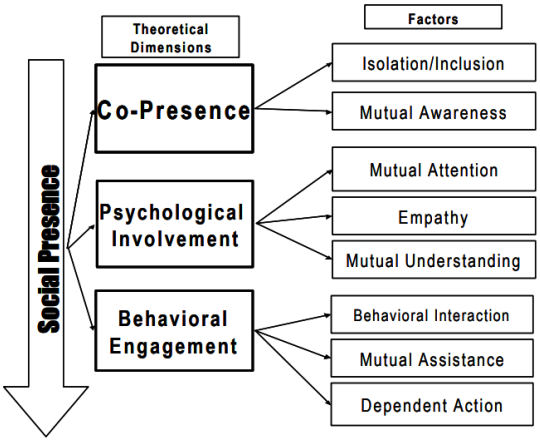

Figure 2: Factor structure of the NMMSP (Biocca et al., 2001).

The Networked Minds Measure of Social Presence (NMMSP) is made up of a questionnaire that consists of multiple items for the scale of the aforementioned factors, which proposes a rough hierarchy among the dimensions of social presence and measures the extent to which individuals feel interconnected through networked mediated interfaces (Biocca et al., 2001). This approach is consistent with other conventional subjective measures of social presence and promises high sensitivity and reliability in cross-media comparisons.

2.2.2 Relationship with Connectedness. The concept of "social presence" is related to the concept of "connectedness", which is classified by Biocca et al. (2001), as psychological involvement. Ijsselstein et al. (2003) presented those two concepts are complementary in the awareness system. Rettie (2008) summarized this in Figure 3 and pointed out that connectedness' is potentially useful in the analysis of communication.

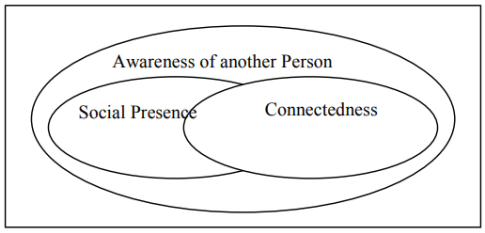

Figure 3: The relationships between social presence, awareness and connectedness (Rettie, 2008).

In this study, connectedness is studied together with social presence as related concepts.

2.3 Honest (unconscious) Behaviour

2.3.1 Honest signal. The unconscious mind was defined by Freud (1955) as a pool of thoughts, memories, urges and feelings outside of human consciousness. According to Hua and Fei's (2009) study's outcome of behaviour on interaction design, unconscious behaviour is the representation of the unconscious needs based on long-term life experience, psychology, instincts and emotional influences. Unconscious behaviour may therefore be an important factor in determining demands (Kamil & Abidin, 2013).

Honest signals are considered as those that are not processed consciously or are not controllable (Pentland, 2008, p. 4). In Pentland's study (2008), he concentrated on "influence, mimicry, activity and consistency" as the honest human signals, derived from the structure of the human brain and biology (p. 4). Those honest signals are measured by the timing, energy, and variability of the interaction. From the observation of all the experiments during the study, the conclusion has been drawn that people use combinations of honest signals in real life rather than using them individually (Pentland, 2008). Then Pentland (2008) defined four characterize social roles, exploring, listening, teaming, and leading (p. 22), which can be used to predict precisely the consequences of many important interactions.

In this study, the honest signals were served as part of the system design rather than the objects being measured, and their performance through the animal-form avatar will be used as an important element of the experiment. Due to the time and technical constraints of this study, the method of detection and transmission of the participants' honest states differed from the theory, which has been further described in the design section 3.1 and experimental procedure section 3.3. The future implementation suggestion can be found in future work.

2.3.2 Unconscious interaction among students. Based on research from Araya & Hernández (2016), students' unconscious interactions can improve teaching and learning practices as a strong tool. Most students do not make decisions consciously and most of the time, they are unaware of their decisions (Araya & Hernández, 2016). They pointed out that observing students' behaviour rather than listening to them can be more authentic (p. 333).

3 METHOD

3.1 Design

3.3.1 Platform overview. Microsoft Teams has been chosen as the reference live online classes platform during the study as TU/e offers an enterprise version of this application to all lecturers and students through the "Office 365" plan for free. Additionally, Microsoft Teams supports both synchronous and asynchronous online learning (Pal & Vanijja, 2020), providing a well-integrated educational space.

The animal models used in this study have been launched by Live2D and PrprLive. Live2D is a software technology that creates dynamic expression into an original 2D illustration and is utilized for a wide range of applications (What is Live 2D, 2020). Prprive is a Live2D live broadcast support software. It enables high-frame-rate Live2D animation with high-performance facial capture and supports the import of two expression configuration profiles, exp3.json and cfg (1-reality, 2020). Open Broadcaster Software (OBS) Studio, a free open source broadcaster software, was used in this study for creating scenes made up of multiple sources as a virtual camera. Specifically, it allows the animal models to be layered on top of the webcam source and then display the designed scenes (See Section 3.3.2 for more details).

Lastly, Face Analysis (Visage|SDK live), a software development kit developed by the company Visage Technologies AB, was used as one of the criteria for assessing participants' emotions in the experiment. The output of this software is the probability distribution for each of the six universal emotions: happiness, sadness, anger, fear, surprise, disgust, and additionally neutral (Emotion recognition, 2021).

3.3.2 A-Vibe system. Humans can usually explain the emotions of animals, while they can also explain ours, as a result of our facial expressions, gestures and postures that share a common origin in life (Hua & Fei, 2009). With both this idea and the inspiration from the theory of "Honest Signals" (Pentland, 2008), the A-Vibe system was built, as a non-real-time animal-form avatar system that works to translate the students' current "honest" state into a vivid,

customised animal form. “Honest” state refers to inner real emotions instead of the emotions displayed to be seen directly. The animal-form design is aimed to protect privacy while displaying the “honest” state, which brings up the argument about the relationship between the avatar and oneself. The system overview can be found in experimental procedure section 3.3 (Figure 9).

Animal models that were animated and rendered via Live 2D were used in this study; “This content uses sample data owned and copyrighted by Live2D Inc. The sample data are utilized in accordance with terms and conditions set by Live2D Inc. This content itself is created at the author’s sole discretion (Live2D Inc., 2022).” These animal models include a total of eleven characters (e.g. rabbits, cats, dogs, etc.) and various animated behaviours (e.g. head shaking, mouth opening, etc.) based on real-time face capture. The developer is able to change the additional animal avatar animations and control their behaviour.

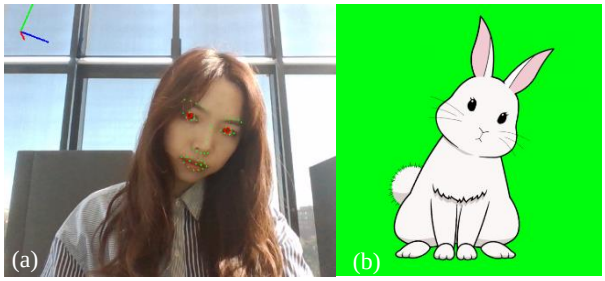

Figure 4. Examples of interaction with users: (a) tracked face, (b) animated avatar.

When the user starts the system and choose one avatar, it presents an idle state. To facilitate the development of classroom performance and some specific emotional expressions, the avatars were designed to be more expressive. Thus, apart from the real time facial tracking output, seven different moods of the avatars are animated: idle, laughing, sweating, questioning, surprising (shocking), nodding and clapping. Each animation is triggered by manually pressing the corresponding key on the keyboard. The animation time lasts about three seconds. Pressing the “1” key on the numpad can return the avatar to the default state immediately.

In OBS the different video sources are combined into one cohesive scene, which is turned into a virtual camera so that Microsoft Teams can use it as the input for the camera. Two scenes were created in OBS, which can easily be switched between: (1) Live video output and avatar, and (2) only avatar.

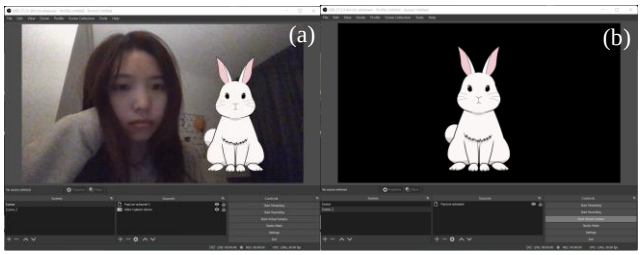

Figure 5. Two scenes in OBS: (a) live video output and avatar, and (b) only avatar (idle/default status of one of the avatars).

3.2 Participants

The participants of the study comprised a total of twenty-four master’s students (mean (M) ± standard deviation (SD) age 24.3 ± 1.40) experienced in online education from Eindhoven University of Technology (TU/e). The first eight participants took part in the pilot test (data to be analysed). The following sixteen participants (mean (M) ± standard deviation (SD) age 24.6 ± 1.40) took part in the formal experiment and all data were included in the final analysis. Their basic demographic information is as follows:

		N
Age	22-23	4
	24-25	6
	26-27	6
Gender	Male	8
	Female	8
Experience in online classes	Yes	16
	No	0

Table 1: Demographic information about the participants.

Purposive sampling in the non-probability sampling method was used in the study. Purposive sampling allows the researchers to decide which samples will represent the main audience based on their prior knowledge, which is “used to select respondents that are most likely to yield appropriate and useful information” (Kelly, 2020, p. 317).

3.3 Experimental Procedure

The experiment was carried out in a closed room, where the A-Vibe system was pre-setup. Before the experiment started, all participants were briefed on the purpose and steps of the experiment (Appendix A) and provided with a digital consent form (Appendix B) before participation. After the consent form was obtained, participants were asked to complete a demographic survey with one additional questions about how much cooking experience they have (on a scale of 1 = None to 5 = A lot): How much experience did you have with cooking (especially desserts)?

The experiment was conducted in a series of sequential steps: “Preparation” - “Tutorial” - “Trial 1” - “Trial 2” - “Trial 3” - “Post-questionnaire” (see Figure 6). The total time lasted approximately fifty minutes per participant.

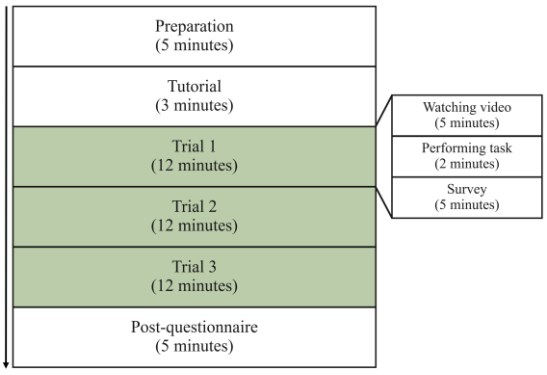

Figure 6: Experimental procedure.

Initially, the participants were shown ten animal-form 2D avatars and were instructed to pick the most favoured one. The avatar chosen by the participant was used during the subsequent experiment. This was followed by a tutorial to help the participants to get familiar with the webcam settings and some basic operations, which took approximately three minutes.

Each participant was required to take part in three trials, one for each condition (FtF, AO, LA). Table 1 provides a brief description of the trials.

Trial	Live video	A-Vibe
Face to Face (FtF)	Off	Off
A-Vibe Only (AO)	Off	On
Live video & A-Vibe (LA)	On	On

Table 2: Different conditions of each trial.

In the face-to-face condition (FtF, Figure 7), the participant and the experimental assistant were sitting in one room where they could talk and watch the video together face-to-face. In the other two conditions (AO, LA, Figures 8), the participant and the experimental assistant were located in separate rooms, connected via the online video conferencing interface in Microsoft Teams. The details about AO and LA have been described in 3.3.2.

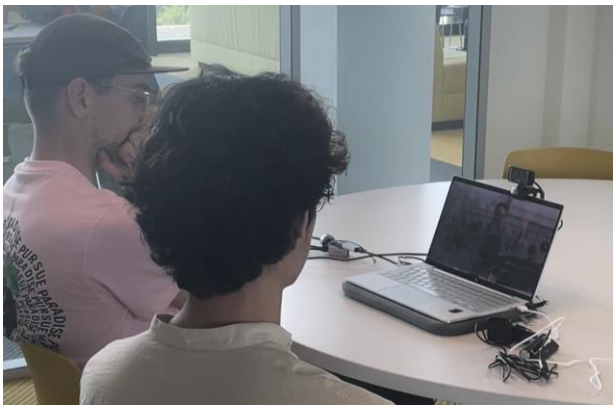

Figure 7: Example of FtF condition.

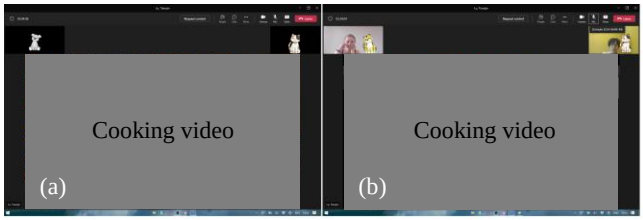

Figure 8: Screenshots of video conferencing conditions: (a) AO; (b) LA.

Due to the limited study time and amount of participants, the study was designed as a within-subject experiment, in which the order of the three experimental conditions was randomly assigned. In every trial, there were common sub-steps: "Watching video" - "Performing task" - "Survey". Participants need to watch a brief five-minute instructional video (Appendix C) about cooking per trial with the experimental assistant. Immediately following the video, they had two minutes to describe the steps in making the dish from the watched video, together with the experimental assistant. At the end of each trial, participants completed a survey. After all three trials, participant filled in a post-questionnaire.

In the conditions of AO and LO, participants were in the same room as the experimenter when "Watching video". The experimenter manipulated the participant's avatar based on the human observation and the results of Face Analysis. However, participants' inputs had priority over the inputs of the experimenter in controlling the animations mentioned above during the experiment. There was a numpad on the experimenter's side for controlling the avatar back to the default state.

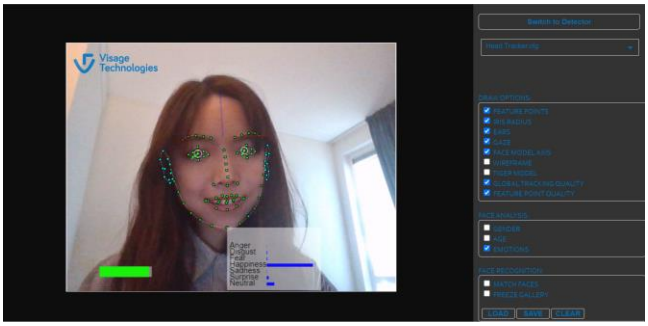

Figure 9: Screenshot of the face analysis settings and results.

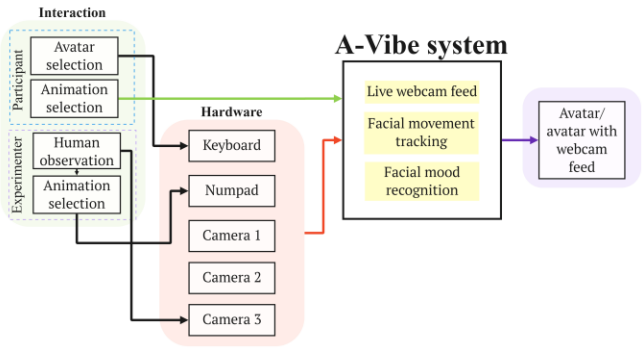

Figure 9: System overview.

See Appendix D for the physical apparatus set-up and the experimental environment. The experimenter would leave the room at the "Performing task" and "Survey" time. When all trials were over, the participant completed the post-questionnaire.

3.4 Measures

The survey applied after each of the three trials consisted of three self-report instruments: (1) The Inclusion of Other in the Self (IOS) Scale (Aron et al., 1992); and (2) Semantic differential questionnaire (SDQ) (Short et al., 1976); (3) the Networked Minds Measure of Social Presence (NMMSP) (Biocca et al. 2001), for measuring participants' degree of connectedness and perceived social presence. Appendix E summarizes the items included in the questionnaires (2) and (3) with their sources and the Likert scale used for each.

Besides, a post-questionnaire (Appendix F) has been provided with five questions at the end of the experiment. Two general questions were meant to assess the potential customer acceptance of the A-Vibe system, followed by three open questions for gathering some qualitative data.

It is worth mentioning that for the pilot test, the participants' questionnaires (SDQ and NMMSP) were in a fixed order. In the formal experiment, the order of the questionnaires (SDQ and NMMSP) for each participant was randomised in order to minimise the chances of response bias.

3.3.1 The Inclusion of Other in the Self Scale. The IOS scale, developed by Social psychologist Aron et al. (1992), is a seven-step, interval-level scale used to measure "a person's sense of direct interconnectedness with another (p. 602)". The IOS scale is a highly reliable measure of the subjective closeness of a relationship in psychological terms (Gächter et al., 2015), which is used to evaluate the level of closeness of the participant with the experimental assistant after each round of test. In the IOS scale, participants select the picture that best describes their relationship and each diagram represents a different degree of overlap between two circles (Aron et al.,1992). Participants were asked to answer the question: "Which picture best describes your relationship with X", where the X is replaced with "your experimental partner" in the experiment. Figure 10 depicts the scale used in the study.

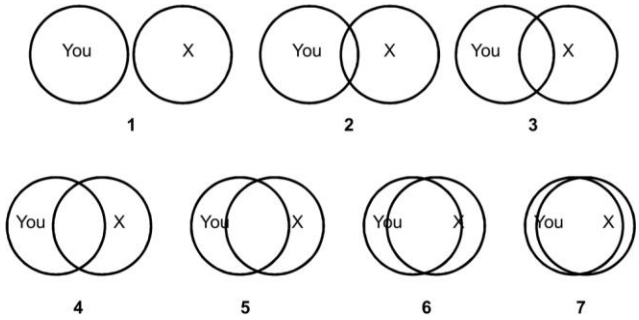

Figure 10: The IOS scale (Gächter et al., 2015), used in the questionnaire, where 1=no overlap; 2=little overlap; 3=some overlap; 4=equal overlap; 5=strong overlap; 6=very strong overlap; 7=most overlap.

3.3.2 Semantic Differential Questionnaires. Short et al. (1976) point out that the key subjective method for measuring social presence is the semantic differential technique (Osgood et al., 1957). Participants are asked to rate the telecommunications media on a series of seven-point, bi-polar scales, like warm 1----2----3----4----5----6----7 cold. Similar to one of the methods taken by De Greef and Ijsselsteijn (2001), eight bi-polar pairs were selected directly from Short et al.'s social presence measurement tool in this study, for measuring students' perceived social presence. Four bi-polar pairs were used to measure the presence of social richness: insensitive-sensitive, cold-warm, impersonal-personal and passive-active. Another four were used to measure the aesthetic sensibility of the media: small-large, closed-open, colorless-colorful and ugly-beautiful.

3.3.*3 Networked Minds Measure of Social Presence*. All thirty-eight items of the Network Minds measure of Social Presence were used in the study. This questionnaire is a measure to detect the difference between face-to-face and mediated interactions in perceived social presence level, and in which the items target the experience of the mediated interactions as the main criterion (Biocca et al., 2001). More explanation has been given in *2.2.1*.

3.5 Data Analysis

Quantitative data retrieved from the online survey was collated in Microsoft Excel and exported to SPSS® Statistics 25 for analysis. Qualitative data were clustered into different themes to provide insights into the research question.

4 RESULTS

4.1 Reliability Analysis

A reliability statistical analysis of all items in each factor was performed by using Cronbach's coefficient alpha, which provides an important basis for the results of the following data analysis results.

Factor	N of items	Average Cronbach's alpha
Social presence	4	0.63
Social presence - *Aesthetic appeal*	4	0.63

Table 3: Test result for internal consistency for SDQ.

The alpha score for the factors in SDQ looks sufficient (> 0.6). However, for both "Corrected item-total correlation (CITC)" and "Cronbach's alpha if item deleted", S3 obtained a failing value (See Appendix G for the details) and therefore was removed. This was followed by a second reliability analysis, with the results shown in Table 4.

Factor	N of items	Average Cronbach's alpha
Social presence	3	0.73
Social presence - *Aesthetic appeal*	4	0.63

Table 4: Test result for internal consistency for SDQ after removing S3.

In the NMMSP, the factors "Mutual awareness", "Mutual assistance" and "Dependent action" reached an insufficient alpha score (< 0.6) thus being excluded from further analysis.

Factor	N of items	Average Cronbach's alpha
Isolation/aloneness	2	0.63
Mutual awareness	6	0.56

Mutual attention	8	0.66
Empathy	6	0.74
Mutual understanding	6	0.91
Behavioural interdependence	6	0.64
Mutual assistance	4	0.48
Dependent action	2	0.45

Table 5: Test result for internal consistency for NMMSP.

4.3 Means Comparison

The average score and standard error were calculated for every factor in the IOS scale, SDQ and NMMSP. More detailed information about all sub-scores can be found in Appendix H.

4.3.1 The IOS scale. The mean value and standard error of the degree of connectedness, measured by the IOS scale, are shown in Figure 11.

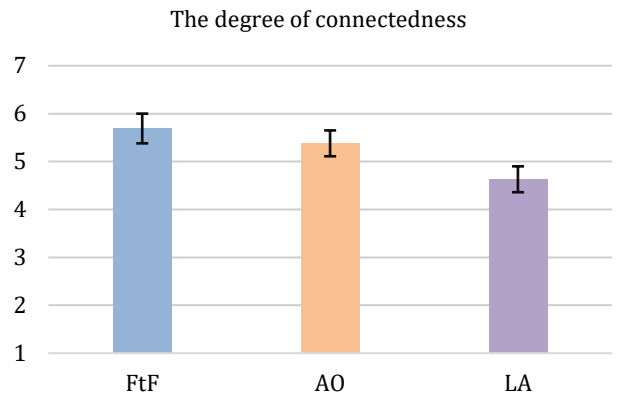

Figure 11: Mean differences and standard errors in the connectedness factor, measured by the IOS scale (Y-axis starts at 1).

The mean values of every condition were compared in an analysis of variance with the conditions of FtF, AO and LA as a within-subject factor. The main effect of conditions was significant for connectedness ($F=3.634$, $p=0.034<0.05$). After that, the ANOVA post-hoc tests (Bonferroni Correction) were performed for multiple comparisons. The connectedness mean score in the FtF condition ($M=6.25$, $SD=1.00$) was significantly higher than it was in the LA condition ($M=4.92$, $SD=0.87$, $p=0.035<0.05$). Furthermore, no significant differences could be found between the conditions FtF & AO ($p=1.000>0.05$) and LA & AO ($p=0.211>0.05$).

4.3.2 Semantic Differential Questionnaires. The mean value and standard error of social presence, measures by SDQ, are shown in Figure 12.

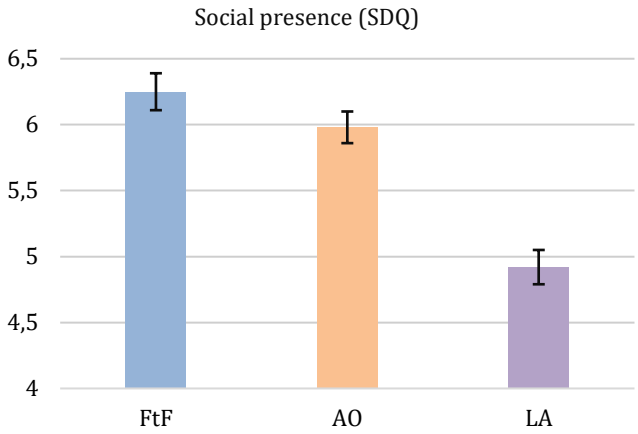

Figure 12: Mean differences and standard errors in the social presence factors, measured by SDQ (Y-axis starts at 4).

The mean values of every condition were compared in an analysis of variance with the conditions of FtF, AO and LA as a within-subject factor. The main effect of conditions was significant for social presence ($F=16.219$, $p=0.012<0.05$).

After that, the ANOVA post-hoc tests (Bonferroni Correction) were performed for multiple comparisons. The social presence mean score in the FtF condition ($M=6.25$, $SD=1.00$) was significantly higher than it in the LA condition ($M=4.92$, $SD=0.87$, $p=0.017<0.05$). Furthermore, the measured social presence in the AO condition was significantly higher than in the LA condition ($p=0.038<0.05$). No significant differences could be found in the factor between the conditions of FtF and AO ($p=0.993>0.05$) .

The results show that social presence, measured with SDQ is higher in the FtF condition than in the video conferencing conditions. The avatar alone supports a higher sense of social presence than when the real-time video and avatar show up together.

The mean value and standard error of social presence-aesthetic appeal, measured by SDQ, can be seen in Figure 13.

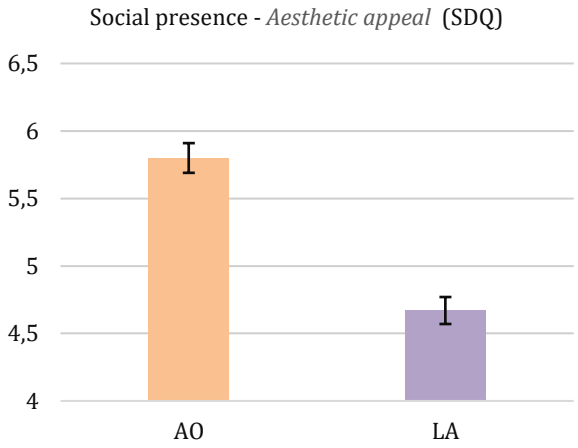

Figure 13: Mean differences and standard errors in the social presence-aesthetic appeal factor, measured by SDQ (Y-axis starts at 4).

The mean values of every condition were compared in an analysis of variance with the conditions of AO and LA as a within-subject factor. The main effect of conditions was significant for social presence-aesthetic appeal ($F=67.466$, $p=0.004<0.05$). The Bonferroni Correction results show the social presence-aesthetic appeal mean score in the AO condition ($M=5.80$, $SD=0.86$) was significantly higher than it was in the LA condition ($M=4.91$, $SD=0.80$, $p=0.004<0.05$).

This indicates that social presence-aesthetic appeal, measured with SDQ is higher in the AO condition than in the LO condition. The mean value of all items in the AO condition reaches a higher score than the one in the LA condition.

4.3.3 Networked Minds Measure of Social Presence. The mean value and standard error were calculated for every factor in NMMSP and are shown below (Figure 14).

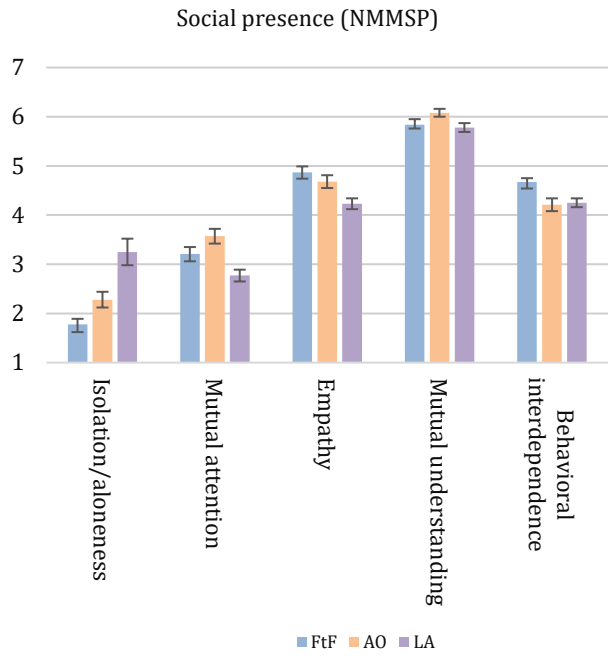

Figure 14: Mean differences and standard errors in the social presence factors, measured by NMMSP (Y-axis starts at 1).

No significant differences could be found in any of the factors of NMMSP ($p>0.05$). Under the different conditions (FtF, AO and LA), samples show consistency for all factors. As shown in Figure 14, three conditions scored very similarly in all items. Therefore, no conclusions can be drawn from this questionnaire.

4.4 Analysis of Variance

To assess whether these differences were due to the group mean differences related to the topic of the video (cooking), a one-way analysis of variance has been chosen to analyse the impact of the prior cooking experience ($M=3.1$, $SD=0.68$) on mean values of the IOS scale and SDQ. The results of this analysis ($p>0.05$) showed that the samples with different cooking experiences do not show significant differences for all of the group mean differences. This implies that the volatility of the data from the samples shows consistency and no variability. It can therefore be inferred that the results of connectedness and social presence measured in this study were due to the different experimental conditions.

4.5 Potential Customer Acceptance

A-Vibe gained positive responses in terms of the participants' desire for future use, which shows that this avatar system has great potential for the future. Fourteen (87.5%) participants answered yes and Two (12.5%) participants answered no regarding the question: "Would you use or utilize the system in the future? And why?"

Participants who answered "yes" generally said that they felt the animal forms were cute, which brought about a positive impact on their learning mood and thus may contribute to more interaction with their peers. However, Participant 8 who answered "no" pointed out that: "The avatar kind of distracted me from time to time, however, this was all new, so that could've influenced a little too." This shows the presence of the avatar has the chance to encroach on the student's attention. Participant 15, who also did not want to use it explained that: "I feel like it is more engaging than just voice, but I could not replace seeing someone's actual face for me", asking for richer information which should be contained by this system

Overall, the system achieved a good grade: 7.4 (M) ± 1.20 (SD) (on a scale of 1–10), indicating the participants' fondness for A-Vibe.

4.6 Insights into the Avatar System

4.6.1 Understanding of the avatar. Ten participants (62.5%) saw the avatar as themselves in the experiment as the representation of the avatars matched their changing moods. Participant 2's answer mentioned that the avatars of the experimental assistants conveyed emotions well, which brought about the feeling that "the avatars were representing us to communicate to each other."

Four participants (25%) identified the avatar as their pet. Interestingly, Participant 1 expressed: "I have a cat at home, so I always relate this cat avatar to my own cat when I interact with it." Another participant who also chose the cat avatar thought it is just a "cat" and wrote, "I really like cats so in my eyes it is a really cute 2D cat." Participant 15 thought the avatar was "just a cartoon character" and did not feel a connection to this avatar.

4.6.2 Privacy aspects. The answers to the question, "Do you think the animal avatar format protects your privacy? And why?", were: nine (56.25%) yes and seven (43.75%) no, along with reasons.

The responses of those who agreed, all pointed to the condition of AO, which would protect privacy while encouraging the interaction. The effect of the honest signalling component was weak. Participant 7 has mentioned that "it's fun to see my 'honest' state in the form of an animal but at the same time I can say it's not me", while other participants did not show much concern about this design point.

Regarding the participants who answered no, some said they did not care; some raised doubts about it. As they mentioned that in the LA condition, the live video is still presented, so there is no perceived protection of privacy in essence. In addition, Participant 12 said that the current system, which uses multiple cameras and facial analysis software, would feel a bit "over" if applied to a real online classroom. Participant 22 expressed that "even my real state was through the visual language of the animal, I still felt uncomfortable".

4.6.3 Richness of content. In the last optional question: "Is there anything else you would like to share?", a number of comments were made about the content presented by the system. Participant 4 mentioned the wish to send "personalized text for the speech bubbles" so that the text-based messaging function could be integrated into the system. Participant 12 suggested a "frame for the avatars" between avatars and live video in the LA condition. Another participant indicated a desire for adding a background for the avatar, e.g. grass or sky, as it felt strange to have the avatars "hanging" over the screen, especially in the case of LA. More participants commented on a preference for a customisable background for the avatar in the condition of AO (the background was black in the experiment). Participants 1,3,4,9, and 10 all expressed a wish for more emotionally expressive animations to choose from. It is worth mentioning that Participant 9 stated that if the avatar could just convey real-time emotions, the communication with the other side can be better, while "the current honest design sometimes causes confusion".

5 DISCUSSION

The following discussion summarises the main elements in the current study, from both a quantitative and qualitative perspective, which should be considered when evaluating the results obtained.

The main goal of this study is to investigate the impact of animal-form avatars in the live online classes environment on students' connectedness and social presence by delivering honest signals. In order to achieve it, experiments of three trials, one for each condition (FtF, AO, LA) were conducted to compare the degree of connectedness and social presence in mediated videoconferencing with the introduction of avatars with the face-to-face condition.

Considering the difficulty of the implementation of detecting honest signals and reflecting them to the avatars, the alternative chosen for this study differs from the detection of unconscious signals in the original definition. Assessing the degree of honesty of honest signals was not included in the measurement of this study. The value of this study lies in the measurement of the connectedness and perceived social presence, rather than in the in-depth analysis of honest signals. However, this would somehow affect the user experience as the response to the question about "privacy" and the participants' understanding of the avatar shows that the avatar system did not really bring up the argument about the relationship between the avatar and oneself. Thus, the implementation of honest signals is necessary in future research.

The IOS scale measured results showed that connectedness was the gold standard in the condition of face-to-face, while it was not significantly associated between AO and LA. However, participants expressed a facilitative effect of this system on interaction, which further promotes connectedness.

By using SDQ, it has been successfully found that differences not only between the face-to-face and LA conditions but also between the two mediated conditions themselves in terms of the social presence scale. This result supports one of the hypotheses in Christie's study (1973) that the social presence dimension can distinguish between different variations of the same mediated system, which in this study is videoconferencing. The semantic difference measures also suggest that the AO condition is more capable of supporting a high sense of social presence than the LA condition in video conferencing. The concept of AO condition videoconferencing was encouraged as it also has positive effects on the user's social presence in terms of aesthetic appeal. Overall, the experiment result shows that this avatar system can potentially influence the degree of connectedness and social presence.

However, the experimental results suggest that NMMSP is not a valid indication in this study of how social presence is influenced by different conditions. Future evaluative studies should be carried out by trying other reliable questionnaires, as well as adding some objective or physiological measures.

5.1 Limitations

In total, eighteen sample results were included in the final data analysis. This small sample size reduces the validity of the study. In addition to this, the results of the experiment were subject to many human factors. The performance of the experimental assistant who repeatedly participated in the experiment (whose performance was not considered in the data analysis) was not guaranteed to maintain the same level every time, and both proficiency with the content of the experiment and his fatigue level could affect the communication in the experiment, further affecting the participants' experience of the experiment.

The videos used to be watched in the experiment were around five minutes, which has a large gap compared to the time duration for real online live classes. Furthermore, the difficulty and variation of the different learning content in the actual class could also lead to an impact on the results.

Lastly, about the avatar design, the expressiveness capabilities of different avatars are not uniform; for example, the initial state of the avatar in cat form looks happier than the avatar in rabbit form mainly due to the different shapes of their mouths and was more expressive in showing happy emotion.

6 CONCLUSION

Through research, design, experiment and analysis, the research question of this study can be answered, which is: "What are the impacts of introducing animal-form avatars that can transmit honest

signals to live online classes on students' connectedness and social presence?"

Twenty-four Masters' students from TU/e with experience in online classes took part in the experiment and completed the survey, with the results of sixteen of them being counted in the final data analysis.

The research question can be then answered as followed: First, the degree of connectivity and social presence increases from mediated communication conditions LA to AO and real-life face-to-face communication. Despite the overall rating of all factors in the IOS scale and SDQ, the face-to-face situation is still the best, but an excellent performance of the system under the AO condition can be seen. Participants reported that this animal form of the avatar added to the enjoyment of the online class and also encouraged their interaction. Moreover, the definition of the honest signals in the system and how it is transmitted needs to be further investigated, but the interest and positive attitude expressed by the participants so far is a good sign.

A-Vibe was generally well-liked by the participants and has gained good potential customer acceptance, while it was not without criticism. The introduction of the animal avatar into the live online classes can lead to distractions for students and the non-real-time presentation brought some confusion for users. Importantly, the system design and functionality leave much room for improvement.

In the end, based on the results obtained from this study, it can be claimed that the research and development of animal avatars in the live online classes are of great value for the students' connectedness and social presence. This study is also significant as it confirms the potential for video conferencing-mediated communication to perform at a good level of social presence compared to face-to-face communication, which is in line with Swan's (2013) view. It is hoped that this research will bring meaningful insights to researchers in the field of remote education, and contribute to more enjoyable video conferencing communication in the future live online classes.

7 FUTURE WORK

The current results reveal the significant impact of the animal-form avatars on the connectedness and social presence of students, and future work could further explore interactions between lecturers and students in live online classes. Applying the designed avatar system to a real online course could be considered an alternative to a long-term experimental environment setting. Comparing the proposed conditions of both AO and LA with the condition of only real-time video of the users could also be a design direction for future experiments.

Regarding the design of the avatar system, three webcams are currently used to implement all the functions, but ideally, only one camera is needed, where the same video stream is then for all the detection. Therefore it is better if one system handles all necessary functions.

Lastly, the way of capturing and transmitting "honest states" output in the experiment, should be improved in the future, for example, by using tools like bio-sensors (Haag et al., 2004) or sociometer likewise sensors as stated in the original honest signal theory (Pentland, 2008), to sense the real states and further reflect them to the avatars. Meanwhile, privacy and ethical aspects should be kept in mind when it comes to deciding what tools to use. These tools should be easy to use and accessible from the user's perspective while maintaining the suitability and marketability of the system.

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Appendix A EXPERIMENT INTRODUCTION

A-Vibe is an avatar system, designed for online classes. This non-real-time avatar works to translate the student's current "honest" state into a vivid customised animal-form. The aim is to increase the unintentional cues used in interpersonal communication by using a metaphor that amplifies subtle physical or non-verbal signals. The experiment has three rounds and you will be working with an experimental assistant to complete. The whole experiment will take approximately **55** minutes.

Tips: The non-real-time honesty avatar in this experiment will be manipulated by the researcher through observation and some criteria. The order of the following rounds may not follow the label numbers.

Before test

Please read the consent forms and fill in some basic information. Then choose an avatar you like! Tutorial time!

Round 1 (Face-to-face)

You will watch cooking tutorial 1 (around 5 minutes) together with the experimental assistant (EA) together face-to-face. After finishing watching, you have 2 minutes to describe with EA the steps for making this dessert (***Description time***). In the end, you will need to fill in the survey (***Survey time***).

Round 2 (Your real-time video + A-Vibe)

You will watch cooking tutorial 2 (around 5 minutes) together with EA via MS Teams. Your avatar will appear in the bottom right corner of your live video. → ***Description time*** → ***Survey time***.

Round 3 (A-Vibe only)

You will watch cooking tutorial 3 (around 5 minutes) together with EA via MS Teams. Your avatar will appear in place of your live video. → ***Description time*** → ***Survey time.***

Post-questionnaire

Please fill in the post-questionnaire.

Appendix B CONSENT FORM

This study has been designed by Tianqin Lu. The research objective is to investigate the impact of social interaction on the missing social presence of online class through the use of animal-form avatars. The aim is to enhance students' social presence in the online classroom thus supporting the learning process.

Dear participants,

The research is part of the Vitality Squad master's program at the Department of Industrial Design at Eindhoven University of Technology. Participation is voluntary. Participation requires your written consent. Before you decide whether you want to participate in this study, you will be given an explanation about what the study involves. Please read this information carefully and ask the investigator for an explanation if you have any questions. You may also discuss it with your partner, friends or family.

The whole study will require approximately **55 minutes** to complete. During the study, the following will happen:
- Images will be taken during the study.
- You will complete one survey after each round (3 rounds in total).
- Your name will be anonymized in the report; however, your working title will be mentioned.

This study will not ask you for any personal information and the data collected will be used only for this project. The data will be kept on a password-protected academic online platform at the Eindhoven University of Technology. All the data collected during the study will be processed confidentially and test subjects will never be recognisable in publications, academic material or any other mean.

You can withdraw your consent to the use of your personal data at any time. The study data collected until the moment you withdraw your consent will still be used in the study.

If you have any questions, please contact: Tianqin Lu (t.lu@student.tue.nl).
If you have any complaints about the study, you can discuss this with the researcher. If you prefer not to do this, you may contact the Ethics Committee at the TU/e by ethics@tue.nl.

Your participation is very much appreciated, thank you!

Appendix C INSTRUCTIONAL VIDEOS

Waffles Recipe (Preppy Kitchen, 2021a): https://www.youtube.com/watch?v=iR64hfkGQeU&ab_channel=PreppyKitchen

Chocolate Cookies Recipe (Preppy Kitchen, 2021b): https://www.youtube.com/watch?v=loqCY9b7aec&ab_channel=PreppyKitchen

Garlic Bread Recipe (Preppy Kitchen, 2022): https://www.youtube.com/watch?v=wBFrmiDDIek&ab_channel=PreppyKitchen

Appendix D APPARATUS

In the conditions of AO and LA, participants and experimenters were in the same room. Specific settings: Webcam 1 - input for live video; Webcam 2 - input for facial analysis; Webcam 3 - input for facial capture of the avatar. During the experiment, the large screen shows the results of the participant's facial analysis.

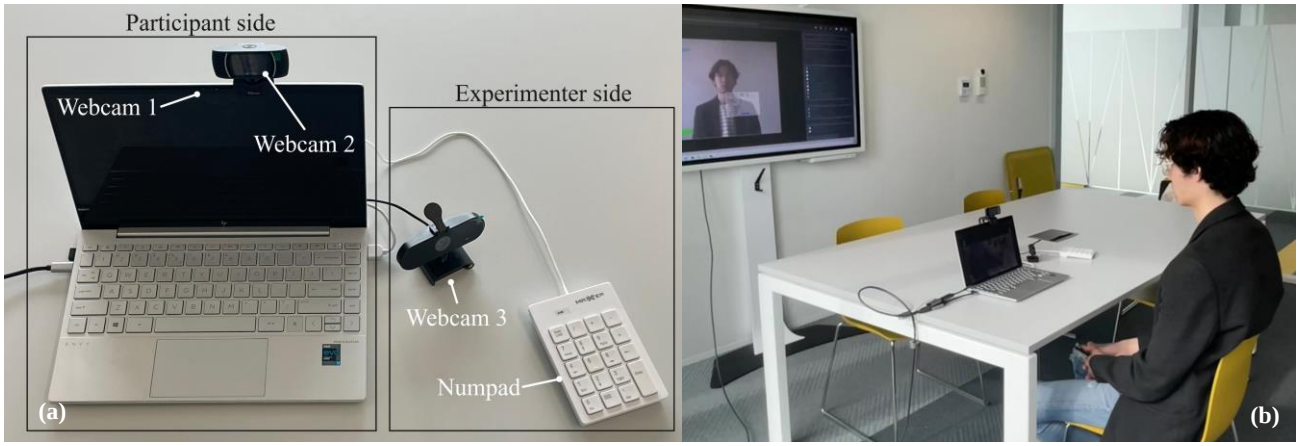

Figure D1: Experimental set-up: (a) apparatus set-up, and (b) experimental environment overview.

Appendix E SURVEY

The survey used in the study consisted of the following work: (1) the Inclusion of Other in the Self (IOS) Scale; (2) Semantic differential questionnaire (SDQ); and (3) the Networked Minds measure of Social Presence (NMMSP). The original scales for each item were retained to maintain scale consistency with the original questionnaires.

Item	Questionnaire	Likert scale
Q2: Semantic differential questionnaire		
Social presence		
S1: Insensitive-sensitive	SDQ	1-7
S2: Cold-warm	SDQ	1-7
S3: Impersonal-personal	SDQ	1-7
S4: Passive-active	SDQ	1-7
Social presence-Aesthetic appeal (only used in AO & LA conditions)		
S5: Small-large	SDQ	1-7
S6: Closed-opened	SDQ	1-7
S7: Colorless-colorful	SDQ	1-7
S8: Ugly-beautiful	SDQ	1-7
Q3: Networked minds social presence questionnaire		
Isolation/aloneness		
N1: I often felt as if I was all alone.	NMMSP	1-7
N2: I think the other individual often felt alone.	NMMSP	1-7
Mutual awareness		
N3: I hardly noticed another individual.	NMMSP	1-7
N4: The other individual didn't notice me in the room.	NMMSP	1-7
N5: I was often aware of others in the environment.	NMMSP	1-7
N6: Others were often aware of me in the room.	NMMSP	1-7

Mutual attention		
N7: I sometimes pretended to pay attention to the other individual.	NMMSP	1-7
N8: The other individual sometimes pretended to pay attention to me.	NMMSP	1-7
N9: The other individual paid close attention to me	NMMSP	1-7
N10: I paid close attention to the other individual.	NMMSP	1-7
N11: My partner was easily distracted when other things were going on around us.	NMMSP	1-7
N12: I was easily distracted when other things were going on around me.	NMMSP	1-7
N13: The other individual tended to ignore me.	NMMSP	1-7
N14: I tended to ignore the other individual.	NMMSP	1-7
Empathy		
N15: When I was happy, the other was happy.	NMMSP	1-7
N16: When the other was happy, I was happy.	NMMSP	1-7
N17: The other individual was influenced by my moods.	NMMSP	1-7
N18: I was influenced by my partner's moods.	NMMSP	1-7
N19: The other's mood did NOT affect my mood/emotional-state.	NMMSP	1-7
N20: My mood did NOT affect the other's mood/emotional-state.	NMMSP	1-7
Mutual understanding		
N21: My opinions were clear to the other.	NMMSP	1-7
N22: The opinions of the other were clear.	NMMSP	1-7
N23: My thoughts were clear to my partner.	NMMSP	1-7
N24: The other individual's thoughts were clear to me.	NMMSP	1-7
N25: The other understood what I meant.	NMMSP	1-7
N26: I understood what the other meant.	NMMSP	1-7
Behavioural interdependence		
N27: My actions were dependent on the other's actions.	NMMSP	1-7
N28: The other's actions were dependent on my actions.	NMMSP	1-7
N29: My behaviour was in direct response to the other's behaviour.	NMMSP	1-7
N30: The behaviour of the other was in direct response to my behaviour.	NMMSP	1-7
N31: What the other did affected what I did.	NMMSP	1-7
N32: What I did affected what the other did.	NMMSP	1-7
Mutual assistance		
N33: My partner did not help me very much.	NMMSP	1-7
N34: I did not help the other very much.	NMMSP	1-7
N35: My partner worked with me to complete the task.	NMMSP	1-7
N36: I worked with the other individual to complete the task.	NMMSP	1-7
Dependent action		
N37: The other could not act without me.	NMMSP	1-7
N38: I could not act with the other.	NMMSP	1-7

Table E1: Summary of the questionnaires (Q2&Q3) used in the study.

Appendix F POST-QUESTIONNAIRE

- Would you use or utilize the system in the future? And why?
- What grade do you give the system as a whole, on a scale of 1–10?
- Do you think that the form of animal avatar protects your privacy? And why?
- What does this avatar represent in your mind, e.g. yourself, your pet? And why?
- Is there anything else you would like to share? (Optional)

Appendix G RELIABILITY

The initial results of the reliability analysis of SDQ factors are as follows:

Semantic differential questionnaire factors	Cronbach's alpha			
	FtF	AO	LA	Mean
Social presence	0.628	0.612	0.664	0.63
Social presence- Aesthetic appeal	-	0.654	0.606	0.63

Table G1: Alpha reliability results for SDQ factors.

Specific alpha reliability results on S3 in different conditions:

Item	Corrected item-total correlation (CITC)	Cronbach's alpha if item deleted	Cronbach's alpha
S1	0.509	0.531	0.628
S2	0.665	0.424	
S3	0.291	0.657	
S4	0.354	0.636	

Table G2: Alpha reliability results for social presence items in the FtF condition.

Item	Corrected item-total correlation (CITC)	Cronbach's alpha if item deleted	Cronbach's alpha
S1	0.462	0.506	0.612
S2	0.630	0.391	
S3	0.145	0.813	
S4	0.531	0.451	

Table G3: Alpha reliability results for social presence items in the AO condition.

Item	Corrected item-total correlation (CITC)	Cronbach's alpha if item deleted	Cronbach's alpha
S1	0.320	0.684	0.664
S2	0.691	0.398	
S3	0.220	0.719	
S4	0.597	0.491	

Table G4: Alpha reliability results for social presence items in the LA condition.

As the corresponding CITC value for S3 was less than 0.3, it indicated a weak relationship with the rest of the items and was subjected to deletion. The final results of the reliability analysis of SDQ factors are as follows:

Semantic differential questionnaire factors	Cronbach's alpha			Mean
	FtF	AO	LA	
Social presence	0.657	0.813	0.719	0.73
Social presence- Aesthetic appeal	-	0.654	0.606	0.63

Table G5: Alpha reliability results for SDQ factors after removal of S3.

The results of the reliability analysis of NMMSP factors are as follows:

Networked minds measure social presence questionnaire factors	Cronbach's alpha			Mean
	FtF	AO	LA	
Isolation/aloneness	0.565	0.626	0.695	0.63
Mutual awareness	0.745	0.694	0.227	0.56
Mutual attention	0.667	0.535	0.765	0.66
Empathy	0.690	0.811	0.719	0.74
Mutual understanding	0.921	0.893	0.919	0.91

Behavioral interdependence	0.471	0.848	0.594	0.64
Mutual assistance	0.534	0.755	0.150	0.48
Dependent action	0.407	0.525	0.425	0.45

Table G6: Alpha reliability results for NMMSP factors.

Appendix H DESCRIPTIVE STATISTICS

The Inclusion of Other in the Self (IOS) Scale factor	FtF			AO			LA		
	M	SE	SD	M	SE	SD	M	SE	SD
The degree of connectedness	5.69	0.31	1.25	5.38	0.27	1.09	4.63	0.27	1.09

Table H1: Descriptive statistics for the IOS scale.

Semantic differential questionnaire items	FtF			AO			LA		
	M	SE	SD	M	SE	SD	M	SE	SD
Insensitive-sensitive	6.13	0.18	0.72	6.06	0.19	0.77	4.38	0.20	0.81
Cold-warm	6.13	0.20	0.81	5.69	0.20	0.79	5.19	0.21	0.83
Passive-active	6.50	0.34	1.37	6.19	0.21	0.83	5.19	0.19	0.75
Small-large	-	-	-	5.19	0.23	0.91	3.94	0.19	0.77
Closed-opened	-	-	-	5.88	0.13	0.50	4.81	0.19	0.75
Colorless-colorful	-	-	-	6.13	0.22	0.89	4.88	0.19	0.72
Ugly-beautiful	-	-	-	6.00	0.20	0.82	5.06	0.11	0.44

Table H2: Descriptive statistics for the items in SDQ.

Semantic differential questionnaire factors	FtF			AO			LA		
	M	SE	SD	M	SE	SD	M	SE	SD
Social presence	6.25	0.14	1.00	5.98	0.12	0.81	4.92	0.13	0.87
Social presence-Aesthetic appeal	-	-	-	5.80	0.11	0.86	5.67	0.10	0.80

Table H3: Descriptive statistics for the factors in SDQ.

Networked minds measure social presence questionnaire factors	FtF			AO			LA		
	M	SE	SD	M	SE	SD	M	SE	SD
Isolation/aloneness	1.78	0.11	0.61	2.28	0.16	0.89	3.25	0.27	1.55
Mutual attention	3.21	0.14	1.61	3.57	0.15	1.70	2.77	0.12	1.32
Empathy	4.87	0.12	1.20	4.68	0.13	1.26	4.23	0.11	1.05
Mutual understanding	5.84	0.11	1.04	6.08	0.08	0.74	5.78	0.09	0.90
Behavioral interdependence	4.67	0.08	0.82	4.21	0.13	1.30	4.25	0.09	0.88

Table H4: Descriptive statistics for all sub-factors in NMMSP.

Appendix I EXPERIMENTAL DATA

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Cooking experience	3	4	3	4	2	3	2	3	2	3	3	3	3	4	4	3

Table I1: Participants' cooking experience (on a scale of 1-5).

	FtF				AO								LA							
Items	S1	S2	S3	S4	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
P1	7	6	7	6	5	4	5	5	4	6	7	6	4	4	5	5	3	4	5	4
P2	6	7	6	8	7	6	6	6	5	6	5	5	4	6	5	5	3	5	5	5
P3	6	5	4	6	7	6	7	6	5	6	7	7	4	5	4	6	4	4	6	5
P4	5	5	6	3	7	7	6	8	4	6	6	5	4	4	4	4	4	5	5	5
P5	6	7	7	8	6	6	6	7	5	6	5	6	4	5	4	6	2	3	4	5
P6	6	7	6	7	6	6	7	6	6	6	7	6	4	6	6	6	5	5	5	6
P7	6	6	5	7	6	6	6	7	7	7	6	7	6	6	4	5	4	6	5	5
P8	6	6	3	5	6	5	4	6	5	5	5	5	4	5	4	5	4	4	4	5
P9	7	6	7	6	5	6	5	5	5	6	7	7	4	4	5	5	4	5	5	5
P10	6	5	6	5	7	6	7	6	5	5	5	6	4	6	5	5	4	5	6	5
P11	5	6	5	6	7	6	2	6	5	6	7	7	6	6	5	6	4	5	3	5
P12	5	5	4	8	5	5	6	5	5	6	7	5	4	4	4	4	5	5	5	5
P13	6	7	5	7	6	6	6	7	4	6	5	6	4	5	4	4	4	5	5	5
P14	7	7	7	7	6	6	7	6	6	6	7	6	4	6	5	6	4	5	5	6
P15	7	7	5	8	6	6	6	7	7	6	6	7	6	6	4	6	4	6	5	5
P16	7	6	6	7	5	4	6	6	5	5	6	5	4	5	4	5	5	5	5	5

Table I2: Experimental data of SDQ.

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23	N24	N25	N26	N27	N28	N29	N30	N31	N32	N33	N34	N35	N36	N37	N38
1	2	7	7	6	6	4	5	6	6	4	1	1	1	4	7	4	7	6	4	7	7	7	7	7	7	6	5	5	5	5	5	7	6	7	7	5	1
2	2	6	7	7	5	3	6	4	4	4	2	2	2	4	4	5	5	6	6	6	6	6	7	7	7	6	6	4	4	5	5	7	6	6	7	5	2
1	2	7	7	6	5	2	4	3	4	4	2	1	1	7	5	7	5	5	7	6	7	6	7	7	6	4	3	4	5	3	5	6	6	7	7	2	3
2	2	6	7	5	4	4	5	3	6	2	3	1	2	5	5	5	4	6	5	7	6	6	5	7	6	5	5	4	4	4	4	7	6	7	7	1	1
2	2	6	6	5	4	2	4	2	3	4	1	1	1	5	5	4	6	6	4	6	6	6	6	6	6	5	5	5	5	5	5	6	5	6	6	1	1
1	1	7	7	6	5	3	6	3	4	5	7	5	7	6	4	3	3	5	4	6	4	5	4	5	4	3	3	5	3	4	5	6	6	7	6	2	1
3	2	5	6	6	5	3	5	4	2	4	2	2	1	2	2	2	2	5	4	5	5	6	5	6	5	6	4	4	5	4	4	6	6	6	5	2	2
2	2	6	6	6	6	2	3	4	4	3	6	3	2	4	4	4	4	5	6	5	5	4	5	6	6	5	4	5	5	4	4	6	5	7	7	4	5
1	2	7	7	7	7	2	5	4	4	3	1	1	1	4	7	4	7	6	4	7	7	7	7	7	7	5	4	5	5	5	4	6	7	7	7	5	1
2	3	6	7	6	6	3	6	4	4	3	2	2	2	4	4	5	5	6	6	6	6	6	7	7	7	6	6	4	5	3	4	7	6	6	6	5	2
1	1	7	7	6	6	2	4	3	4	2	2	1	1	7	5	7	5	5	7	6	7	6	7	7	6	3	4	4	5	4	5	6	6	7	6	2	3
2	2	6	6	6	5	4	5	4	3	2	3	1	2	5	5	5	4	6	5	7	6	6	5	7	6	5	5	5	3	3	4	6	6	6	6	1	1
1	1	5	6	5	5	3	6	3	5	4	7	1	7	6	4	3	3	6	4	6	2	5	4	5	4	3	4	3	3	5	5	6	6	5	6	2	1
3	2	5	6	6	5	4	3	4	6	4	2	1	1	5	5	4	4	6	4	4	4	4	5	4	5	6	4	3	4	4	4	7	6	7	6	2	2
2	1	6	6	5	5	4	5	4	4	2	6	3	2	6	5	4	4	5	6	5	5	4	5	6	6	5	4	5	5	4	4	7	6	7	7	4	3
2	2	6	6	7	6	3	4	2	3	4	1	1	2	5	5	4	6	5	4	7	6	6	6	6	6	5	5	5	5	5	5	7	5	6	6	1	1

Table I3: Raw experimental data of NMMSP-FtF.

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23	N24	N25	N26	N27	N28	N29	N30	N31	N32	N33	N34	N35	N36	N37	N38
1	2	6	7	4	4	1	4	4	6	4	2	1	1	4	5	4	5	5	4	7	7	7	7	7	7	6	4	3	4	5	4	7	7	7	6	1	1
2	3	5	4	6	5	6	6	5	6	5	6	5	2	6	6	7	7	6	6	5	6	6	6	5	6	5	4	5	5	6	6	5	5	6	6	2	2
1	3	6	5	6	5	5	5	5	6	4	3	1	1	5	6	3	6	6	4	6	7	7	7	7	7	6	4	5	4	6	4	7	6	7	7	3	2
2	2	6	4	4	4	3	1	1	2	4	5	4	6	2	2	2	2	6	6	6	6	6	7	6	6	6	2	2	2	2	2	6	6	6	6	1	1
2	2	5	5	6	6	2	2	4	4	4	5	4	4	4	4	4	4	5	4	6	6	6	7	6	6	6	4	2	2	4	4	6	6	6	6	3	4
3	3	7	5	6	5	3	7	7	6	4	2	3	1	6	6	5	7	5	6	6	6	5	6	6	7	5	2	3	3	5	3	5	5	6	6	1	3
2	3	6	5	4	4	1	1	3	3	2	5	2	2	5	5	4	4	4	4	6	5	5	6	6	6	4	4	5	5	6	4	7	6	7	6	3	2
2	2	5	5	4	3	3	6	3	3	3	3	3	4	5	4	4	4	4	5	5	5	4	5	5	6	5	5	4	5	5	5	5	6	5	5	1	2
3	4	7	6	4	4	2	4	3	5	4	2	1	1	4	5	4	5	3	4	7	7	7	6	7	7	6	4	3	4	5	4	7	6	7	6	2	1
3	3	5	4	6	5	5	6	5	6	5	6	5	2	6	6	6	7	6	5	7	6	6	6	5	6	5	4	5	5	6	6	5	6	6	6	1	2
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1	2	5	4	3	4	3	1	1	2	4	5	4	6	2	2	2	2	6	6	6	6	6	7	6	6	6	2	2	2	2	2	5	5	6	6	1	3
2	2	7	6	6	6	3	2	4	4	4	5	4	4	4	4	4	4	5	4	6	6	6	7	6	6	5	4	2	2	4	4	6	6	6	7	3	2
2	5	6	6	6	5	3	7	7	6	4	2	3	1	6	6	5	7	5	6	6	6	5	7	6	7	5	2	3	3	5	3	5	5	6	6	2	3
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Table I4: Experimental data of NMMSP-AO.

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23	N24	N25	N26	N27	N28	N29	N30	N31	N32	N33	N34	N35	N36	N37	N38
1	4	6	4	7	4	2	2	3	3	4	1	1	1	4	6	4	4	7	6	6	7	6	6	7	7	3	4	4	4	3	4	6	6	5	7	4	2
5	5	5	5	3	4	1	1	2	2	4	6	2	3	4	4	4	4	5	5	6	6	6	7	7	6	5	5	5	5	4	4	5	5	5	6	2	3
2	5	7	5	6	5	1	2	4	3	5	5	2	2	4	5	5	5	3	3	6	7	6	7	7	7	2	2	4	4	3	4	6	5	7	7	2	2
2	1	6	5	5	3	1	1	2	3	2	4	2	2	4	3	3	2	2	3	6	6	6	6	6	6	2	5	4	5	3	5	6	6	5	6	1	1
3	4	5	4	2	6	2	5	3	2	4	7	4	3	4	4	4	4	5	5	6	4	5	4	5	5	5	4	5	6	5	4	6	5	6	6	5	5
2	4	5	5	3	4	2	1	3	4	3	6	4	3	6	5	6	5	5	4	6	6	6	6	6	5	5	3	4	5	5	5	6	6	6	3	2	3
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4	5	3	4	5	4	2	5	5	5	4	4	4	2	4	4	2	2	2	3	6	4	4	4	5	5	5	5	4	4	5	4	6	5	6	4	2	3
3	4	3	4	4	4	1	3	4	3	3	2	3	1	4	6	4	4	3	3	6	5	4	4	5	5	3	4	4	4	4	5	6	5	7	7	3	3
5	5	5	4	3	4	1	3	2	2	4	6	2	3	4	4	4	4	6	5	6	6	6	7	7	6	5	5	5	5	4	4	6	5	6	6	2	3
2	5	6	5	5	5	2	3	4	3	5	5	2	2	5	5	5	5	4	4	6	7	6	7	7	7	3	2	4	5	5	5	6	5	7	7	2	2
2	1	3	5	5	3	2	2	3	3	3	4	2	2	4	3	3	2	6	4	6	6	5	6	6	6	5	4	5	6	5	4	6	6	6	6	5	1
6	4	5	4	3	5	1	2	3	2	4	4	4	3	4	4	4	4	6	6	5	4	4	4	5	5	5	4	5	5	5	4	6	5	6	6	1	2
2	3	5	5	3	4	2	3	3	3	3	4	4	3	4	5	4	5	6	4	6	6	6	6	6	5	5	3	4	5	4	5	6	6	6	6	2	3
1	2	5	5	3	3	2	3	2	1	1	1	1	1	5	5	4	4	4	4	6	6	6	6	7	7	3	2	4	5	4	4	7	6	6	6	2	3
4	5	6	4	4	4	3	5	3	3	4	4	4	2	4	4	4	4	5	5	6	6	4	4	5	5	5	5	4	4	5	4	5	5	5	6	2	4

Table I5: Experimental data of NMMSP-LA.

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
System grade	7	8	6	8	7	9	10	5	7	8	8	8	8	7	6	7

Table I3: System grade (on a scale of 1-10).