Journal Pre-proof

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PII: S1071-5819(23)00113-1
DOI: https://doi.org/10.1016/j.ijhcs.2023.103104
Reference: YIJHC 103104

To appear in: *International Journal of Human - Computer Studies*

Received date : 6 April 2023
Revised date : 30 June 2023
Accepted date : 1 July 2023

Please cite this article as: K. Abramczuk, Z. Bohdanowicz, B. Muczyński et al., Meet me in VR! Can VR space help remote teams connect: A seven-week study with Horizon Workrooms. *International Journal of Human - Computer Studies* (2023), doi: https://doi.org/10.1016/j.ijhcs.2023.103104.

Meet Me in VR! Can VR Space Help Remote Teams Connect: A seven-week study with Horizon Workrooms*

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ARTICLE INFO

Keywords:
digital transformation
remote teams
remote work
VR collaborative space
Zoom fatigue
VR meetings

ABSTRACT

In 2020, office life switched abruptly towards a remote work model. Office meetings have since moved to virtual spaces. Unfortunately, remote video meetings have become associated with declines in engagement, collaboration, and learning, as well as 'Zoom fatigue'. In this article, we study the potential of virtual reality (VR) technology as a solution to these problems and as a medium to enrich remote work environments. For seven weeks, we collected data on the meetings of a team of eighteen knowledge workers. For five of those weeks, the meetings were organized in VR. We used a mix of qualitative and quantitative methods to gather feedback on those sessions and to compare them with a regular video conferencing baseline. Our results demonstrate that both technologies have applications in the work environment—albeit in different situations. We provide best-practice guidelines for the use of VR by remote teams and present design implications for VR collaborative spaces.

1. Introduction

1.1. Overview

Remote work has recently become widespread, and is gradually becoming a new norm (Gould et al., 2023). For many workers, this change means that returning to the office is less feasible. While in some aspects, remote work has led to visible improvements, we have observed marked deterioration in the quality of functioning in other important areas of work (Rudnicka et al., 2020; Park et al., 2023). These primarily concern the social relationships formed when people meet in work contexts. Research indicates that remote meetings are often associated with decreased engagement, teamwork, and learning (Mohamedbhai et al., 2021). Consequently, the technology industry is increasing its focus on improving existing technologies and developing alternative ones that enable meetings in virtual spaces, including virtual reality (VR). Examples include Horizon Workrooms, Microsoft Mesh, and Spatial, which aim to use VR technology to make virtual meetings resemble in-person ones. Such technologies are marketed as new ways to connect, collaborate and create together.

In this work, we present an empirical study of user behavior that aims to explore the potential of immersive VR for improving the functioning of remote teams—particularly in the context of computer-mediated group communication and collaboration. Our research questions concerned VR as a technology for remote team meetings. We were particularly interested in gathering longitudinal feedback that would allow us to evaluate the medium-term (over several weeks) effects of implementing VR meetings in a natural work environment. For this purpose, we invited an eighteen-person team to organize all of its meetings in a VR space, Horizon Workrooms (Meta, 2021a), for over a month. We gathered both qualitative and quantitative feedback on the team's experience using focus interviews, surveys, and diaries.

*This document is the result of a research project funded by the National Information Processing Institute.
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We were interested in answering three research questions:

RQ1 How might the adoption of VR as a meeting technology develop? To what extent do people's initial attitudes influence this process, and how do those attitudes change over time?

RQ2 How is the virtual environment for meetings perceived, and what types of meetings are best suited to it?

RQ3 Can VR fill some of the social gaps created by remote work environments? Specifically, are VR meetings perceived as more socially engaging (e.g. via enhanced social presence or better attention allocation), and does this perception translate into improvements in group development?

Our investigation of RQ1 was based on the perspective of digital transformation (see Sections 1.4 and 3.1). We examined the prospect of adopting VR as a meeting technology in its current stage of development. RQ2 refers to the characterization and efficiency of meetings in VR compared to in-person meetings and videoconferencing. We sought to discover what types of meetings can be held successfully in VR and how participants interacted with the Horizon Workrooms environment (see Sections 1.3 and 3.2). To discover whether VR meetings can deliver on their promise to help remote teams connect (RQ3) and what space they might occupy among a broader set of tools for remote teams, we evaluated both the virtual meeting experiences (e.g. in terms of presence) and the group itself (Sections 1.2 and 3.3).

The contribution of this article is twofold.

- It presents a unique medium-term study on VR meetings in a natural work setting based on rich qualitative and quantitative data. This allowed us to study the process of VR technology's adoption and potential rejection, and to place the immediate results of its implementation in the broader context of the functioning of the team.
- It uncovers important aspects of introducing VR into work environments. This has allowed us to formulate guidelines for teams interested in including the technology in their work repertoire, and to identify potential improvements to VR technology and VR collaborative spaces that will enable its easier implementation and better functionality in work settings.

1.2. Remote meetings and team spirit

The quality of meetings has been the subject of much debate as it relates directly to the productivity of organizations. To understand this, a framework has been proposed that contains key elements of successful meetings that relate to execution, psychological safety, and physical comfort (Constantinides et al., 2020; Constantinides and Quercia, 2022). Although execution has been studied extensively, psychological safety and physical comfort have largely been neglected—apart from greater attention paid to walking meetings (Haliburton et al., 2021) and changes in posture (Damen et al., 2020). Only recently has deeper understanding been sought on how users configure their videoconferencing software—usually with the intention of mitigating common concerns, such as identifying active speakers, viewing meeting attendees, and users verifying their own appearances (Balogova and Brumby, 2022). Remote meetings, despite their many possible adjustments, pose difficulties related to, for example, nonverbal cues, including lack of proper eye contact (which may degrade attention) (Langner et al., 2022) and inability to read body language. Researchers have attempted to address this by building systems that use various sensors (Dean et al., 2014; Choi et al., 2021). Attention is a multifaceted construct, comprising various categories and processes that serve different purposes and are exposed by different activities involved in video meetings. These functions may require various features to support attention (Kuzminykh and Rintel, 2020a). Their shortcomings in current solutions can also be seen in people's tendency to multitask during virtual meetings, depending on the characteristics of the meeting, such as its size, length, time, and type (Cao et al., 2021). Participants' low engagement in meetings can be a deliberate social choice (Kuzminykh and Rintel, 2020b), and they may need to be given choices on the extent to which they engage in meetings. Some studies propose additional tools, such as personalized meeting dashboards, to mitigate some of the limitations of video calls (Samrose et al., 2021). The situation is complicated further by hybrid meetings, as remote attendees often encounter difficulty discerning who is speaking among on-site participants. This could be mitigated by binaural recording (Rosset et al., 2021). Another difficulty of the transition to video meetings is the degradation of social connections due to the video participants' tendency to come together only for specific tasks. The absence of such 'conversational transitions' causes coworkers to sacrifice the productivity and bonding that occurs during the transition time before and after in-person meetings (Gonzalez Diaz et al., 2022). This problem could be addressed partially by moving workspaces to the metaverse, but that also creates other important considerations (Park et al., 2023).

1.3. VR technology for meetings

Remote VR meetings have already proved promising for remote collaboration in architecture (Hsu et al., 2020), design (Mei et al., 2021), creative tasks (Pan and Mitchell, 2020), medical training in a one-on-one setup using PC-connected VR headsets (Sadeghi et al., 2021), and scientific research (Olaosebikan et al., 2022). Several pilot studies have concluded that VR meetings generate higher degrees of immersion (Steinicke et al., 2020) and stronger feelings of presence (Campbell et al., 2020) than traditional video calls. Different prototypes and frameworks have been explored to present how the unique properties of VR can facilitate effective meetings and collaboration. This might include support for turn-taking (Li et al., 2022), creative collaboration (He et al., 2020), training (Kostov and Wolfartsberger, 2022), and design (Podkosova et al., 2022). Based on a comparative study of VR and video meetings, VR behaviors, such as gaze distribution and gesturing, resemble in-person meetings; in video meetings, participants must compensate to retain the same degree of social connection by increasing the share of gaze directed at the face (Abdullah et al., 2021). The body language of avatars in VR meetings can serve as an indication of communication willingness (Kurzweg et al., 2021), further closing the gap between video- and voice-based communication, and in-person collaboration. HTC, the producer of the Vive family of VR hardware, makes accessories for its VR headsets that enable eye- and face-tracking. Other major manufacturers of VR hardware have either demonstrated or announced similar solutions for their products. This demonstrates development of VR technology that is focused not on single-user experience but on multi-user online spaces that support social activities and collaboration. Little is known about the effects of prolonged use of VR—particularly in 'real life' conditions. Only groups of people who work together daily in the same organizations can compare the technologies and the experiences of in-person, video-based, and VR-based collaboration.

1.4. Digital transformation

The introduction of new technologies into the workplace is an interesting subject that falls under the umbrella of digital transformation (Vargo et al., 2021), which has accelerated since 2020 in a wide range of workplace environments due to the COVID-19 pandemic (Agostino et al., 2020). While many benefits undoubtedly come with the use of new technologies at work—particularly those that relate to automation and reductions in repetitive tasks—challenges are also associated with digitization and transitioning work environments. New technologies redefine the scope of responsibilities and requirements, alter the nature of work and value chains, and often increase the work demands related to learning new processes, tools, and employee roles (Parviainen et al., 2017). The rapid onset of change has frequently prevented the best change management practices from being implemented. When transition periods are replaced by the simple communication of changes (Kazim, 2019), the negative consequences of the digital transformation become more prominent. These include 'technostress' (Tarafdar et al., 2015) and digital transformation stress (Makowska-Tlomak et al., 2021), leaving employees prone to burnout—and even depression (Tarafdar et al., 2011; Vargo et al., 2021). Among the negative outcomes associated with the ongoing digital transformation—particularly the switch to remote meetings—are declines in engagement, collaboration, and learning (Mohamedbhai et al., 2021), as well as feelings of exhaustion that are commonly called 'Zoom fatigue' (Nesher Shoshan and Wehrt, 2022). The potential consequences of introducing VR technology to the work environment remain to be seen. Biener et al. (Biener et al., 2022) studied individual work in VR. Our work extends this line of research by focusing on meetings and group work.

2. Method

This study is exploratory in nature and was implemented in the form of so-called action research (Elden and Chisholm, 1993; Sjoberg et al., 2007)—in particular, participatory action research, which assumes that the highest competence in understanding the laws that govern the operation of a given community lies with its members. They have relevant first-hand experience with the dynamics of the studied environment and, therefore, can potentially better understand its processes and practices and identify potential improvements (Reason and Bradbury, 2007; Passos et al., 2012). With this in mind, this study was conducted in-house, at the researchers' organization. To minimize the risk of bias, researchers from other organizations also contributed to this work. They did not partake in the study, but were involved in working on its methodology and writing up the results. The study used surveys and focus groups. The first two authors of the study prepared, conducted, and analyzed the qualitative part of the study, and their experiences are not included in this data. Due to the specificity and small size of the sample, which do not allow for wider population inference, the results should be treated as a qualitative case study that highlights some of the potential consequences of adopting VR for work meetings.

2.1. Participants

Eighteen people participated in the study (seven men, ten women, and one person who chose the option 'other'). The average age of the participants was thirty-eight years (minimum: 23, maximum: 48). The participants had worked in the team for a minimum of four months and a maximum of over eleven years (mean: 3.88 years). Immediately before the study, sixteen of the participants worked almost exclusively from home. Four participants started working with the team only after the COVID-19 pandemic had begun. One participant worked remotely from another city before the outbreak of the pandemic. Only three declared that they participated in in-person meetings during a standard work week. All participated in internet video calls and spent approximately five hours a week, on average, in such meetings.

The overall VR experience in the team was likely higher than average, but not extensive. Three participants declared that they had never used VR before, and another nine declared that they had only used the technology occasionally. Three participants were VR experts who work with VR applications daily and had used VR for entertainment before the study. The most popular VR activities before the study were viewing 3D videos and attending VR events.

2.2. Ethical considerations

Due to the potentially significant impact the technology could have on the participants' work, and physical and emotional experiences, the study was reviewed by the research ethics board of the National Information Processing Institute, and was approved. We conducted introductory meetings with participants to address any questions or concerns in advance, and to inform them about the study timeline, data gathering, and processing. We underlined the importance of reporting genuine experiences, positive or negative, with no right or wrong answers. We assured the participants, that they could return to their regular work practices at the end of the study. We mitigated the threat of the research interfering with the quality of the current work and participants' wellbeing by leaving the final choice of meeting technology to the participants. The quantitative data was gathered anonymously, and the participants were not prompted to complete their diary entries after each meeting. Throughout the study, we provided technical guidance and support.

2.3. Timeline and Tools

A complete overview of the study timeline is presented in Figure 1. For seven weeks between May 9 and June 24, 2022, we gathered data on all of the team's meetings. The first two weeks served as a baseline measurement and an adjustment period during which the participants learned to complete their meeting diaries while the meetings continued in the format that was standard for the team: videoconferencing. At the end of that period, VR headsets were distributed among all team members. During the next five weeks, the team was encouraged to meet in VR whenever they would normally use video communication. This was not obligatory, and final decisions regarding technology were left to the participants.

To assess how different social experiences could be realized in video and VR formats, six additional gatherings with voluntary participation were organized during the study period. Collective activities at these meetings included playing Pictionary, viewing short videos, and participating in a seminar. Each activity was arranged in both video and VR. In addition, a VR minigolf tournament in the *Walkabout Minigolf* game was organized for willing participants.

Aside from the diaries, we gathered other data at various points:

- **A kick-off questionnaire** initiated the study. It included questions on current work meetings, team perception, VR experience, and expectations regarding VR. It also incorporated adapted tools to measure initial group development (Leuteritz et al., 2020), initial satisfaction with teamwork (Hamlyn-Harris et al., 2006), attitudes toward digital transformation (Makowska-Tlomak et al., 2021; Makowska-Tłomak et al., 2022), and the Polish version of the Ten-Item Personality Inventory (Gosling et al., 2003; Łaguna et al., 2014).

- **Initial group interviews** were conducted in focus groups of three to five people using Zoom. They lasted approximately sixty minutes and were intended to collect qualitative insights into the topics of the kick-off questionnaire.

- **Meeting diaries** were completed for seven weeks after each meeting within the team—regardless of the technology used and the goals of the meetings. The questionnaires incorporated adapted tools to measure the perception of meetings (Nezlek et al., 1994; Nowak and Biocca, 2003; Vorderer et al., 2004). Each meeting organizer was asked to provide additional details on each meeting's characteristics, such as its duration and its number of participants.

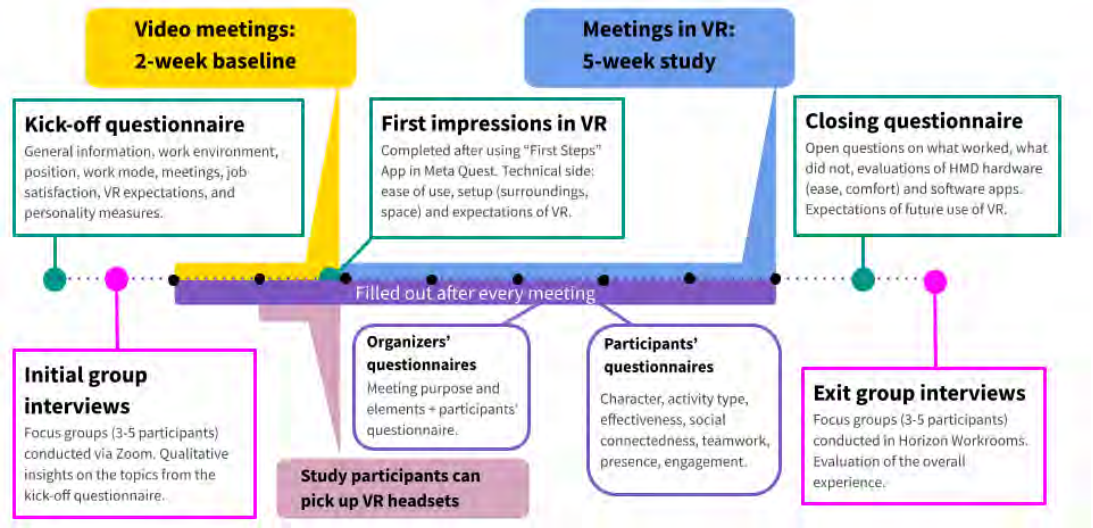


Figure 1: The timeline of the study with all key study elements.

- **A first impressions questionnaire** followed an intermission period during which the participants were green-lighted to collect their headsets, complete the technical setup procedure, and begin interacting with the VR environments. The questionnaire was completed after these initial interactions. The participants were asked to evaluate their interactions and report their expectations regarding VR for the second time. As the questionnaire aimed to collect first impressions on VR technology, the three VR expert participants were excluded from it.
- **A closing questionnaire** was deployed after the seven-week period. It comprised questions on VR technology, VR meetings, and team perception. Here we measured the development of the group (Leuteritz et al., 2020), its work satisfaction (Hamlyn-Harris et al., 2006), and its attitudes toward digital transformation (Makowska-Tłomak et al., 2021; Makowska-Tłomak et al., 2022) again.
- **Exit group interviews** were conducted using Horizon Workrooms in focus groups of three to five participants. Each lasted approximately sixty minutes and focused on the evaluation of the overall experience, and on its impact on individual and group wellbeing.

Details regarding measures used in the quantitative analysis are presented in Section 3. Additional tables are provided in the supplementary materials.

The use of qualitative interviews allowed new themes to be captured that had not been anticipated prior to the study and allowed us to gain insight into the reasoning behind the quantitative data obtained. The interviews were conducted by a moderator and an observer, who took notes according to qualitative standards for this type of research. Videos recorded during the interviews were later transcribed, and divided into utterances that were analyzed using thematic analysis (Braun and Clarke, 2006). We took a semantic, realist approach to identify recurring themes in the data and establish relationships between them. After creating an initial categorization, two researchers analyzed each interview and discussed the results until they reached agreement. Two cross-categorizations were used to label each data extract. The first one concentrated on the topic and the other on the nature of the utterance (see Table 1). Next, all of the data pieces relevant to answering the research questions were extracted and summarized with a focus on searching for new insights and deeper understanding of the problem. Special attention was paid to topics' co-occurrence in the given and neighboring utterances. The objective of the qualitative component was not to determine the prevalence of the

	main theme	sub-themes
topic categorization	VR hardware	headset, controllers, tracked keyboards
	surroundings	physical space, technological surroundings (e.g. phone, computer software),
	virtual space	appearance, audio, functionalities
	avatars	appearance, facial expressions and gestures
	meetings	meetings characteristics, interaction elements, multitasking
	work	team, work tasks
type categorization	experiences	physical sensations, emotions (individual and group related), cognitive experiences (e.g. realism, presence, immersion, concentration)
	evaluations	positive, negative, change, barriers and lack of thereof
	needs	psychological (e.g. control, contact), functionalities

Table 1
Thematic analysis categorizations.

identified themes (we used quantitative data for this). Nevertheless, we refer to the approximate incidence of certain topics within the participants' narratives. The following terms are used: a few (mentioned by approximately one-quarter or fewer of the participants), approximately half, and a majority (about three-quarters or more of the participants or more).

2.4. Hardware and software

The hardware used in the study comprised Meta Quest 2 virtual reality head-mounted displays (HMDs)—standalone, wireless devices that require no connection to an external computer and are powered by internal batteries. Every HMD was used as delivered, which means that no custom or premium head straps, lenses, or other modifications were provided. The only customizations permitted were spacers for glasses and silicone covers, which are provided by default with every version of the device. The retail price of the Meta Quest 2 at the time of this study was around $400. As of June 2023, the retail price is $299.99.

Meta Quest 2 allows for adjustment of interpupillary distance (IPD) using three predefined settings. Each participant was advised to adjust the IPD to their preference. The internal battery can endure approximately two to two-and-a-half hours of activity, including remote meetings—although this can be extended using an external power bank or a power source.

The participants were permitted to select input methods based on their preferences:

- Meta Quest 2 tracked controllers.
- Meta Quest 2 hand tracking, which allows the users' own hands to be represented as semitransparent 3D models in the virtual environment in real time. How and when this method of input can be used depends solely on the active applications; not every application supports the feature.
- Mouse and keyboard—only when using the Oculus Remote Desktop application together with the Horizon Workrooms application to connect to an external computer (see below).

The communication software used for the two-week baseline stage included Zoom and Discord. These applications were staples of the team's workflow and required no training nor technical support during the study. At the beginning of the five-week VR stage, the participants were guided through the full Meta Quest 2 setup process by both a quickstart guide written for the study and a member of the technical team. The quickstart process involved connecting the Meta Quest 2 headsets to Facebook accounts via the dedicated Oculus mobile application, creating a guardian environment (VR play space), and downloading the First Steps[1] (Meta, 2019) experience from the Oculus app store.

Team members were asked to download mandatory free applications, including Horizon Workrooms Beta and one paid application, *Walkabout MiniGolf*[2] (Mighty Coconut, 2020). All participants received in-store credit to purchase the game. The software guide for participants also included a recommended applications section. None of these applications were mandatory, and their purchase were at the participants' discretion. An exception among the software

[1] An introductory Meta Quest 2 experience recommended for first-time VR users, which showcases the device's capabilities and controllers.
[2] A VR minigolf multiplayer game.

Figure 2: Remote work meetings using Horizon Workrooms. Left: a presentation for the team from the moderator's perspective; middle: a brainstorming session using the virtual blackboard; right: a team meeting in which some participants connected via webcam and web browser.

used was the optional Oculus Remote Desktop (Meta, 2021b), an application, available both for Microsoft Windows and macOS operating systems, which allows desktop mirroring to the Horizon Workrooms environment. That feature, paired with keyboard passthrough mode, allowed the participants to fully utilize their computers during virtual team meetings, using their mice and keyboards as additional means of interaction. Four of the participants were blocked from using that complementary application for technical reasons, and were thus unable to use their computers during the VR meetings throughout the study.

The study focused on the use of the Horizon Workrooms application during meetings, collaboration, and co-working in a virtual environment. The application simulates meeting rooms that are equipped with tables, blackboards, projectors, and television screens (see Figure 2). A detailed description of this environment, its setup, and its functionalities is available in the supplementary materials of this article. The main reasons that Horizon Workrooms was selected for the study were the option to create collaborative online spaces for each room inside a virtual organization (which resembles popular applications like Slack), the option to share and present files using the integrated blackboard with markers, the option to present in front of an audience, the option for each user to connect via their own personal or work computer via Oculus Remote Desktop and use it in real time as a virtual desktop solution, the support for hand tracking, the rich avatar customization options, and the option to join VR meetings from a web browser. The workroom environment was set up by the researchers. All participants were aware that the space could be customised, and some experimented with it independently. As part of the team-building exercises, the participants were tasked with creating close-to-life avatars of their own (using the Avatar edit tool in the Oculus User Profile).

3. Results

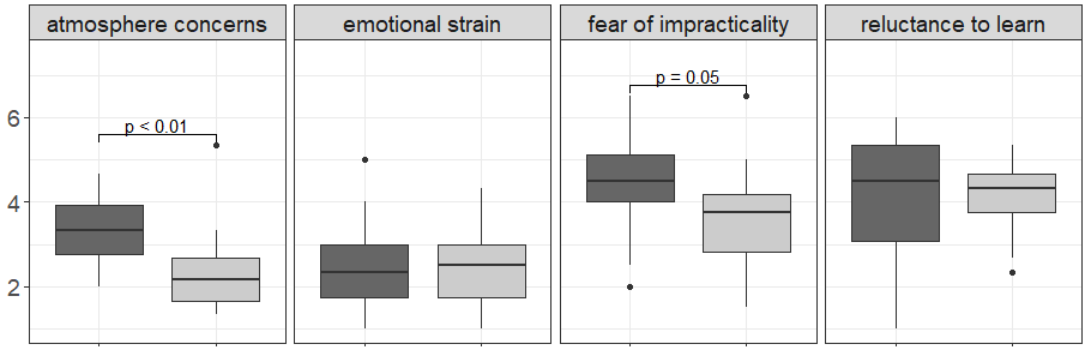
3.1. Adaptation to the VR environment

The first research question concerned the adoption of VR as a meeting technology. Below, we present an analysis of how participants' attitudes and opinions on VR developed during the study as they had opportunities to gather experience with the technology. In all of the analyses, we report statistics for some scales. Unless stated otherwise, these are seven-point scales with a middle point of four.

3.1.1. Digital Transformation

In the kick-off questionnaire, we measured participants' initial attitudes towards switching to VR meetings using the digital transformation approach. We adopted items from the Digital Transformation Attitudes Scale (Makowska-Tłomak et al., 2021; Makowska-Tłomak et al., 2022) and added four additional items. All questions were reformulated to apply explicitly to VR meetings. The low number of observations does not allow for factor analysis, but a qualitative analysis of covariances led us to construct four measures using simple sums of scores. These were[3]:

[3]These measures, along with all the relevant items, are available in the supplementary material of this article.



(a) Digital transformation attitudes sub-scales in the kick-off (dark grey) and final (light grey) questionnaires with p-values of the corresponding paired samples' t-tests wherever they were significant.

		atmosphere concerns	emotional strain	fear of impracticality	reluctance to learn
negative perception of technology during the meeting	kick-off	0.09 (0.74)	0.33 (0.19)	0.31 (0.23)	0.20 (0.44)
	final	0.62 (<0.01)	0.51 (0.04)	0.63 (<0.01)	0.45 (0.07)
wellbeing after the meeting	kick-off	uncorrelated	-0.18 (0.48)	-0.26 (0.32)	-0.35 (0.16)
	final	-0.58 (0.01)	-0.58 (0.01)	-0.50 (0.04)	-0.37 (0.14)

(b) Correlations between digital transformation attitudes and participants' perception of technology used for the VR meetings and wellbeing after the VR meetings during the study. The values presented for the kick-off questionnaire measures are Pearson correlation coefficients; those presented for the final questionnaire measures are partial correlation coefficients controlled for participants' initial attitudes. P-values are presented in brackets. The correlation coefficient for wellbeing and atmosphere concerns measured in the kick-off questionnaire was practically zero.

Figure 3: Digital transformation attitudes during the study.

- emotional strain – three items e.g.: *I feel annoyed that I will have to learn a new tool instead of focusing on my current work*
- fear of impracticality – four items e.g.: *I am concerned that implementing this solution will be very impractical*
- reluctance to learn – three items e.g.: *I talk to colleagues to find out what they think about the solution* (reversed)
- concerns over team atmosphere deteriorating – three items e.g.: *Implementing this solution will cause chaos and growing frustration*.

Among all of the sub-measures, fear of impracticality of VR produced the highest mean, followed directly by reluctance to learn. We analyzed how the participants' initial attitudes related to their subsequent experiences. We used two sets of questions in the meeting diaries for this purpose: questions related to negative perceptions of meeting technology (three items e.g.: *The technology used made it difficult to conduct this meeting*) and wellbeing after the meeting (four items on a five-point scale e.g.: *Evaluate how you felt after the meeting. I felt: dissatisfied/satisfied*). Confirmatory Factor Analysis performed on this data delivered satisfactory results ($X^2 = 21$, df = 12, CFI = 0.99, rmsea = 0.05) with all standardized factor loadings above 0.57. Therefore, we constructed simple mean scores for each diary entry that referred to VR participation on two scales: negative technology perception and participants' wellbeing. Next, for each participant, we computed mean evaluations on both of the scales. We correlated[4] the evaluations with the participants' initial digital transformation attitudes. We discovered that although the correlations generally ran in the expected direction, they were rather weak (see Figure 3b).

[4]Unless stated otherwise, the correlations reported are Pearson correlation coefficients.

We reassessed digital transformation attitudes in the final questionnaire using items formulated in the past tense, so that they referred to the participants' actual experiences. All of these newly emerging attitudes, except for reluctance to learn, were correlated visibly with participants' experiences during the study (see Figure 3b). These results seem to indicate that participants' initial attitudes were neither decisive nor particularly indicative of how their experience would go. Their evaluation of VR technology evolved over time. For two sub-measures, we observed noticeable differences. By the end of the study, the participants felt that VR was more practical and better for the team atmosphere than they had expected (see Figure 3a).

Additional insight into this is offered by the qualitative data. The majority of participants described some elements of the adaptation process. In accordance with the quantitative insights suggesting a minor role for preconceptions, the majority talked about surprise and changes in their attitudes. The surprise typically related to the virtual space (particularly the spatial audio) and the resulting experience of presence and/or copresence. This might be related to falling atmosphere concerns. In the context of change, the most commonly used phrase was *getting used to*. Half of the participants declared they had got used to virtual space, the avatars, and the requirements posed by the technology. This sheds light on why the fear of impracticality might have dropped. Another reason, however, likely relates to the evolution of the usefuleness evaluations discussed in the next section.

Our sample is too small to run complex models. To formulate initial insights regarding whether the newly formed attitudes toward digital transformation shaped by experience gathered during the study were of any practical consequence, we computed their correlations with participants' opinions regarding the usefulness of VR for work meetings at the end of the study. Two sub-measures of digital transformation attitudes correlated highly with usefulness evaluations: reluctance to learn (cor = - .55, $p = 0.02$) and fear of impracticality (cor = - .85, $p < 0.01$). Participants less open to new possibilities offered by VR doubted its usefulness more. This reluctance to learn remained somewhat stable across the study, and we found that it was correlated significantly with the conscientiousness trait measured using TIPI (Łaguna et al., 2014) (cor = .53, $p = 0.02$). This might indicate that this dimension is personality-related, and that those with a clear preference for planned/standard behavior will find VR meetings and technological change less appealing. Fear of impracticality, on the other hand, was more likely to be influenced by experience. Participants who harboured such fears after experimenting with VR were less convinced of VR's usefulness. Practicality, therefore, deserves special attention from practitioners who aim to popularize VR work meetings. We consider more details on usefulness evaluations in the following section of this article.

3.1.2. Evolution of usefulness evaluations

In this section, we present data on the evolution of evaluations of VR's usefulness for work meetings across the study. The three time points we consider are the kick-off questionnaire, the first impressions questionnaire, and the closing questionnaire.

Before the study commenced, participants believed that VR would prove somewhat useful for work meetings (a mean of 4.33 on a seven-point scale). This conviction typically grew slightly (but not significantly) after the first encounter with the headsets (mean = 4.79), and after the study was completed, when they had gained more experience (mean = 5.06). Apart from their general evaluations of usefulness, the participants were asked how they believed VR meetings compared to in-person and video meetings. Their answers were given on a seven-point scale that ranged from 'definitely worse' to 'definitely better'. Initially, the average participant believed that VR meetings would be worse than in-person ones (mean = 2.61) and similar to video calls (mean = 3.89). That belief did not change when they gained experience; however, by the end of the study, the participants had decided that VR meetings were better than video meetings (an increase from mean = 3.89 to 4.78, $p = 0.04$).

To discover where this conviction could have originated from, we can examine the more detailed evaluations. Participants were asked to compare VR meetings with the default used before the study (videoconferencing) in several dimensions, and to indicate whether they thought VR was suitable for meetings with various goals. The data on these evaluations is presented in Figure 4. At the beginning of the study, it was anticipated that compared to videoconferencing, VR meetings would be slightly less effective, more enjoyable and engaging, and more tiring. These evaluations remained stable throughout the study, except for efficiency. With enough experience, the participants concluded that VR meetings could be more efficient than video ones. This increase was accompanied by a steady increase in the conviction that VR is useful for meetings aimed at generating new ideas, organizational meetings, and informal meetings. The sole, but notable, exception was meetings directed toward substantive work. After the initial euphoria, these evaluations returned to their original levels. Some light as to why this was the case is provided by the qualitative interviews, in which work tasks were mentioned in the context of VR:

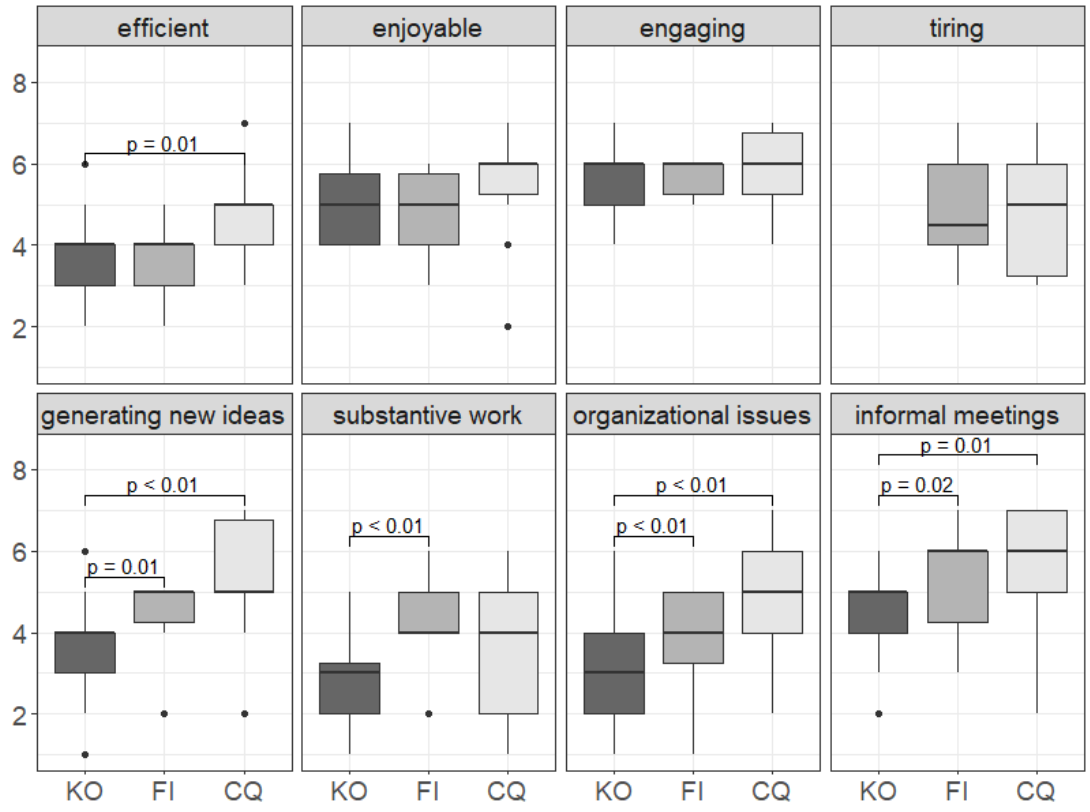


Figure 4: Evaluation of VR meetings over time. The evaluation was conducted during three periods: before the study (KO – the kick-off questionnaire), after trying VR technology (FI – the first impressions questionnaire), and at the end of the study (CQ – the closing questionnaire). P-values for significant mean differences between the kick-off questionnaire and the later questionnaires were added. [Top panel] Comparison of VR meetings with video meetings in four dimensions with 4 signifying 'the same', values lower than 4 signifying that VR meetings were 'less efficient/enjoyable/engaging/tiring' than video meetings, and values higher than 4 signifying that VR meetings were evaluated as 'more efficient/enjoyable/engaging/tiring' than video meetings. Tiresomeness was not evaluated in the kick–off questionnaire. [Lower panel] Evaluation of the usefulness of VR for meetings with various goals.

> 'I think for meetings it is OK. I also like smaller meetings. I would divide them depending on the purpose. In my opinion, VR is good for brainstorming, and for the free exchange of ideas. It's easier to interject something and it doesn't throw the interlocutor out of the flow because something starts to crackle, etc. But you can't work on documents. You can't use it yet for creative work.' [Participant 3]

> 'At first, we were playing around, to check what it looked like. After a while, the question arose whether we could do real work here. And unfortunately, it blows. Even with screen-sharing. It was also impossible to use the tracked keyboard sensibly.' [Participant 14]

A few participants reported that they felt the need to create and exchange notes, work together on files, or share with each other what they had found on the Web. With one exception, VR proved impractical in these cases. The exception related to a meeting in which note-taking was performed by a participant who was a VR expert.

On the other hand, VR was appreciated for its potential to improve the quality of discussion and emotional contact. The social aspect is also visible in evaluations regarding private applications of VR technology. The highest rankings had initially been assigned to prospective single-player gaming and the viewing of 3D videos; by the end of the study,

the top choice was multiplayer gaming. After single-player gaming, two other social uses were rated highest: socializing and VR events. This suggests that the social potential of VR, underrated as it may be by inexperienced users, is very real.

3.1.3. Problems reported

One of the most commonly mentioned problems with popularizing VR deployment in real-life applications mentioned in the literature is so-called cybersickness (Davis et al., 2015; Chang et al., 2020), which typically relates to vection. The office meeting environment is stationary and is an example of what was called a 'near' application (McCauley and Sharkey, 1992). Nevertheless, we observed several types of physiological issues that could have resulted from long initial exposure times (Chang et al., 2020). Our study allowed us to discover whether they persisted.

In the first impressions survey, many participants indicated that the goggles were uncomfortable and difficult to adjust, which led to problems with visual acuity, general head and face discomfort, and headaches. These negative perceptions were confirmed both during the qualitative and quantitative interviews at the end of the study, and were experienced by majority of participants. From the qualitative interviews, we know that, particularly for women, the weight of the goggles and the poor fit of their shape to the head were problematic—in one case, so much so that using them became impossible:

> 'At first, I liked it very much, but unfortunately, I felt very bad afterwards and I stopped liking this tool altogether [...] My first very positive impressions shifted to total coolness and discouragement. While wearing the goggles my face hurt. They pulled my hair. They are too heavy for me, and after half an hour I had to support them with my hand. As I stayed in them longer, my head and eyes hurt—especially when I used the computer in the goggles and read something on the virtual screen.' [Participant 12]

A few participants stated that the negative physical sensations became less intrusive after they had become more accustomed to the goggles. Interestingly, a few participants also indicated that these negative physical sensations were less noticeable while playing games in which the user focuses on completing tasks:

> 'It's uncomfortable for me in these goggles. As we sit in a meeting, I adjust them constantly. I feel them on my nose. The goggles bother me a lot. But when I play games, it isn't there. Maybe because I am focused on some task: catching a fish or playing golf.' [Participant 8]

Among the less frequent problems that occurred once or a few times during the study, almost all (sixteen) participants mentioned colliding with physical objects that were not visible in VR. Nine participants had experienced overheating of their HMDs, six had experienced balance issues, and four had felt nauseous. One participant mentioned that VR immersion had led to increased loneliness-related anxiety after leaving the virtual environment. One felt that there was pressure to avoid negative comments regarding VR.

Technical problems were less common than physical ones. The participants declared that such problems occurred once or a few times during the study. The problem reported by the greatest number of participants was low battery life (fifteen indications). This was followed by the cable used to charge the HMDs being too short (thirteen indications), forgetting to charge the HMDs (twelve indications), and unstable internet connections (twelve indications). Battery life and charging were also mentioned by approximately half of the participants in the qualitative interviews, where they were singled out as a motivational barrier and a factor that had led to stress.

Figure 5 presents the evaluations for various components of VR technology after the first launches of the HMDs and at the end of the study. Because the final survey included VR experts who had not participated in the first impressions survey, they are excluded from these results. Repeated use led to (insignificant) drops in evaluations of the HMD, both in terms of comfort and enjoyment—neither of which had been very high initially. Controllers fared better. Eight of the participants attempted to use the hand-tracking function during their first trials with VR during the study. Three of them enjoyed hand tracking more than using the controllers; the remainder deemed it generally less comfortable, pleasant, and intuitive. By the end of the study, all of the participants had experimented with this feature. On average, it was rated slightly lower than the controllers. From the qualitative interviews, we discovered that the problem was that the hand-tracking gestures were unreliable, unintuitive, and prone to conflict with keyboard use because they activated accidentally during typing. The VR environment and the applications were evaluated very positively in all dimensions. The VR space was considered pleasant, intuitive, attractive, engaging and convincing. When we repeated the measurement at the end of the study, all of the mean evaluations were somewhat lower, but remained very high.

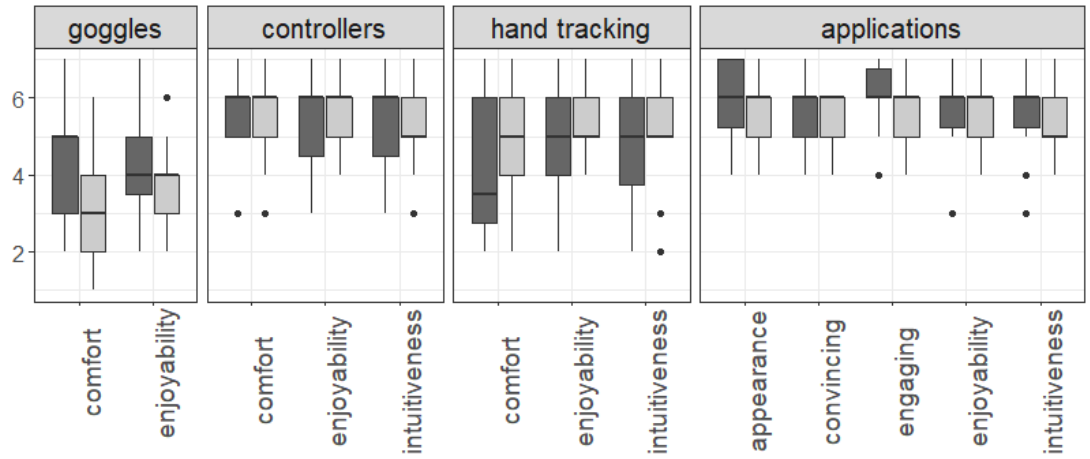


Figure 5: Evaluations for various components of VR technology after the first launch of the HMD (dark grey) and at the end of the study (light grey). No pairwise comparison between the initial and final evaluation indicated a significant change.

3.2. Use and evaluation of VR meetings

The second research question related to how the virtual environment for meetings was perceived and what types of meetings seem to be best suited to it. Here, we present what meetings occurred in VR and how that translated into their evaluations during and after the study.

3.2.1. Characterization of meetings

Using diary entries, we collected data on the meetings that occurred within the team during the study period. The diary data comprised 338 entries for 105 meetings. For seventy-seven of those meetings, we have data on their basic characteristics. The meetings varied in length, from fifteen-minute updates to seven-hour sessions of collaborative work. Half of the meetings lasted no more than seventy-five minutes. In line with earlier research on remote meetings' daily rhythm (Cao et al., 2021), the distribution of meeting hours was bimodal with one peak around 11 am and another around 2 pm. Between two and eighteen people participated in each meeting. The mean number of participants was 4.32. Of the meetings, 80% were planned and 20% were spontaneous.

Of the 105 meetings in the dataset, forty-six included some VR participants (forty-one included only VR participants), twelve were conducted in person, and forty-seven were mostly video meetings with some hybrid participation. Of the latter forty-seven, twenty-eight occurred during the first stage of the study, before the HMDs were distributed to all of the participants. The VR meetings and the video meetings were similar in terms of length (mean length: approx. 64 minutes in both cases), the number of participants (an average of 4.8 for VR and 4.3 for video), and the daily rhythm. During the two-week video baseline, the average time spent in a meeting by a participant that had some meetings on that day was fifty minutes. During the five-week period with VR meetings, the average time spent in a meeting by a participant that had some meetings on that day was fifteen minutes for video and sixty-nine minutes for VR meetings. It is noteworthy, however, that after the third week of the study, very long meetings tended to be moved from VR to a videoconferencing format.

The meetings' organizers were asked to indicate the main objectives of their meetings. These can be classified in a number of ways (Goff-Dupont, 2018; Lid, 2017). In our study, seven team-specific meeting goals were identified. We report four that were selected the most frequently. One of the main goals of 39% of the meetings was substantive work on ongoing projects. For 30% of them, it was organizational issues; 29% pertained to informal meetings, and 21% involved brainstorming on new ideas. Table 2 presents the frequencies with which various meeting elements and goals were present in the VR and videoconferencing formats (please note that a single meeting could have multiple goals). Two differences are notable. First, meetings aimed at completing substantive work were more common in videoconferencing than in VR ($p = 0.04$). This was probably caused by the difficulties with information-sharing and

Mode		Meeting Goal: generating new ideas	substantive work	organizational issues	informal meetings
VR	percent	22%	28%	25%	42%
	goal completion	5.75 (0.72)	5.30 (0.75)	6.56 (0.37)	6.60 (0.23)
video	percent	20%	53%	37%	13%
	goal completion	6.33 (0.33)	6.56 (0.18)	6.36 (0.15)	6.50 (0.29)

Table 2
Goals of VR and video meetings: percentage share and mean goal completion evaluation on a seven-point scale (standard errors in brackets).

note-taking that we discussed in earlier sections. Second, team-building meetings were more common in VR ($p < 0.01$). This is due to group gaming.

3.2.2. Evaluation of VR meetings

Most frequently, meeting organizers claimed that their goals were met (see Table 2). Some minor (insignificant) differences in the degree of goal completion can be observed when we compare meetings with different goals and in different modes. They align with the observations made above: the goals were seen as realized to a higher extent when the meetings aimed at substantive work were held as video meetings. Moreover, the estimates for VR meetings were much more variable than those for video.

When asked about their preferences in the final questionnaire, the participants indicated that VR meetings are best with between three and nineteen people. The best meeting duration was between fifteen and thirty minutes, followed by slightly longer meetings that lasted up to sixty minutes. In the qualitative interviews, it was mentioned that longer meetings in VR were excessively tiring, while very short meetings did not seem worth starting up the HMD for. Participants referred to the need to perform a 'VR turn-on ceremony' which consisted of taking out the HMD and controllers, checking the battery status, preparing the room space, and activating the HMD before joining the meeting.

Six issues arose during the initial qualitative interviews when we asked about the possible consequences of moving meetings to VR. These were lack of multitasking, greater engagement, the emergence of spontaneous exchanges in the periphery of meetings, better conversation dynamics, fewer demands regarding the organization of discussions, and an increased sense of togetherness. These expectations were largely confirmed. In the final questionnaire, we asked the participants how they rated VR in all of these respects. The ratings were high except for the inability to multitask. All of these evaluations were further confirmed during the qualitative interviews.

The increased sense of copresence was mentioned by the majority of participants in the context of meetings. It was often discussed together with remarks on avatars' gestures and postures. Participants said they could see in which direction others were looking, and on whom they focused their attention. This, in turn, led to an increased sense of their engagement and intentions.

> 'On Zoom, I don't feel like I am with you all at once, but in VR I have that feeling. I'm aware that I can't see you, only the avatars, but I still feel that I get a better sense of your intentions. [...] In video meetings, I have a sense of contact with the people who speak, but in VR, I have a sense of being together in one space—even with the people who don't speak.' [Participant 6]

Another theme that was often linked to the sense of togetherness was interaction dynamics. Spatial sound was mentioned in this context by the majority of participants. It improved the meetings' flow and made it possible to exchange remarks on the side of the main meeting conversation without interrupting the main speaker. Speaking out was also easier and more natural, as it did not create the stretched-out silences and awkward interruptions that are typical during videoconferencing when the sound source is being switched from one speaker to another:

> 'When you are in VR, someone will naturally start talking and this dynamic will resemble what would happen in reality. On the other hand, on Zoom the host has to speak like on the radio. There is no possibility to say something to one colleague only, and every comment is on the whole forum. On Zoom, the "small

talk" at the beginning of a meeting is usually ended by the host, which is unnatural, while in real life it goes more smoothly.' [Participant 16]

As for multitasking, in the qualitative summary, the majority of participants mentioned that the feature had both advantages and disadvantages. On one hand, it deprived participants of the ability to fulfill simple, undemanding tasks while listening in during a meeting. This thereby decreased perceived efficiency, eliminated the possibility of reacting to events in the 'real' environment, and blocked some habitual activities, such as drinking coffee or pacing. On the other hand, it contributed to increases in engagement.

In the final questionnaire, we invited the participants to share their opinions on what types of meetings were well-suited to VR. The top three choices were free discussion, joint action (e.g. gaming), and presentations. Some insight into these evaluations is offered by qualitative data.

Free discussion was indicated by the majority of participants in the qualitative interviews as one of the meeting forms that is very well suited to VR. It was often mentioned in the context of various positive emotions, a relaxed atmosphere, and increased engagement. Interestingly, in relation to the latter, one participant mentioned that VR allowed for temporarily *spacing out* during such discussion without redirecting attention elsewhere, which can happen during videoconferences.

Presentations and gaming were organized as part of the study as collective activities. While it was expected that gaming in VR would be appreciated, the seminar presentations were somewhat of a 'dark horse'. In the qualitative interviews, a few participants admitted that they had not expected the presentations to be so realistic and enjoyable. They appreciated the opportunity to ask questions naturally and to interact with other participants and the presenter, as well as the effective simulation of the lecture room and blackboard.

As for the informal meetings, according to the majority of participants, the minigolf tournament in VR built relationships, provided a strong sense of copresence, and was perceived as realistic. One limitation was the possibility to play with a maximum of four people. The Pictionary game in VR was mentioned by approximately half of the participants as a particularly satisfying experience. They felt that it was similar to playing in person, and it was assessed more highly when it took place in the VR environment than via videoconference. In the case of viewing videos together, on the other hand, ratings of the experience in the VR environment and via videoconferencing were similar.

Some meetings were deemed particularly unsuitable for VR. As well as the meetings that required joint work on files and the sharing of information from the web, a few participants mentioned meetings aimed at discussing serious and personal subjects, such as issues related to employment, compensation, and job quality assessment.

3.2.3. The Horizon Workrooms platform and avatars

In general, Horizon Workrooms was evaluated as enjoyable, intuitive, good-looking, engaging, convincing, and useful. On a seven-point scale, the lowest rating given was 4 and all of the averages were above 5.5. The most positive descriptive comments given in the final questionnaire in an open question concerned the spatial audio. Other frequently-mentioned advantages included the availability of different room settings (table arrangements), the possibility to write on the blackboard (both directly and from one's seat at the table), and the accurate reproduction of avatar gestures. A definite problem with Horizon Workrooms was participants' limited ability to edit documents. Figure 6 presents a list of Horizon Workrooms functionalities (see supplementary material for a description) alongside their rating statistics and the number of participants who used them. The most commonly-repeated activity was using hand tracking, followed by checking the appearance of one's own avatar.

The qualitative interviews revealed additional problems. One related to greater control over virtual space. A few participants expressed the need to be able to move through it more naturally and unrestrictedly. They said that when they discovered a potentially accessible place, but could not get there, they felt confined and the immersion was broken. Moreover, a few participants stated that they would appreciate more freedom in terms of selecting and manipulating the elements of the virtual space. They mentioned they would like to play music or decorate the meeting room in a less restricted manner. Approximately half of the participants mentioned needs related to functionalities, such as sharing their screens with selected meeting participants only (e.g. the person sitting next to them, like in an in-person meeting), enlarging their screens or adding more screens to facilitate reading, and taking private notes. A few participants said they would like to read actual facial expressions. Finally, a few postulated that better integration of technological surroundings would be desirable. They mentioned using controllers (instead of a mouse) to navigate their computer screens, and accessing telephones to contact people outside of the meetings more easily and control the incoming notifications.

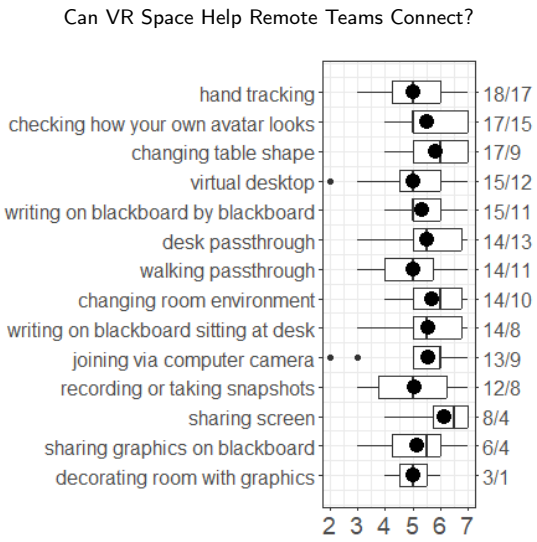


Figure 6: Evaluations of Horizon Workrooms functionalities ordered by the number of participants who tried them. The dots indicate the means. The numbers on the right correspond to the number of participants who *tried a given functionality at least once/used it more than once*.

A separate interesting subject is avatars. Our work confirms the applicability of findings on avatars from studies conducted in video environments (Panda et al., 2022; Nowak and Biocca, 2003) to the VR environment. First, according to thematic analysis, avatars that resemble actual users increased social presence and facilitated contact. Virtually all of the participants checked on their avatars during meetings (see Figure 6). In the qualitative interviews, the majority identified with their representations. A few even regularly changed their avatars' outfits to mimic real life more closely. The majority of participants also became accustomed to the appearances of others' avatars. Interestingly, two people mentioned even that meeting actual people after spending so much time with their avatars could feel strange and unnatural.

> 'I have positive emotions and prefer meetings like this. Even though we are cartoons, it doesn't bother me at all. The meeting feels real anyway. But it's cool if with avatars we resemble ourselves. [...] Then there is such consistency. And if it doesn't match—for example, someone is a purple alien, it gets in the way. The more similar someone's avatar is to themselves, the better the flow.' [Participant 8]

Second, a few participants who are uncomfortable speaking in public felt more at ease during meetings in VR, hidden behind their avatars, as it protected their privacy:

> 'I feel a little hidden behind this avatar and feel more confident than on Zoom. I feel a bit like I'm in an invisibility cloak. I'm here, you can see me, but at the same time you can't see that, for example, I'm blushing. [...] As much as I don't like to speak in a group, it comes to me much easier in VR.' [Participant 10]

Third, the replication of real body movements was used by the participants to decode the degree of attention and the intentions of other participants, which facilitated interactions. However, for a few participants this was difficult. They mentioned that it was easier for them to read gestures in videoconferencing format. They also relied on facial expressions more heavily, while in the study, the avatars' facial expressions were controlled by an algorithm that attempts to match them with users' speech. The participants' true facial expressions remained hidden:

> 'I am bothered by the limitations of these avatars, strange facial expressions, avatars are rigid and cut off nonverbal communication. [...] it was like I was communicating with some motionless figures only by voice and it was creepy. I couldn't see what the reaction was when I spoke to someone. You can tell just by

> body language how someone is reacting to what you are saying, and in VR that's not there.' [Participant 12]

Fourth, the Horizon Workrooms environment enables connection to VR meetings via computer camera, in which case the image from the camera appears on the screen in the virtual meeting room. Generally, the participants appreciated this feature (see Figure 6). Nevertheless, in the qualitative interviews a few found the experience bizarre, stating that it was alienating to be outside of the shared space, and that they felt more exposed in their real-life appearance among cartoonish characters:

> 'It's strange to participate in such a cartoonish meeting, as you yourself are not so, but on camera. There is this fear that I am visible, and in a meeting where everyone else is hidden behind avatars. I felt terribly exposed then.' [Participant 12]

The quote above confirms what has previously been observed in video-only format (Panda et al., 2022). This could potentially be addressed by allowing for a more unified representation of VR and non-VR users. For example, non-VR users could join as avatars, either via video, or in a 3D space such as AltspaceVR, and their movement could be tracked via computer camera. This problem requires further investigation.

3.3. VR meetings as a tool for remote work

The third objective of this study was to discover whether VR could fill some of the gaps created by the abrupt switch to remote work in 2020. We begin this section by describing the nature of those gaps. We proceed to consider the psychology of VR meetings in the study and contrast VR with other tools used for team communication.

3.3.1. Remote work

In both qualitative and quantitative interviews, the majority of team members maintained that the transition to remote work had proceeded well, and believed that the efficiency of their work had improved. However, they also noted disadvantages in terms of team functioning, which are generally consistent with other literature on the subject (Galanti et al., 2021; Elshaiekh et al., 2018) and works cited in 1.2). First, it is more difficult to gather knowledge on the skills and resources of others, and it takes longer to set project arrangements. Second, as remote meetings are arranged in advance, there are few opportunities for the random, spontaneous interactions that often lead to creative ideas. Third, there is less space for private conversations. Fourth, there are fewer common activities. These translate into a decreased sense of team bonding and a deterioration of the collaborative atmosphere.

Remote meetings are typically held via the Zoom platform. Although meetings conducted in this way are regarded effective and easy to implement technically, they also incur a number of frequently-mentioned disadvantages. Participating in such meetings is physically tiring for most people and is accompanied by a low sense of connection. It is difficult to assess others' degree of interest and nonverbal reactions during remote meetings—particularly when participants do not turn on the cameras, in which case it is almost impossible to assess their reactions (Choi et al., 2021).

3.3.2. Team spirit

Relations within the participating team, as rated prior to the study, were very good. In the qualitative interviews, the participants underlined that the group was characterized by good communication, low hierarchy, and good cooperation. When asked in the final questionnaire whether VR had brought about positive changes in the team, half of the participants agreed. In the open question, they mentioned more engaging and spontaneous meetings that made it easier for people to speak up, getting to know other people—particularly those who had joined the team when remote work mode was already in place—and a new energy in the team that resulted from doing something novel together. From the qualitative interviews, we also know that VR allowed some people who had joined the team after the transition to remote work to feel better integrated:

> 'I feel more comfortable now after these meetings in VR. Some kind of barrier has been broken. [...] For me, a person who has not had the opportunity to meet you in person, the VR meetings helped me get to know the people in the organization better. Not having a comparison with how things were before the pandemic, VR has helped me get to know people better than I did while working remotely.' [Participant 10]

One person who lives in another city and has always worked remotely in the team decidedly preferred meetings in VR to the hybrid form from before the pandemic:

> 'At hybrid meetings, when I connected via camera and the rest of the participants were live, I felt like an observer who could faintly hear what was going on. [...] I feel closer to the team when we meet in VR.' [Participant 1]

However, some heterogeneity also existed. A few participants who had previously worked together in the office and had had the opportunity to get to know each other in person did not feel a positive impact of meetings in VR. Moreover, VR meetings proved to be extremely difficult for a few individuals. The HMD caused so much physical discomfort to one participant that she was unable to use it. This participant observed that VR proved to be an exclusionary technology:

> 'I am very discouraged [...]. The goggles turned out to be very impractical on a daily basis. No possibility to drink tea or fully communicate began to irritate, and then to disturb and annoy me. In addition, it turned out that if someone cannot wear them for health reasons, then the technology becomes exclusionary.' [Participant 12]

In the context of meetings and the team, some of the most frequent co-occurring terms in the thematic analysis were realism, naturalness, copresence, and closeness. However, when asked directly, the majority of participants highlighted that despite their high sense of shared presence in the same space, meetings in VR were also significantly different from in-person ones. First, such meetings must be planned in advance. Second, VR does not allow all elements of office life to be recreated—before and after the meetings, in the hallway or in the kitchen.

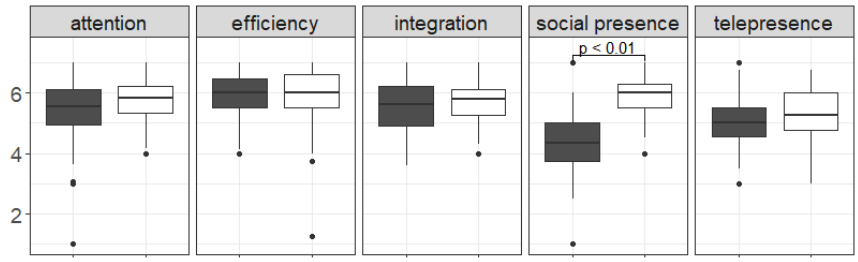
To assess the potential effect of VR meetings on team perception more rigorously, we measured it after each remote meeting. As a starting point, we used the social integration scale (Nezlek et al., 1994), the telepresence and social presence scales (Nowak and Biocca, 2003), and attention allocation and cognitive involvement items from the MEC Spatial Presence Questionnaire (Vorderer et al., 2004). We added items on perceived meeting efficacy. We performed confirmatory factor analysis clustered on meetings. We eliminated three items due to high cross-loadings and one item due to low loading. The final results were adequate ($X^2 = 133$, df = 67, robust CFI = 0.97, robust rmsea = 0.06) with all standardized factor loadings above 0.75. We identified five dimensions:

- social integration – five items e.g.: *I felt like we were working as a real team*
- telepresence – two items e.g.: *The meeting was engaging*
- social presence – two items e.g.: *The meeting was like a face to face meeting*
- attention – three items e.g.: *I gave this meeting my full attention*
- efficiency – two items e.g.: *We used the meeting time well*.

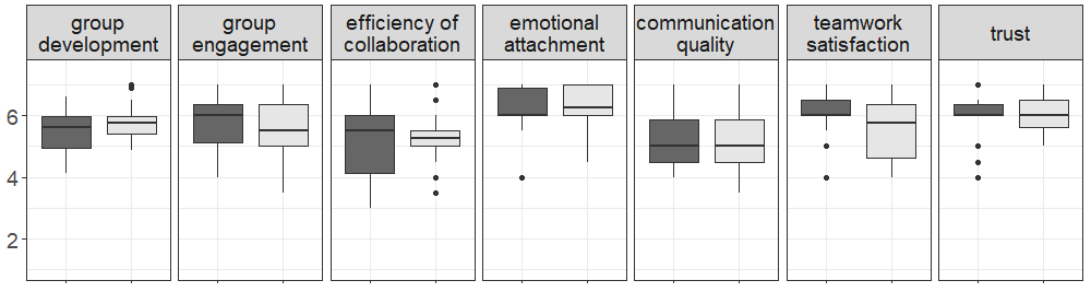
On the basis of this model, we computed simple scores and averaged them for each meeting to obtain an evaluation for each meeting. Figure 7a presents the mean evaluations for VR-only and the baseline video meetings. VR meetings were rated more favorably with respect to social presence. These comparisons should be treated with caution, as VR and video meetings differed in some respects (see Section 3.2.1) that were uncontrolled. The ratings for VR meetings failed to evolve considerably over time—although we did observe slight steady decreases in telepresence and attention, and a slight steady increase in social presence. These changes might be symptomatic of the novelty effect wearing off, which could cause the VR meetings to become less exciting; perhaps this also allowed the participants to direct their attention away from the technology itself and towards other attendees of the meetings.

To explore whether the increased sense of social presence during meetings translated into an increased sense of team bonding and a more collaborative general atmosphere, we used the Group Development Scale (Leuteritz et al., 2020) and a series of additional pairs of items inspired by team work satisfaction scales (Hamlyn-Harris et al., 2006). The low number of observations does not allow for factor analysis, so we used the Group Development Scale as provided and constructed seven tentative measures using simple sums of scores:

- group development – eight items e.g.: *We have a usual way of functioning as a team*
- group engagement – two items e.g.: *We are proud of our achievements as a team*



(a) Team perception during video (dark grey) and VR (white) meetings. Statistics for the meetings dataset. P-value for a paired samples t-test for the only significant difference.



(b) Group development indicators from the kick-off (dark grey) and final (light grey) questionnaires.

Figure 7: Team spirit evaluations during the study.

- efficiency of collaboration – two items e.g.: *We use our time well*
- emotional attachment – two items e.g.: *We like each other in our team*
- communication quality – two items e.g.: *In group discussions, some individual voices are lost* (reversed);
- teamwork satisfaction – two items e.g.: *Working together with the team is a source of satisfaction for me*
- trust – two items e.g.: *I can rely on other members of the team.*

The measures were taken at the beginning and at the end of the study. We found no clear differences in their degrees after introducing VR meetings (see Figure 7b). In our case, the increased sense of presence during the meetings failed to increase the general team connectedness. This does not necessarily signify that VR does not have this potential. The lack of the expected effect could have been due to the high quality of relations with which the team started. Heterogeneity in VR perception could also have contributed. This problem requires further investigation with larger and more variable samples.

3.3.3. Comparison with other tools

In the final questionnaire, we asked members of the team how they viewed the usefulness of various technologies the team used to deal with the drawbacks of remote work. We considered three technologies that the team used: VR, text chat, and videoconferencing. It transpired that each of them was considered best in some areas. On average, VR was seen as the best in terms of decreasing distance, building relationships, creating opportunities for meetings that lead to creative ideas, and presentations. Videoconferencing was preferred for building awareness of available resources and skills, and large or short meetings. Interestingly, chat communication was the tool of choice to communicate personal issues and maintain the team atmosphere. The latter stemmed from the very intensive employment of chat communication. Its major advantage is that it does not require coordination and can be accessed at any time (Rudnicka et al., 2020). It was used for spontaneous interactions, sharing jokes, and developing impromptu ideas. A few of the

participants mentioned that this channel filled the most gaps that result from remote work and maintained the team's connectedness:

> 'Chat is good for sending spontaneous, informal messages. It's that that is the air of our team.' [Participant 6] 'It's signaling that hey, I'm here. I'm working remotely, but I'm here. It maintains the consistency and continuity of the team.' [Participant 8]

In the thematic analysis, videoconferencing was often mentioned to build contrast with VR meetings. The most common topics here were different discussion dynamics, higher engagement in VR, easier multitasking in video meetings, the fact that Zoom is a familiar tool and using it comes effortlessly, and the absence of facial expressions in VR. Interestingly, while a few participants thought that due to the latter, reading others' was easier in videoconferencing, more participants expressed the opinion that VR space and avatars gave them a better idea of others' intentions. Finally, a few participants noted that VR meetings constituted *yet another level* in terms of how little attention one has to pay to their looks. Not only do we not need to *wear pants* anymore, but we can generally ignore our appearance, as the avatar always looks good. This may contribute to psychological safety. We return to this problem in section 4.

4. Discussion

4.1. General discussion

In this article, we studied the process of adopting VR meetings, explored how different types of meetings perform in VR, and examined whether the technology can deliver on its promise of connecting remote teams.

The first research question related to the adoption of VR as a meeting technology, the extent to which people's initial attitudes influence this process, and to which the process influences their attitudes. We had a unique opportunity to study these problems in a real-life context at the employee level (Trenerry et al., 2021). Based on the existing literature on digital transformation (Trenerry et al., 2021) and technology acceptance (Davis et al., 1989), we measured the initial attitudes of participants toward digital transformation in the context of VR (Makowska-Tlomak et al., 2021; Makowska-Tłomak et al., 2022). Although they correlated with the perception of VR adoption during the study, we observed that participants' attitudes towards VR changed as they gained more experience with the technology—in some respects more than others. For example, reluctance to learn was quite stable and appeared to relate to personality traits. The change was visible in two aspects: team atmosphere concerns that were alleviated, and fear that VR would be impractical. Of all the aspects of digital transformation attitudes, fear of impracticality correlated particularly strongly with experienced emotions and perception of technology. Therefore, it seems to be a viable candidate for further study by practitioners who wish to popularize VR work meetings.

In our data, we observe indications that two factors are important when VR adoption is considered. The first points to the importance of a transition period (Kazim, 2019). Our participants needed time to experiment, get accustomed, and learn how to use the newly-introduced technology. This played a vital role in changing their attitudes toward more propitious ones. Regardless of pre-existent caution, the general perception of VR meetings stabilized at quite high levels with the exception of the meetings that required working with files. This example, however, also teaches us about the importance of learning, as the participant who was a VR expert not only could edit files easily in VR, but was also able to convince other people in the meeting with him that it is feasible and smooth.

The second factor, that has been consistently regarded as problematic in other works (Chang et al., 2020), is the cumbersomeness of the HMDs. For some users, this problem becomes a deal breaker. We found that in the team context, this can lead to the technology becoming exclusionary. It also limits the applicability of VR technology to meetings that do not exceed sixty minutes in duration.

The significance of both of these factors may decrease with time, as the general population becomes more familiar with VR technology, and VR hardware becomes more ergonomic and comfortable.

In the second research question, we asked how the virtual environment for meetings is perceived and what types of meetings are best suited to it. The main strength of the VR environment, as indicated previously, turned out to be its ability to build a strong sense of social copresence (Campbell et al., 2020) and immersion (Steinicke et al., 2020). This is achieved using several key elements, such as common space, spatial sound (Kobayashi et al., 2015), accurate gesture tracking (Kurzweg et al., 2021), and customizable avatars (Panda et al., 2022), which together create a sense of natural discussion dynamics in which it is easier to maintain social connection and read others' intentions (Kurzweg et al., 2021; Choi et al., 2021). The implications for VR meetings in this context are that the best types of meeting to be held in VR are those that require the strong connection and engagement of all of the participants. This includes

social events, the generation of new ideas, and participation in seminars (He et al., 2020; Kostov and Wolfartsberger, 2022; Podkosova et al., 2022). This is important on the level of management that dictates the number of and in which format they should be held. Such choices should be made with the strengths and weaknesses of various communication formats in mind (Goff-Dupont, 2018).

Multitasking and avatars, which were frequently mentioned in the qualitative part of our study, lie on the border of two of our research questions. On one hand, they relate to meeting behaviors and organization; on the other, they turned out to be important in the context of psychological functioning in the team and the remote work environment, which relates more closely to our third question: can virtual reality fill some of the social gaps created by remote work environments?

We know that some forms of multitasking can be beneficial (Cao et al., 2021) and that VR technology blocks most of them. While our participants generally appreciated the increased engagement forced by VR, they also sought solutions that would enable them to make this environment more flexible and postulated some changes, such as partial integration with external equipment. People like having a choice (Kuzminykh and Rintel, 2020b). The question related to VR meeting environments' design is how to give it to them without *'throwing the baby out with the bathwater'* and removing the increased engagement experienced in VR.

We established that the findings on avatars in video format also apply in the VR environment (Panda et al., 2022; Nowak and Biocca, 2003). First, avatars that resemble actual users increased social presence and facilitated contact. Second, participants who are uncomfortable speaking in public feel more at ease when they are concealed behind their avatars. Third, participants used the replication of real body movements to decode the degree of attention and the intentions of other attendees. Fourth, some participants felt that the conversations with avatars were artificial and incomplete because they did not show real facial expressions. These findings reveal an interesting duality. On one hand, avatars, with the introduction of face tracking, can become even more *like actual people*. On the other hand, they are only artificial images that create advantages for people who experience difficulties when interacting with others. Our participants mentioned that avatars allowed them to feel more confident because they need not worry about their looks, and because they could *hide* behind these representations and gain more control over which of their reactions are observable by others. Therefore, VR seems to create a unique chance to increase the psychological safety of some people. It gives them opportunities to practice dealing with challenging interactions and can increase the likelihood that they will speak out when needed. This, in turn, might forge benefits for the whole team in the form of better adaptation to changing conditions and more efficient learning (Edmondson, 1999).

In the context of our third research question, we can further note that despite consistently high evaluations of team connectedness during the VR meetings and enthusiastic testimonies about building connections with new team members, we failed to observe any effect of VR meetings on 'team spirit' as measured using validated tools (Leuteritz et al., 2020; Hamlyn-Harris et al., 2006). This could be due to the specificity of the group in our study. Thus, the problem of using VR to support team building requires further investigation. However, we were able to draw two important conclusions. First, in its current state of development, VR is not for everybody, and managing remote teams using this technology requires a great deal of sensitivity to individual needs and problems. Second, although not best suited for full-day individual work (Biener et al., 2022) VR can become one of the tools in the remote teams toolbox with specific applications. In the following two subsections, we present guidelines that can enhance this process.

4.2. Guidelines for remote team meetings

At the end of the study, sixteen of the eighteen participants declared that they wanted to continue meeting in VR. On the basis of these results, we can state that the VR space can be an exciting and unifying experience for remote teams. Based on our findings, we formulate suggestions for remote teams that wish to apply VR technology to their work meetings:

1. Prepare for the transition. Discover what your teams' concerns are, provide technical support, answer all of their questions, and give people time to familiarize themselves with the technology.
2. Rely on neither preconceptions nor first impressions, as attitudes develop over time and people learn.
3. Guide participants to arrange a physical space where they are undisturbed and feel comfortable.
4. Encourage participants to take the time to customize their avatars and make the avatars resemble themselves.
5. Keep VR meetings short, but not too short (thirty to sixty minutes). Remember that starting the VR equipment takes time, so make it worthwhile.

6. Match the form of the meeting to the objective. The types of meetings that are best suited to VR are discussions, team-building events, and presentations. Collaborative work on files and discussion of sensitive issues should happen outside of VR.
7. Keep in mind that individual differences exist in social communication preferences. Adjust the mode of meetings whenever necessary. If possible, enable participants to connect via video if they prefer it.
8. Keep track of how people feel in VR and how this changes. Keep this confidential to avoid group pressure. Ensure that the technology does not become exclusionary.
9. Ensure that VR meetings involve all invited participants. If certain issues are being discussed for an extended period that do not apply to somebody, they will feel like they are wasting their time and efficiency, because they cannot multitask.

4.3. Design implications for VR hardware and software developers

Below, we list some preliminary design implications for collaborative VR spaces that refer both to hardware and to software solutions, formulated based on our results.

Interaction

1. It should be possible to move more freely in meeting spaces. Open and visually appealing environments invite people to explore and enjoy them. Restricting user's ability to teleport and move to visible and potentially accessible places can create feelings of confinement and artificial restriction.
2. The use of keyboards and screens in a meeting environment should be seamless; we should avoid interference between hand tracking and typing. Keyboards should be clearly visible and/or accurately mapped to allow fast and error-free typing. Alternatively, a hand-tracking-based keyboard with touch input could be integrated.
3. Simultaneous use of physical keyboards and controllers is cumbersome and should be avoided.

Avatars and visuals

1. Hyper-realistic avatars are not crucial; realistic recreation of movement is more important as it contributes to copresence. Any movement that looks unnatural, e.g. twisted and stretched arms as a result of tracking errors, feels out of place, breaks immersion, and immediately grabs other participants' attention.
2. Preferably, the same avatars should be available for use in different collaboration spaces. While this may not be an issue for casual use of VR for entertainment purposes, when a group of people use VR on an almost-daily basis and switch between different applications, it is troublesome to switch between different visual representations of the same coworkers.
3. Avatars should also be available to users who join VR meetings via computer camera, as it leads to exclusion for participants without VR headsets. From their perspective, VR users can hide using virtual representations while they are required to use a webcam and are confined to a single point of view.
4. Facial expressions should be more realistic and tracked with cameras, as the absence of close approximation hinders communication for some users.
5. Users like to customize their meeting spaces, and this helps them to overcome initial hesitations and concerns. Therefore, spaces should have many customization options, including changing the scenery and decorations, and music.

Communication

1. Spatial sound is key to high immersion and social presence.
2. Meeting spaces should offer private sub-spaces where users can, for example, share their screen with a selected participant or take private notes without using their computers.
3. The connection to VR meetings of users using their computers' cameras should be redesigned so that such users feel more fully included in the meetings.
4. Some users expect the integration of the meeting platform with telephone and instant messaging software, as well as easier file sharing between the VR space and their computers.

Usage Comfort

1. Streamline session-to-session VR setup to prevent participants from seeing it as not worth their time for short or spontaneous meetings, e.g. integrate a calendar with meeting links directly into the main VR home environment.
2. Lighter HMDs that can be adjusted easily to fit different head shapes—particularly the smaller heads of women—are necessary.
3. HMDs should allow for eating and drinking during meetings.
4. The battery life and cables should be longer, and the battery indicator should be accessible in any work-related setting, as 'battery low' notifications may disrupt work.
5. Strongly encourage users to verify that their predefined play area is safe.

4.4. Limitations and Future Work

This study should be treated as an exploration of how teams may transition to, use, and perceive VR work environments, so that it may pave the way for follow-up work in diverse organizations that use other work methods. The study's key limitation is that it was performed on a small and specific sample. We considered only one work environment. Individual physical characteristics like IPD distance, head shape, eyesight, as well as some psychological factors like individual immersability and cognitive resources, were not considered. We did not account for momentary moods. We were also unable to fully control the hardware environment of the study participants, including the computers they used and their peripherals. Likewise, we did not control their at-home VR spaces and boundary setups. Each participant was exposed to different environment-specific distractions in their homes. We used only one model of HMD, and focused on the Horizon Workrooms environment, which both have their own limitations.

A variety of interesting research directions could be pursued to further study the problem of VR work meetings. First, since the results presented in this article are based on the experience of one team using one platform, further research would be advisable to assess whether these results hold in other professional environments. It would be useful to discover whether our results can be replicated in a larger-scale study with various teams and using various software solutions. Second, the VR environment's potential in other areas similar to those of the encounters assessed in this study can be discovered—for example, in remote education or in the conducting of qualitative marketing research, training, or workshops. Third, the mixed mode in which some participants use VR avatar representations while others use video is an interesting case for the study of avatar communication. Finally, the problem posed in the title of this article, remote teams' connectedness, remains without a definite answer. Although the meeting-level indicators seem to assert that VR has potential in this regard, we found no universal effect. We are curious to discover whether this result holds among other teams and what the long-term effects of using VR for meetings on 'team spirit' are.

5. Conclusion

Research such as this, which provides a comparative digital footprint, is crucial to the understanding and facilitation of teamwork (Leonardi, 2021), as more workplaces transition into remote modes of work—not by necessity, but by choice. VR technology remains at an early stage of development; however, it is already possible to identify areas in which the technology has strong potential as a complementary tool deployed to aid the communication of teams that work remotely. A comparison of pre- and post-test measurements revealed that as participants became more familiar with VR technology, they identified more advantages in using it for meetings that require creativity or a sense of copresence, and include presentations or casual discussions. It is important to note that, for the most part, the participants felt that the meetings held in VR met the objectives set for them. The participants of VR meetings were also more focused on the content of the meetings and perceived them more frequently as shared experiences, and less as observed ones—as was the case with videoconferencing software. They appreciated being able to observe each other's movements, as it allowed them to communicate not only with words, but also with gestures.

However, the study also highlighted the weaknesses of VR technology at its current stage of development. Considerably more work is required to increase the technical capabilities of VR headsets. Most of all, the headsets should become lighter and more adjustable, so that a larger number of people feel comfortable using them—particularly for prolonged periods. Using the headsets proved to be quite exhausting, with comfort ratings dropping over the course of the study, although one would expect the opposite result: as users become more familiar with the devices, using them should gradually become easier. Unless this is accomplished, managers will risk alienating some members of their teams, and decreasing rather than increasing their teams' coherence. Software should be improved to provide more flexibility, more natural movements and facial expression of avatars, and tools for collaborative work with documents, text editing, and spreadsheets.

CRediT authorship contribution statement

Katarzyna Abramczuk: Conceptualisation, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualisation, Writing – original draft, Writing – review & editing. **Zbigniew Bohdanowicz:** Conceptualisation, Data curation, Funding acquisition, Investigation; Methodology, Project administration, Supervision, Writing - original draft, Writing – review & editing. **Bartosz Muczyński:** Conceptualisation, Resources, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Kinga H. Skorupska:** Investigation, Methodology, Visualisation, Writing – original draft; Writing – review & editing. **Daniel Cnotkowski:** Resources, Supervision, Writing – original draft; Writing – review & editing.

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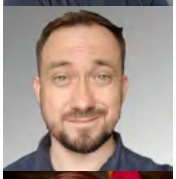

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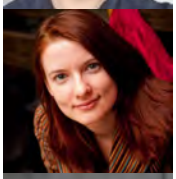

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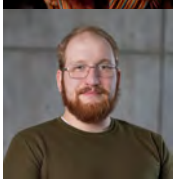

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Highlights for
Meet Me in VR! Can VR Space Help Remote Teams Connect: A Seven-Week Study With Horizon Workrooms

1. VR meetings can enrich remote work environments.
2. VR collaborative spaces are well-suited to social events, brainstorming, and seminars .
3. Participants who join VR meetings via video, without avatars, might feel excluded.
4. Practicality is the greatest concern for remote teams switching to VR meetings.
5. Meeting in VR leads to higher social presence, but not group development.

CRediT author statement

Katarzyna Abramczuk: Conceptualisation, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualisation, Writing – original draft, Writing – review & editing. **Zbigniew Bohdanowicz:** Conceptualisation, Data curation, Funding acquisition, Investigation; Methodology, Project administration, Supervision, Writing - original draft, Writing – review & editing. **Bartosz Muczyński:** Conceptualisation, Resources, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Kinga H. Skorupska:** Investigation, Methodology, Visualisation, Writing – original draft; Writing – review & editing. **Daniel Cnotkowski:** Resources, Supervision, Writing – original draft; Writing – review & editing.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: