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An experimental comparison of participants' experience in face-to-face, video, and virtual reality meetings

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The increasing prevalence of remote working and the challenges it presents underscores the need for alternative technologies that can provide a more healthy, natural and social remote meeting experience. However, there is a limited understanding of how such technologies compare to other modalities, especially face-to-face communication. This study investigates the impact of three meeting modalities - face-to-face, videoconferencing, and virtual reality (VR) - on participants' experience of social presence, wellbeing, and task engagement during a meeting involving a negotiation task. Despite the hypothesis that these experiences would significantly differ across modalities, no such differences were found. We suspect that characteristics of the meeting participants and the negotiation task, the meeting duration, as well as the measurements used have moderated the effect of meeting modality on experience. The VR modality was however perceived as more enjoyable, suggesting that immersive technologies like VR hold potential for enhancing the remote meeting experience. The results also underscore that there is no one-size fits all solution when it comes to choosing the best meeting modality. The study stresses the need for ongoing research to optimize the remote meeting experience in the context of different meeting objectives and practical considerations.

KEYWORDS

extended reality, meetings, social presence, wellbeing, Meta Horizons

1 Introduction

Remote working has recently evolved and holds promises for a long term societal impact, such as a reduction of emissions and of the time inefficiency associated with commuting. For employees, it potentially offers a better work-life balance with equal or even increased productivity. However, remote working also comes with a cost, mainly due to the necessity of having to communicate at a distance (previously mainly taking place through audioconferencing) and a resulting lack of social interaction with colleagues. This may cause mental health issues, such as an experience of loneliness and isolation (Van Zoonen and Sivunen, 2022).

The currently most widely used means of remote communication, i.e., online videoconferencing, partly relieves these issues, but during online meetings participants still experience a lack of social presence, i.e., “the sense of being with another person” (Hove and Watson, 2022; Short, Williams and Christie, 1976). Videoconferencing may also cause additional problems. Skowronek et al. (2022) give a good overview of the different aspects of videoconferencing that influence the user experience, communication behaviour and task performance of videoconferencing participants. An example is heightened fatigue due to the physical or mental effort it requires (Bailenson, 2021; Fauville et al., 2023; Montag et al., 2022; Wiederhold, 2020). These and possibly other disadvantages of remote communication result in remote working lagging behind expectations and wishes. However, contextual accelerants like the COVID-19 pandemic have underscored our society’s adaptability, emphasising the crucial need for ongoing research to create a more positive experience of remote communication by employees.

To create a socially improved, healthier experience of meeting remotely and a possible increase of productivity, promising new technologies are being developed as alternatives to videoconferencing. Apostolopoulos et al. (2012) provide a framework and overview of the different technical solutions for remote conferencing, from classical communication over email and telephone, via telepresence up to immersive communication methods. New technologies vary from telepresence to virtual reality, and are designed to create a closer resemblance to face-to-face meetings. They facilitate immersive interactions in three dimensions (3D), to tackle the disadvantages of videoconferencing which takes place in two dimensions (2D) while keeping the advantages intact. In telepresence meetings participants located at two different places communicate via a large screen mounted at the wall. Through the placement of furniture at both locations the suggestion is created that they are seated at the same table. More recently, in virtual reality meetings, participants communicate using a head mounted display (HMD), where a virtual world is presented in which avatars representing participants are seated at a table. First steps towards testing the potential advantage of VR have been made, with promising indications that meeting in virtual reality affords a better social presence than videoconferencing does (Abdullah et al., 2021; Hennig-Thurau et al., 2023). Moreover, such meetings were found to be more pleasurable, which is an important determinant for task performance (Lehmann-Willenbrock and Allen, 2014).

At the same time it has become clear that different meeting objectives call for different technological solutions (Standaert et al., 2021), and that creating the best meeting experience is not simply a matter of applying the most advanced technology at hand. For example, a straightforward verbal exchange of information can easily take place via audioconferencing only, whereas resolving conflicts and disagreements within a group and building a relationship is facilitated better by either face-to-face or telepresence meetings. This relationship between task and medium was first introduced in the task-media fit hypothesis by McGrath (1993). In addition, more practical aspects, such as the number of participants, meeting duration and associated costs, play a role in the choice of technology.

In our current study, we have experimentally investigated the influence of three meeting modalities (face-to-face,

videoconferencing and virtual reality) on the experience of meeting participants concerning social presence, wellbeing and task engagement. We have chosen these modalities, since they all (unlike audioconferencing) offer both audio and video communication, and do not require a dedicated room (as is the case in telepresence meetings). Moreover, virtual reality is claimed to relieve many of the disadvantages of videoconferencing, and to closely mimic face-to-face meetings.

The research question is as follows: “How does the meeting modality (face-to-face (F2F), video (V), and virtual reality (VR) of a negotiation meeting influence participants’ experience of social presence, wellbeing, and task engagement?”

2 Background

2.1 Meeting modalities, objectives and other characteristics

2.1.1 Modalities

Beside face-to-face meetings and audio-conferencing, videoconferencing and telepresence have come up as popular meeting modes (Karl et al., 2022; Standaert et al., 2021), each with their own characteristics. In face-to-face meetings participants are physically present in the same room. Consequently, they are able to hear each other’s voices (speech and vocal tone) from the direction where they are seated (spatial audio), they can use shared computer screens and/or work spaces, they experience co-location, they can see each other’s body language and gestures, they can discern each other’s facial expressions and they can observe what other participants are looking at (Standaert et al., 2021). Audioconferencing facilitates meeting at a distance, but here participants can only hear each other’s voices (speech and vocal tone), and they can possibly use shared computer screens. Videoconferencing enables the meeting participants to hear each other’s voices (speech and vocal tone), they can use shared computer screens and/or work spaces, they can see each other’s body language and gestures, albeit only to a certain extent (depending on the camera position), and they can discern each other’s facial expressions. Note that these capabilities all have a lower quality compared to face-to-face meetings, caused by the 2D nature of videoconferencing. Videoconferencing does offer neither an experience of co-location, nor the possibility to observe the direction of a sound (who is speaking?) or what other participants are looking at. It is best experienced in a desktop setting, but may also take place via a smartphone. Generally, we can consider videoconferencing as an established and advanced technology. Skowronek et al. (2022) give a good overview of the different technical and non-technical aspects that influence the user experience, communication behaviour and task performance of video conferencing participants. Telepresence meetings offer the same capabilities as videoconferencing, with the added value of a suggestion of co-location and the possibility to observe what other participants are looking at. Mostly, the direction of a sound cannot be perceived in telepresence. Also, it requires dedicated and furnished meeting rooms on both sides to establish the experience of co-location.

Virtual reality takes the next step in offering the experience of co-location, by creating a virtual meeting space where avatars

representing all participants are present (Meske et al., 2022). Essentially, virtual reality offers the same capabilities as face-to-face and telepresence meetings do. However, the quality of these capabilities depends to a large extent on the quality of the design of the virtual space (experience of co-location, direction of sound and use of shared computer screens and/or work spaces) and of the avatars (hear each other's voices (speech and vocal tone), see each other's body language and gestures, discern each other's facial expressions and observe what other participants are looking at). In particular, the fact that participants are represented as avatars may stand in the way of experiencing real interpersonal communication. Also, it requires the use of a head mounted display (HMD).

2.1.2 Objectives

The effect of meeting modality on the experience of a meeting is influenced by the specific objective of the meeting. Four key meeting objectives (exchanging information, making decisions, communicating sentiments, and building relationships) have been identified and related to four meeting modalities that, based on their capabilities, are most suited to reach them (audioconferencing, videoconferencing, telepresence, and face-to-face) (Standaert et al., 2021; Standaert et al., 2022; Straus and McGrath, 1994). Exchanging information includes communicating both routine and nonroutine information, as well as clarifying an issue or idea (Daft et al., 1987; Lengel and Daft, 1988), which can take place in all meeting modalities. Making decisions includes finding a solution and generating consensus on an idea (Allen et al., 2014; Jay, 1976; Leach et al., 2009; McGrath, 1984). Communicating sentiments includes exchanging opinions and confidential or sensitive information, as well as communicating feelings, emotions, or concerns (Fish et al., 1992; King and Xia, 1997; Rice, 1993). Both making decisions and communicating sentiments are hard to achieve in audioconferencing. Finally, building relationships includes building and maintaining trust, as well as assembling a team (Hoegl and Gemuenden, 2001; Mennecke et al., 2000; Te'Eni, 2001). For this purpose either telepresence or face-to-face meetings are required.

Virtual reality has the potential to support exchanging information and making decisions. However it is not clear yet to what extent sentiments can be communicated, in particular understanding feelings, emotions, or concerns may be harder. The use of avatars representing participants might stand in the way of this objective. In a similar way, it is unclear to what extent individuals experience using avatars as a barrier in building relationships. It has however been shown that avatar realism influences how an avatar is perceived, with realistic avatars being associated with higher acceptance, better quality of communication, and better social interactions (Garau et al., 2003; Latoschik et al., 2017; Roth et al., 2016). Even though videoconferencing enables meeting participants to see each other's physical attributes, being together in a shared space as avatars might still provide more social presence, enabling the communication of sentiments and relationship building to some extent.

2.1.3 Other characteristics

Other meeting characteristics, such as the number, personal characteristics (including experience with meeting technology),

roles and interpersonal relationships of the participants, the nature of the task to be performed, the duration of the meeting as well as usability issues of the technology used may influence the experience (Allen et al., 2021; Morrison-Smith and Ruiz, 2020). For example, participants who are mainly experienced in face-to-face meetings may have trouble noticing and interpreting social cues in technological settings, particularly if participant numbers increase. Certain tasks may require other means of communication than verbal only, such as whiteboards, post-its and digital presentations. Although these means may be easier to perceive in technological settings, they may also take attention away from the speaker and make it harder to provide contributions. Also, longer technological meetings may drain energy from participants, e.g., because of a prolonged screen time and more effort to follow the interactions or contribute at appropriate moments. Finally, since technology, in particular the somewhat immature virtual reality, may cause usability issues, this may raise barriers that stand in the way of a seamless integration with daily work practices.

2.1.4 Technological readiness

Generally, we can consider video conferencing as an established and advanced technology. In some way the level of immersion of the medium can be an indicator for the level of natural interaction and the availability and quality of non-verbal cues. For example, Life-Like Telepresence (Lawrence et al., 2021) can be seen as a high-class video conferencing system with real size depictions of remote users and ideally matching gaze. Immersive communication in VR is usually addressed via systems that represent users via computer-generated artificial avatars (McVeigh-Schultz et al., 2019). In recent years the maturity, technological readiness, and number of VR communication solutions has rapidly increased. Some of the most important ones (each with individual strengths, weaknesses, and levels of interaction) are Microsoft Mesh, Odyssey, Break Room, Frame VR, Alakazam, VR Chat, Rec Room, Engage, Glue, Spatial, and Meta Horizon Worlds. Meta Horizon Worlds currently offers the most integrated (in terms of hardware and software) and complete overall experience.

2.2 Choices for our study

In our study, we have chosen to experimentally compare face-to-face, videoconferencing and virtual reality meetings. Current research lacks direct comparison to face-to-face as a modality, leading to a limited understanding of how the two technologies relate to face-to-face communication. The three modalities all offer both audio and video communication, and are all, unlike audioconferencing, to a certain extent suitable for three meeting objectives: exchanging information, making decisions and communicating sentiments. We also excluded telepresence meetings since we wanted the modalities to be usable in comparable situations, without having to visit a room specifically designed for this purpose. We chose virtual reality since this technology was expected to be stable and mature enough to be used as a full-fledged condition in a lab experiment. We provided participants with a fictive negotiation task of which the topic was familiar to them, and which contained elements of all three meeting objectives under consideration. By providing the participants with a

familiar but fictive topic, group dynamics not involving sensitive topics or moral norms could be stimulated (Abdullah et al., 2021). In addition, a negotiation task focuses on communication only and does not require any additional tools that various technologies may or may not offer. We also made some choices which were practical for the experimental setting, such as a limited number of meeting participants who did not know each other and a limited duration of the meeting. These practical choices also limited the possibility of the fourth meeting objective: building relationships. Further details of the experimental design are provided in Section 3.2.

2.3 Meeting experience

In different meeting modalities, the participants' experiences may vary across at least three aspects: feeling of social presence, physical and mental wellbeing and engagement in the task to be performed together.

2.3.1 Social presence

Social presence, the 'sense of being with another person', is recognized as a crucial element in social interactions. It is found to predict good collaboration and learning, due to its impact on engagement and interaction dynamics. Short et al.'s Social Presence Theory (1976) states that the emotional connection people feel in mediated communication (such as phone calls) might be less than in face-to-face settings, due to the decrease of social cues, resulting in a diminished awareness of others. Over time, this theory has been used to understand why new technology-mediated communication, such as videoconferencing, is found to be less personal and immediate than face-to-face communication.

In virtual worlds, mediators such as avatars are used in communication and interactions. The Embodied Social Presence theory (ESP) suggests that social presence can be achieved when persons feel represented (embodied) by their avatars in the virtual world (Zhang et al., 2022). For this reason, new immersive technologies are expected to perform better in terms of social presence than videoconferencing, since real-time multisensory social interactions enable users to experience very realistic environments and interactions. In studies exploring the effects of social interactions in VR, social presence has indeed been found to be higher when compared to less immersive alternatives. In turn, this related to enjoyment and relatedness (the need for establishing meaningful and rich social interactions) (Barreda-Ángeles and Hartmann, 2022), motivation and learning outcomes (Robb and Sutton, 2014), and the development of social skills such as communication, collaboration and empathy (Zhao et al., 2014). Hence, the benefits of VR through increased social presence appears evident.

To further enhance (social) presence through avatar embodiment, research has explored various aspects of avatar representation that could enhance avatar embodiment, highlighting factors such as appearance (realism), control, and point of view (Casanueva et al., 2000; Fribourg et al., 2020; Suk and Laine, 2023). Fribourg et al. (2020) found that control and point of view tend to be more influential than appearance, with a clear preference for motion capture techniques and a first-person perspective. Additionally, avatars that are more realistic and

personalized, rather than abstract or standard, are associated with higher levels of perceived embodiment and (co-)presence. Importantly, striving for photorealism can result in an uncanny level of realism, which may cause discomfort among meeting attendees, as found in the study by (Bonfert et al., 2023). The authors therefore highlight the importance of expressiveness and versatility over photorealism. The current study employs VR technology that features a first-person perspective, high levels of control, and sufficient realism, which is expected to promote effective avatar embodiment. It is important to note that measuring social presence is a rather precarious task, since different terminologies and a large number of questionnaires create unreliable measures that are hard to compare (Sterna and Zibrek, 2021). Questionnaires are often adjusted towards a specific experimental context (Biocca et al., 2003), or they are used in a context where the measurements are less relevant. For example, when using items such as 'the other person felt real to me', in a research design that compares a face-to-face to an online alternative, the item feels off for the participants in a real-life setting, and seems more adequate for comparing different social technologies. In the context of researching meeting modalities, including a face-to-face baseline is critical, since new meeting technologies aim to mimic the functional capabilities of face-to-face communication. Therefore, the current study includes a face-to-face condition to serve as a baseline, and adopts a social presence measure that has been used in a comparable study (Kuzminykh et al., 2020).

2.3.2 Wellbeing

Not only does the decrease of informal interactions in videoconferencing meetings impact the social presence of people involved, but it also has notorious effects on aspects related to wellbeing. During the pandemic, the term 'Zoom fatigue' surfaced, relating to the exhaustion and drain that comes from the constant gaze people engage in during video conferencing (Fosslien and Duffy, 2020). This phenomenon, also called videoconference fatigue, has also been found to be associated with burnout and depression (Montag et al., 2022). A theoretical underpinning for this effect lies in the notion that when comparing videoconferencing with face-to-face encounters, there are fewer social cues, which makes the interpretation and production of information more cognitively heavy (Bailenson, 2021). In other words, social cues reduce the cognitive capacity needed to engage in social interaction, making it less draining than a similar encounter in a 2D video setting. Moreover, the constant self-reflection in video conferencing causes users to constantly view themselves, resulting in both negative affect and anxiety (Bailenson, 2021).

Following the (embodied) social presence theory it would seem that virtual technologies with great capabilities, unlike videoconferencing, can establish a level of social presence similar to real-life interactions, diminishing all negative effects of meeting remotely. However, there are opposing powers such as higher levels of exhaustion that might counteract these effects. According to the media naturalness theory, a communication medium can be too rich, lead to information overload and cause individuals to be overwhelmed, dissatisfied and less productive (Hantula et al., 2011). This theory was confirmed by Hennig-Thurau et al. (2023), who indeed found that participants in a VR setting experienced more exhaustion than the participants in a 2D condition. Besides,

headaches, nausea, and dizziness are relatively common effects of using a VR HMD (Caserman et al., 2021; Chattha et al., 2020). In order to find out to what extent the positive effect of social presence and the negative effect on wellbeing balance each other out, more research needs to be done regarding specific contextual factors.

2.3.3 Task engagement

An important prerequisite for communication in any modality is engagement of participants with the task at hand, i.e., the willingness to work on the task. When the engagement is low only limited communication will take place. In our study, we use a negotiation task based on a scenario where participants need to reach a common decision (see Section 3.3 for a detailed description of the task). Each participant plays a specific role that entails certain personal preferences, which need to be negotiated during the meeting. Participants need to read and process information on their role before the meeting and act accordingly during the meeting. To stimulate task engagement, the topic of the negotiation was chosen to be fun and familiar to the participants. Also, a bonus was provided for the participant who had managed to realise the most personal preferences in the decision.

To describe task engagement we use existing concepts on learning engagement from the literature on effects of modality on presence (Persky et al., 2009; Uhl et al., 2023). These concepts all focus on information that needs to be processed, similar to what our participants needed to do. Persky et al. (2009) define learning engagement as consisting of the following variables: elaboration of information (thinking deeply about the information) (Eveland Jr, et al., 2003), attention to the information, motivation to engage with the content and interest in it (how interesting the information is) (Moreno and Mayer, 2005), involvement (how important participants consider the information to be) (Cheng, 2005; Roser, 1990), believability of the information, and enjoyment (adapted from Swinth et al. (2001)). Uhl et al. (2023) combined Persky's et al. (2009) variables into three constructs: approval (six items), information consideration (three items), and involvement (one item). In our study we have included these ten items in the questionnaire, after minor text adaptations to better reflect our task (see Section 3.3).

To our knowledge there is limited knowledge of whether task engagement differs between meetings in different modalities. Uhl et al. (2023) compared three modalities in the context of social skills training: a real-life role play training, a learning app and a virtual reality training application. They found that approval for VR was higher than for the app.

2.4 Hypothesis

Videoconferencing is often found to underperform compared to virtual reality, concerning social presence, wellbeing, and task performance. Current research lacks direct comparison to face-to-face as a modality, leading to a limited understanding of how these technologies relate to face-to-face communication. Still, we hypothesise that in our study the face-to-face condition will perform better than videoconferencing and VR, considering the experience of social presence, wellbeing, as well as task engagement. However, we do hypothesise that this overperformance will be higher when compared to videoconferencing than to VR. The following hypothesis was formulated:

Face-to-face meetings have a higher experienced (a) social presence, (b) wellbeing and (c) task engagement than video-conferencing and VR do, where the difference with video-conferencing is larger than with VR.

3 Materials and methods

3.1 Participants

A total of 141 participants, all students, took part in the experiment, forming a total of 47 groups across three conditions. Participants were randomly divided between the three meeting modalities. An effort was made to balance gender across the groups, and to have little to no familiarity between participants in the same group. Inclusion criteria were the ability to speak Dutch fluently, and being aged between 18 and 27. Of the participants, 95 (67, 4%) were female, and 45 (31, 9%) were male. One participant identified as non-binary. Of the 47 groups, 14 were women only, 2 were men only, and 31 were mixed. All participants were compensated financially for their participation. A financial bonus was given to participants if they were able to negotiate in accordance to their preference (see Supplementary Material). This bonus was calculated based on a predefined point system.

3.2 Experimental design

The hypotheses were tested in a controlled setting, using a between-subjects experimental study design. The three conditions that were compared consisted of the three meeting modalities: face-to-face (F2F), video (V), and virtual reality (VR). In each condition, a negotiation task was executed by groups of three participants. In F2F, participants were placed in a triangular set-up at a round table. In the V condition, each participant was placed in a separate room with a videoconferencing set-up. In the VR condition, participants were also placed in separate rooms, and wore a VR headset. In the VR space, the participants were virtually seated at a table of four (see Figure 1).

3.3 Negotiation task scenario

During the experiment, groups of three participants conducted a negotiation task in one of the three conditions. The task was inspired by Abdullah et al. (2021) and adapted to a student context, to fit the participant group. In the adapted scenario, the three participants were told that they formed a student committee that had to plan a party for new students, as a final event of their introduction week. Participants were instructed to make decisions on four different issues regarding this party: the number of fire breathers performing at the party, the number of security guards, the ticket price, and the end time of the party. For all four issues, the participants were given four options to choose from. Different roles were assigned to the participants (secretary, treasurer, and logistics and safety, each with their own preferences for all four issues. The roles were given to the participants separately, and they were instructed to come up with their own arguments to negotiate. The full instructions for the task can be found in the Supplementary Material. The participants were informed that they could receive a financial bonus if they were able



FIGURE 1 Avatars representing the meeting participants in in Meta Horizon Workrooms.

TABLE 1 Technical specifications of the Forexa USB webcam.

Resolution	1920 × 1080
Framerate	15–30 fps
Megapixels	2.1 Megapixels

to negotiate in accordance to their preference. The point system on the basis of which the bonus was calculated was not revealed to the participants to prevent distraction. Participants were given a maximum of 15 min to reach an agreement, and they were warned 3 min before the meeting ended.

3.4 Materials

3.4.1 Videoconferencing

In order to facilitate a video-meeting, three separate rooms were provided with a laptop connected to a monitor with a webcam. Each laptop had Microsoft Teams running on it, with all additional functionality such as chat disabled. During the video meeting, the local participant was displayed in a small window in the lower right corner, whereas the remote participants displayed in large windows. Webcam and sound settings were tested before each experiment to make sure everything was working properly. Participants did not have to interact with the technology. Instead, the experiment leader started the meeting in each room. Technical specifications of the webcam are provided in [Table 1](#).

3.4.2 Virtual reality

For the VR condition, Meta Quest Pro HMDs were used. The Quest Pro is a standalone device, no additional hardware is

TABLE 2 Technical specifications of the Meta Quest Pro headset.

Resolution	1800 × 1920 pixels per eye
Visual Field of View	106° horizontal × 96° diagonal
Refresh Rate	90 Hz
Pixels per Degree	22 ppd
Eye and face-tracking	YES
Spatial Audio	YES
Weight	722 g

required. The HMDs are equipped with two cameras; one capturing facial expressions and one capturing frontal view. The latter was necessary to track the hands of the participants and to enable the participants to see the task sheet with their role described on it. Participants did not have to use controllers. The only interaction the participants had with the interface was selecting the virtual room by pinching with their thumb and index finder. The technical specifications of the VR headset are provided in [Table 2](#).

The business meetings were held in Meta Horizon Workrooms, a virtual collaboration platform developed by Meta. Users were represented by avatars, as is depicted in [Figure 1](#). Although the avatars were human-like, they retained cartoonish features and were displayed only from the waist up. The avatars could be adjusted in advance by each participant to mimic their own appearance using the separate smartphones which were connected to of the three HMDs. Although participants could only see their hands and not themselves, due to the platform’s use of a first-person perspective, personalization was still expected to be beneficial, as each group

member could see the other two members. Since participants briefly saw each other before the start of the experiment, they were able to identify the avatars as the persons they just saw. Moreover, knowing that the avatar resembles your own appearance, even if you cannot directly see it, is arguably still beneficial for avatar embodiment (Fribourg et al., 2020).

Horizon Workrooms aims to provide a more immersive meeting experience by incorporating spatial audio, as well as eye and face-tracking. This means that the gaze direction could be mimicked by the avatar, as well as eye and mouth movement. Facial expressions could therefore be accurately represented by the avatar. Gestures and body rotation were also directly mimicked, without holding controllers. These specifications enabled, at least to some extent, a natural translation of non-verbal cues. The accurate representation of gestures and facial expressions are expected to contribute to the participants' experience of control and realism. Available presentation and collaboration tools were disabled.

3.4.3 Surveys

Three separate laptops were used to conduct questionnaires before and after the negotiation meeting, made in Survalyzer. The pre-questionnaire included questions regarding demographics, control measures and questions on wellbeing. The post-questionnaire included questions on general experience, social presence, task engagement and wellbeing.

3.5 Procedure

The total duration of the experiment was 30 min to 1 h, depending on the condition. First, the facilitator welcomed the participants, and instructed them to read through an information sheet that gave them some information on the procedure of the experiment. Next, the participants were asked to sign a consent form, and the facilitator explained in short what the experiment was about. If there were no further questions, each participant was given a laptop to fill out the pre-questionnaire. Subsequently the facilitator explained the meeting scenario and gave a clarification if necessary. In condition 3, the participants were also instructed on what they could expect in the VR environment, and on how to use the headset. They were also given the opportunity to adjust the avatar that represented them in the virtual world. This was done on a smartphone that was connected to the headset. After plenary instructions, participants were led into the meeting room (F2F) or the separate rooms (V and VR). All participants were given some time to read the information on the scenario and familiarize with their role. In the V and VR conditions, the facilitator checked if all technology was working properly. At the signal of the facilitator the subjects started the meeting. In both the V and VR condition, the facilitator was in the meeting with a separate device, with both camera and microphone turned off. This was done to record the meeting, and participants were informed that facilitators had no active role in the meeting and were not listening. The meeting took no longer than 15 min. After 12 min, the participants were notified that they had 3 min left. In the F2F condition this was done by a knock on the door; in the V condition by a virtual hand-raise in Teams, and in the VR condition the facilitator briefly turned on the

camera to gesture to the participants. Once the meeting concluded, subjects were given a laptop to fill out the post-questionnaire.

3.6 Measurements

3.6.1 Control measures

To control for confounding variables, certain constructs were measured using the questionnaire. First, experience with videoconferencing or VR and experience with formal meetings were measured. Also, participants were asked to what extent they worked or studied from home. To control for personality, a Dutch translation of the Ten Item Personality Inventory (TIPI) (Hofmans et al., 2008) was included in the questionnaire.

3.6.2 Social presence

Social presence was measured by using an adapted version of Biocca's Networked Minds Social Presence Inventory (NMSPI) (Biocca et al., 2003). Similar to colleagues (Uhl et al., 2023), only the second order social presence, being psycho-behavioural interaction was measured. The first order lies on a perceptual level, dealing with the awareness that another being is in the shared virtual space. The second order goes one step further and is about how easily one feels they can connect with or interact with another person in a shared environment, which was our primary interest. The NMSPI measures social presence using four different scales: (1) attentional engagement, (2) emotional contagion, (3) comprehension, (4) behavioural independence. The items on the scale were adapted to fit the scenario.

3.6.3 Wellbeing

To measure wellbeing, pre and post measures were taken regarding the energy levels and the physical complaints of participants. Three items were used to measure the wellbeing of participants prior to the experiment, each with a 7-point Likert scale. These items were (1) 'How tired do you feel at this moment?', (2) 'How stressed do you feel at this moment?', and (3) 'Do you have physical complaints at this moment?'. An open text-entry was given for participants to specify the physical complaints in case they did experience them. After the experiment, another three items with a 7-point scale were measured, corresponding to the three items measured beforehand. These items were (1) 'How much energy did this meeting cost you?', (2) 'Did you experience stress during the meeting', and (3) 'Do you have physical complaints at this moment?'. As with the pre-measurements, an open text-entry was given for participants to specify physical complaints.

3.6.4 Task engagement

Task engagement was measured using three subscales, adapted from Uhl et al. (2023): approval, information consideration and involvement. The items were slightly adjusted, since the original items were about a learning task. Hence, the word 'training' was replaced with 'negotiation'. The items for approval were (1) 'The negotiation was fun', (2) 'I was content with the negotiation', (3) 'I would like to do a negotiation like this again', (4) 'The subject of the negotiation was interesting', (5) 'The subject of the negotiation was presented in an interesting manner'. The items for information consideration were (1) 'I found it easy to come up with arguments',

(2) 'I derived the arguments from my own life', (3) 'I considered to what extent the arguments from other participants relate to the things I know'. The item for involvement was 'I find it important to learn how to negotiate'.

3.6.5 Overall experience

To measure the overall experience of the participants, some general questions were added to the post questionnaire. These questions included (1) 'How did you experience the meeting?', (2) 'What did you think of the pace of the meeting'. In the case of the V or VR condition, an additional question was asked: 'How did you experience the use of the videoconferencing environment (Teams)/Virtual Reality environment (VR) in this meeting?'. Finally, an open text question was added to ask for points of improvement for the videoconferencing or VR environment.

3.7 Analysis

We used a reliability analysis to check the internal consistency of the subscales. The item for the subscale 'Involvement' of Task Engagement was placed in the subscale of 'Information Consideration' to create a higher internal consistency. To determine if there were differences between the three modalities we used SPSS Linear Mixed Effect Models with group as random effect and modality as a fixed effect. For the data measured before the participants conducted the task, we performed a between groups variation ANOVA in SPSS General Linear Model. The internal consistency of the subscales was as follows: for Task Engagement, the subscale Approval consisted of 5 items ($\alpha = 0.77$), the subscale Information consideration (including involvement) consisted of 4 items ($\alpha = 0.60$). For Social Presence, the subscale Attentional Engagement consisted of 3 items ($\alpha = 0.63$), the subscale Comprehension consisted of 3 items ($\alpha = 0.69$), subscale Behavioural Independence consisted of 2 items ($\alpha = 0.60$), and subscale Emotional Contagion consisted of 1 item. The internal consistency of the subscales ranges from good (Approval, Comprehension) to moderate (Information Consideration, Attentional Engagement, Behavioural Independence).

3.8 Ethical approval

Informed consent was obtained from all participants, and the Ethical Committee of TNO Defence, Safety and Security approved the study.

4 Results

4.1 Meeting duration

The meeting duration was mostly the same across all conditions. Most groups took 15 min, with some exceptions that were done a few minutes earlier. No group took less than 10 min. The F2F groups were a bit faster, probably due to the fact that they did not come across any technical hiccups along the way.

TABLE 3 Results of TIPI.

Personality trait	F	Significance
Extraversion	F (2,138) = 0.254	p = 0.776
Agreeableness	F (2,138) = 0.895	p = 0.411
Conscientiousness	F (2,138) = 1.534	p = 0.219
Emotional stability*	F (2,88.43) = 2.081	p = 0.131
Openness to experience	F (2,138) = 2.129	p = 0.123

*Welch test reported.

4.2 Control variables

Analysis on potential confounding variables showed no difference in experience with videoconferencing or VR technologies. Similarly, no difference in experience with working from home or partaking in formal meetings was found. Pre-measures of wellbeing and the TIPI also indicated no significant differences between all conditions (Table 3). To conclude, the randomisation of participants across conditions was successful.

4.3 Social presence

We found no significant differences between the three modalities on the four Social Presence subscale measures. There was no significant effect of modality on the level of 'Attentional Engagement' indicating that scores on Attentional Engagement were in general the same for each modality' (F (2,44.005) = <1; p = 0.816). This was also the case for the other three subscales 'Emotional Contagion' t (F (2,44.017) = <1; p = 0.925), Comprehension (F (2,44.015) = <1; p = 0.981), and 'Behavioural Independence' (F (2,138) = <1; p = 0.713). Results can be found in Table 4 and Figure 2.

4.4 Wellbeing

We found no difference between the three modality conditions in the amount of stress that was experienced in the meeting (F (44,44.006) = <1; p = 0.679). Similarly, there was no difference found in the amount of energy that the meeting cost or generated (F (2,44.009) = <1; p.732). Also, we found no significant worsening or improvement of physical complaints when comparing measurements before and after the experiment (F (2,44.019) = 2.441; p = 0.099). Results can be found in Table 5 and Figure 3.

4.5 Task engagement

We found no significant effect between the three conditions for both subscales of task engagement. Information Consideration (including Involvement) was not significantly different across conditions (F (2,44) = 1.120; p = 0.336), as was Approval ((F,44.015) = <1; p = 0.459). Results can be found in Table 6 and Figure 4.

TABLE 4 Results social presence.

Modality	Attentional engagement			Emotional contagion			Comprehension			Behavioral independence		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD
F2F	16	5,715	0.531	16	4,401	0.234	16	5,944	0.115	16	4,885	0.151
V	16	5,625	0.153	16	4,229	0.234	16	5,924	0.115	16	4,833	0.151
VR	15	5,763	0.188	15	4,200	0.241	15	5,956	0.119	15	4,711	0.156

4.6 Overall experience

A significant difference was found between conditions in how the meeting was perceived. Pairwise comparison shows that the VR condition was experienced to be significantly more pleasant than the V condition ($F(2,44.014) = 4.904; p = 0.012$). No difference was found in the experienced pace of the meeting between conditions ($F(2,44.008) = 1.244; p = 0.298$) (Table 7).

The question ‘How did you experience the use of this environment’ (scale 1–7) to measure Use of Technology was only asked in conditions V and VR. ANOVA comparing the experience of the environment showed a significant difference between these 2 conditions, with the VR condition having a more pleasant experience ($F(1,29.053) = 27.125; p < 0.001$) (V 4.69 (1.07); VR 6.32 (0.61)).

Most participants left comments in the open text entry of the survey. In the V condition, some comments were made regarding network and audio quality. Moreover, multiple participants commented that participants frequently spoke simultaneously, which negatively influenced their experience. In the VR condition, some participants commented about the technological capabilities, such as the accuracy of movement representation and the sharpness of the front camera. The latter affected how well they could view the paper with their role and preferences. Interestingly, multiple comments were made regarding the table setting. Participants did not like that they could not be equally distributed across the table, which was caused by the uneven number of participants.

5 Discussion, limitations and future work

Three meeting modalities for executing a negotiation task were compared: Face-to-face (F2F), Videoconferencing (V), and Virtual Reality (VR). Meeting experience was measured through three constructs (social presence, wellbeing and task engagement), and some questions on overall experience. The hypothesis that social presence, wellbeing and task engagement would significantly differ across the conditions was rejected. Multiple reasons could underlie this result.

5.1 Participants

Characteristics of the specific participant group (students) may have influenced the results. It is likely that a large percentage of the participant group studied during COVID-19, adapting them to meeting and collaborating solely remotely. This experience might have made this group more resilient to meeting remotely, explaining the lack of effect on social presence, wellbeing, and task engagement. Relatedly, a convenience sample was used, which might have led to a participant group that is more than average open to new technologies. Even though participants did not score significantly differently on the TIPI, other characteristics could have been of influence. For example, genders were not equally represented in the complete dataset (more female than male), and mixed gender groups were largely overrepresented compared to groups with only one gender. As few participants had experience with VR, and

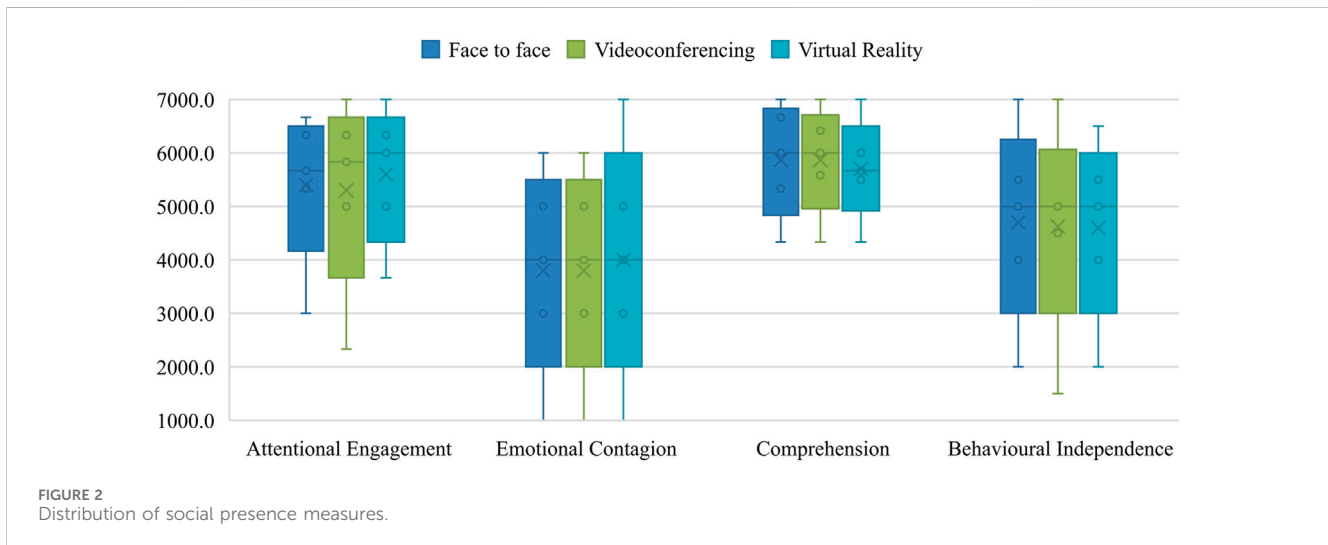
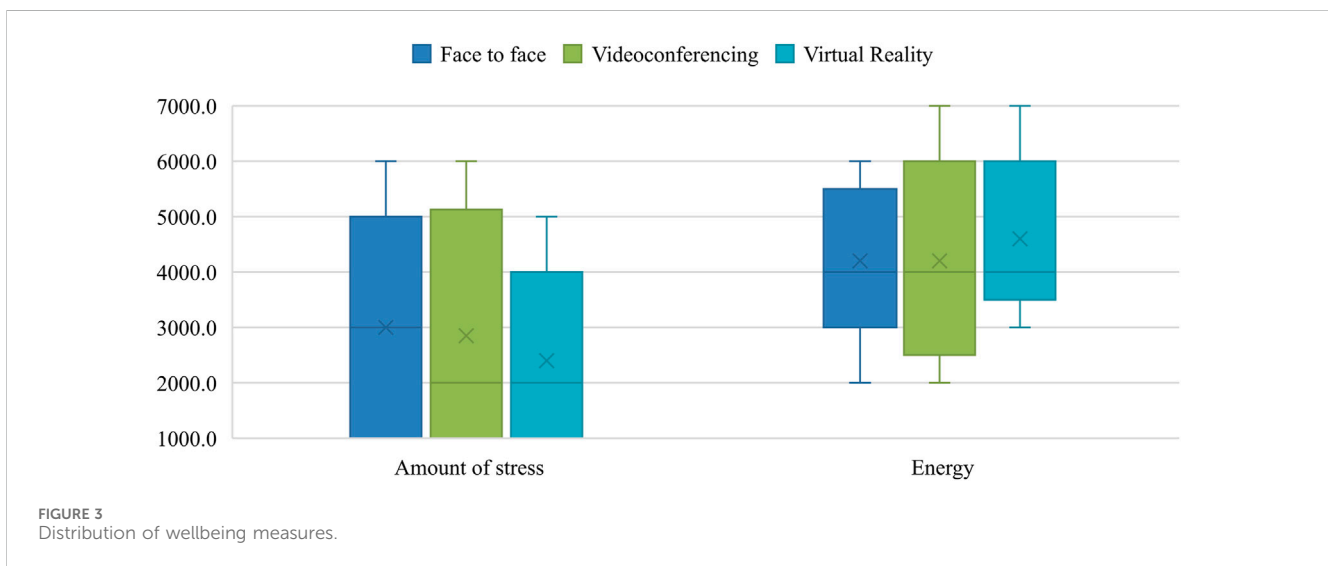


TABLE 5 Results wellbeing.

Modality	Amount of stress			Energy			Physical complaints		
	N	M	SD	N	M	SD	N	M	SD
F2F	16	2,771	0.266	16	4,292	0.168	16	0.063	0.164
V	16	2,750	0.266	16	4,208	0.168	16	-0.188	0.164
VR	15	2,467	0.275	15	4,400	0.174	15	0.333	0.169



experienced significantly more enjoyment in this condition compared to the other two modalities, this group was likely curious to experience VR. As a result, they might have been less receptive towards potential negative effects of wearing the HMDs and limitations of technological capabilities in the virtual space. Future research should aim for a more diverse and balanced participant group in terms of age, gender, and technological familiarity to enhance generalizability.

5.2 Procedure

The presence of facilitators in the V and VR conditions may have influenced participant behaviour during the meetings. Although the facilitators had their microphones and cameras turned off and communicated in advance that they would not be listening, their presence could still have had an impact. In the Teams call, participants could see a rectangle on the screen indicating that

TABLE 6 Results task engagement.

Modality	Approval			Information consideration/ Involvement		
	N	M	SD	N	M	SD
F2F	16	5,154	0.133	16	5,521	0.118
V	16	5,275	0.133	16	5,771	0.118
VR	15	5,396	0.138	15	5,644	0.122

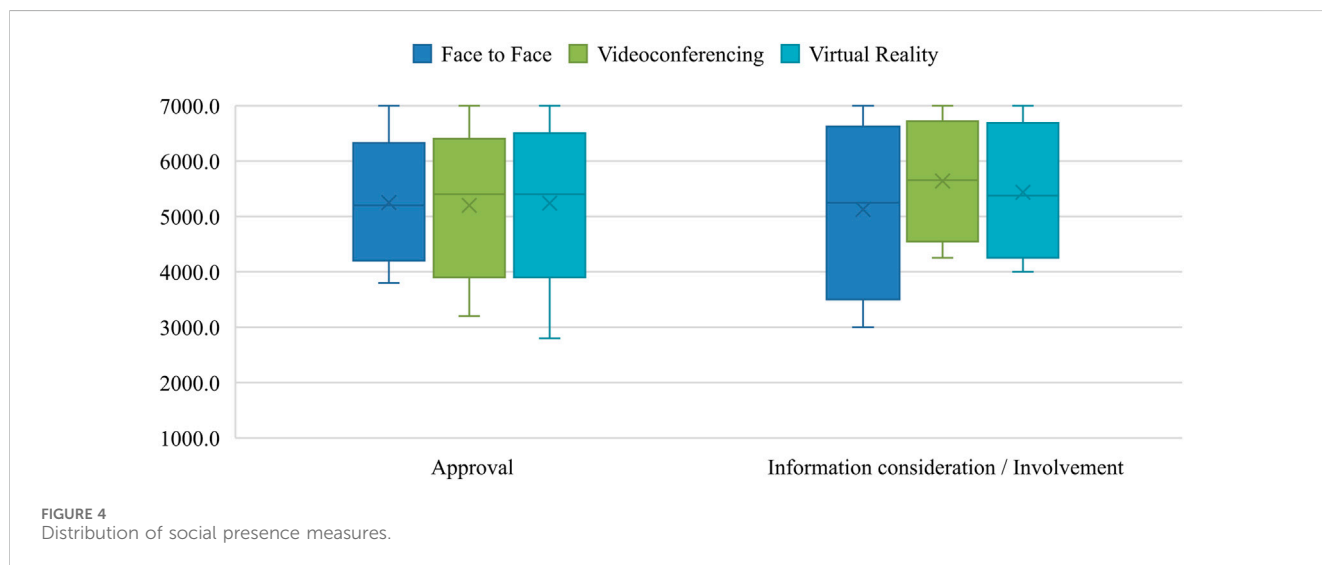


FIGURE 4 Distribution of social presence measures.

TABLE 7 Results overall experience.

Modality	Experience			Pace		
	N	M	SD	N	M	SD
F2F	16	5,521	0.194	16	5,208	0.197
V	16	5,125	0.194	16	4,833	0.197
VR	15	6,000	0.201	15	5,222	0.203

someone else was present in the meeting, and a similar rectangle was visible in the VR environment. Notably, participants often overlooked the hand raise or the brief camera activation used to signal that they had 3 min remaining, suggesting that they were primarily focused on the meeting rather than on the facilitators. Nonetheless, future research should consider minimizing the visibility of facilitators or assessing the effects of their presence more systematically.

5.3 Meeting objectives and negotiation task

The fictive nature of the negotiation task could have been of influence on the results. Participants were given a role and preferences, which could have felt artificial. Although the task was reportedly fun, familiar and easy to understand, the intended

objectives, being exchanging information, making decisions and communicating sentiments, could not have felt completely real to participants. As a consequence there was no real necessity for the participants to truly engage, apart from the possibility of earning some extra remuneration. As previously established, richer technologies are more likely to have advantages over videoconferencing when meeting objectives include building relationships (Standaert et al., 2021). We do not know whether if we had added the objective building relationships as part of the task this would have caused more engagement of the participants. Also, we made the choice for participants not to know each other beforehand, to keep conditions comparable, which could have stood in the way of more spontaneous interaction. Our results are however in line with previous work using a similar negotiation task, where no difference in social presence was found, comparing videoconferencing with VR (Abdullah et al. (2021)). Future research could take the step to study the experience of new technologies in real life settings. Conducting the study in a real-life setting rather than a controlled laboratory environment could provide more realistic insights into how different meeting modalities are used and perceived in everyday contexts. A first step has been taken by Held et al. (2024), whose main findings show promising signs for the use of VR in remote business meetings. The study suggests that participants who conducted their work meetings in VR, experience an improved interaction, more togetherness, and

a better conversational flow. Nonetheless, the study also posited that there are challenges related to the technological readiness of VR, which currently makes a widespread adoption difficult.

5.4 Meeting duration

The meeting length in our study was restricted to 15 min, for practical reasons and to prevent serious physical complaints in the V condition and particularly the VR condition. However, 15 min might have been too short to influence the general experience, social presence, wellbeing and task engagement. In particular effects of using VR over a longer period of time on wellbeing could not be established. Length is likely an influential contextual factor in the effect of meeting modality on experience (Hennig-Thurau et al., 2023; Standaert et al., 2021). The effectiveness of remote meetings decreases if the meeting is longer than 1 h, implying that long meetings generally require more communication capabilities (Standaert et al., 2016). This aligns with the recent study by Macchi and De Pisapia (2024), who showed, after meetings of about an hour, that VR meetings were found to be more fatiguing than VC and FF. The three modalities also yielded different effects on other measures such as idea generation, and task absorption, suggesting that clear differences become evident after a longer period of time. The results of our study confirm that for short meetings (15 min or less) the choice of modality hardly impacts meeting experience, despite possible negative aspects of the technologies used, in particular VR. Future research should focus on experimenting with different (longer) meeting durations, in order to understand the sustained effects of meeting modalities on social presence, wellbeing and task engagement.

5.5 Measurements

The measurements used for social presence in the current study, adopted from Uhl et al. (2023) could have affected the results. They diverge from the commonly used Networked Social Presence Inventory by Biocca et al. (2003). Studies that have employed this standard measurement have not included a face-to-face condition, since this inventory was designed for remote meetings only. Items such as 'During the task I had the feeling of being spatially close to the others in my team.' are less suitable when (immersive) technologies are compared to a face-to-face baseline. Even when comparing VR to videoconferencing, it is arguably likely to quickly find an effect using this measurement. For example, Hennig-Thurau et al. (2023) found that social presence was significantly higher in the VR condition than video conferencing, even for a 5 min meeting. Potentially, the measurements we used measure social presence in a more subtle way, making it more difficult to find a significant effect. Additionally, some measurements were not included, that could have been beneficial for the VR condition as control measures. First, embodiment measurements would have been valuable to examine, to explore whether the avatar representation in this study facilitated embodiment and, consequently, social presence. Moreover, specific questions on the experience of non-verbal cues could have been

insightful. To conclude, more fine-grained measures could have given more insights into how the VR condition was experienced. Future research should use measures that are more sensitive to the underlying capabilities of meeting modalities.

5.6 Modalities

A final direction for future research is the analysis of behavioural patterns, such as gestures and speech patterns. Analysing such patterns could potentially signal future consequences that are not yet experienced. For example, meeting modalities that support longer conversational turns or more interrupting, that could lead to more fatigue over time. This is supported by the study of Abdullah et al. (2021) that showed no significant difference in social presence between video conferencing and VR, but did find differences in conversational patterns. Relevance lies in investigating whether such patterns can be connected to participants' reported experiences during longer exposure.

6 Conclusion

It is often suggested that immersive technologies such as VR could be the ultimate answer to the issues encountered when using videoconferencing, related to social presence, wellbeing and task engagement. These technologies aim to reduce the downsides of videoconferencing by providing a more engaging and realistic experience. It is becoming more and more clear however that a refined understanding of capabilities and effects on experience is needed (Hennig-Thurau et al., 2023). The outcome of the current experimental study, comparing face-to-face, videoconferencing and VR, underlines this, and attempts to further develop this understanding. Social presence, wellbeing, and task engagement were not influenced by meeting modality in a 15 min negotiation task carried out by students. However, the VR modality was perceived as more enjoyable. We suspect that characteristics of the meeting, participants, the negotiation task, the meeting duration, as well as the measurements used have moderated the effect of meeting modality on experience. Future research should analyse conversational patterns in more depth and take the step from an experimental setting to real-life.

Data availability statement

The datasets presented in this article are not readily available because The dataset is anonymized and located on a disk with restricted access. Requests to access the datasets should be directed to sophie.vangent@tno.nl.

Ethics statement

The studies involving humans were approved by TNO internal review board for human-related research. The studies were

conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SvG: Conceptualization, Methodology, Supervision, Writing—original draft, Writing—review and editing. AL: Formal Analysis, Writing—review and editing. NH: Writing—review and editing. AC: Writing—original draft, Writing—review and editing. GL: Project administration, Supervision, Writing—review and editing. SG: Writing—review and editing.

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Conflict of interest

Author AC was employed by Research group Co-design.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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