Emerging Telepresence Technologies for Hybrid Meetings: Experiences and Lessons Learned from an Interactive Workshop

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Abstract

As demonstrated in recent years, telepresence technologies play a crucial role in the hybrid world. However, successfully carrying out hybrid activities that ensure participant engagement and equal opportunities for interaction and collaboration between in-person and remote participants still require significant effort. Building on this premise, this paper presents the methodology and lessons learned of a hybrid workshop involving eight in-person and eight remote participants. During the workshop, various telepresence technologies for hybrid meetings were tested, including 360-degree video-based systems and a telepresence robot. The workshop involved two main interactive activities: one focused on presentations to the audience (both local and remote), and a second focused on hybrid groups discussing a selection of provocative questions to compare and reflect on these technologies in terms of immersion, interaction capabilities, social implications, and practical convenience. In both activities, we ensured that all participants used the telepresence systems. This paper describes all the details that allowed us to successfully organize the workshop in terms of hardware, software used, roles assigned to organizers, and challenges faced. It also gathers the conclusions raised by both the participants and organizers to provide the community with valuable considerations for the design of future hybrid workshops, along with interesting insights obtained during discussions that highlight areas where future research should focus.

CCS Concepts

• **Human-centered computing** → **Collaborative interaction**; **Mixed / augmented reality**; **Interaction devices**.

Keywords

Telepresence, Telepresence Robots, Hybrid Meetings, 360 Video, Avatar

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1 Introduction

The benefits of hybrid work and events are ample [3, 6, 11], making them more accessible and helping towards a more sustainable future. But, are existing technologies ready for such events?

Remoteness for scientific events have been widely explored in the past [1, 19, 21], with an increased attention from the community since the outbreak of COVID-19. Some more recent examples include the IEEE VR 2020 [2] (as a fully remote event) and the ACM CHI 2022[1] (as a fully hybrid) conferences. But scientific events do not seem to be yet prepared for hybridity. For example, the responses from the survey of ACM CHI in the last two years:

- **2023**[2]: participants indicated that asynchronous presentations were notably negative, likely driven by the lack of interaction possibilities with pre-recorded videos
- **2024**[3]: participants highlighted the lack of networking and interaction opportunities (both as attendees and presenters), and the fact that there was little to participate in and insufficient synchronous/hybrid interactions for the sessions they could participate in

Given the crucial role that telepresence technologies will play in the future of hybrid meetings, a number of groups have emerged trying to compare different solutions and to provide guidelines for future events. Within ACM SIGCHI, one such example is what

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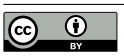

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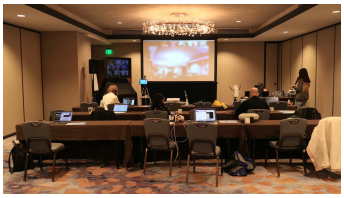
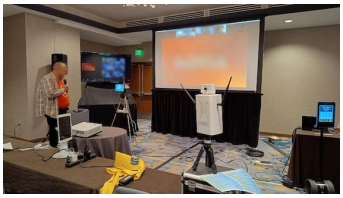
[1] https://chi2022.acm.org/2022/09/16/making-the-first-hybrid-chi-in-2022/
[2] https://chi.acm.org/chi-23-overview-of-the-post-conference-survey/
[3] https://chi.acm.org/chi-24-overview-of-the-post-conference-survey/


a) In-person setup

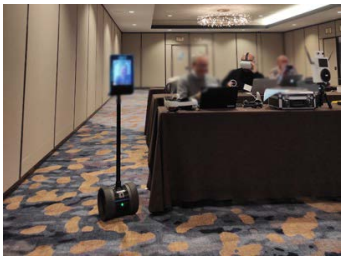

b) Gallery view of remotes and slides


c) Local participant asking a remote via the Owl


d) Local participant asking a remote via the Double


e) Remote via Kubi - remote via Double


f) Organizer using the microphone for The Owl presenter


g) Remote connected via Double


h) Hybrid group setup with the Double (activity 2)

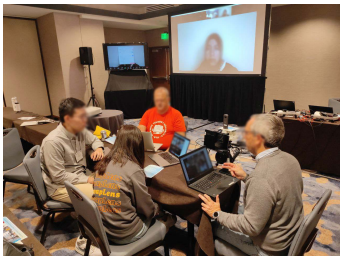

j) Hybrid group setup with the Owl (activity 2)

Figure 1: Different moments during the execution of the workshop where telepresence systems were used.

started as *Future of Work Conversations*[4] in 2020 has been established as CHIWORK[5]. In their Special Interest Group (SIG) at ACM CHI 2023 *Reflecting on Hybrid Events*, they highlighted the problems and trade-offs between hybrid functionalities for conferences [4], highlighting some potential solutions.

There has been many events (workshops/panels) discussing blended reality and collaboration to facilitate remote participation in events [7–9, 13, 18], but few have tried and compared different setups and technologies. For example, the workshops *Social VR: A New Medium for Remote Communication & Collaboration*, at CHI 2020 and CHI 2021, took place in an instrumented Social VR platform (Mozilla Hubs) [20] and compared different conference setups from presentations to discussions [16, 17].

This paper reports on the methodology and lessons learned from a hybrid workshop format intended to evaluate diverse telepresence technologies for hybrid interactions. By integrating the principles of Social VR and mobile robotic telepresence, the workshop sought to move beyond the "strict" conventional 2D tablet-based setups. Participants were invited to bring and test their own telepresence systems, engaging in structured activities that facilitated hands-on evaluations and collaborative discussions. Utilizing a focus group methodology [22], the workshop assessed technologies such as 360-degree video platforms and telepresence robots like the Owl [14] and the Double [5]. Key findings emphasized the critical need for improved interaction mechanisms between remote and local participants. To our knowledge, this is the first HCI workshop designed to systematically explore telepresence systems through active participation, providing valuable insights for the design of future hybrid events and highlighting essential areas for further research in telepresence technologies.

2 Workshop Description

This paper highlights the outcomes and key findings from the second edition of a workshop on Emerging Telepresence Technologies, held at a relevant International Conference[6]. This iteration emphasized interactivity and expanded the scope beyond learning environments to include hybrid applications in domains like professional training, virtual conferencing, and collaborative events.

This workshop took on the challenge of testing telepresence technologies, either developed by participants or commercially available, under the conditions of a conference in terms of participants, logistics, and networks infrastructure, some pictures of the event can be seen in Figure 1.

The workshop had three primary goals:

- **Hands-on experience with telepresence prototypes**: participants had the chance to engage directly with cutting-edge telepresence technologies. The "Call for Systems" ensured a variety of devices were available, encouraging participants (both local and remote) to experience these tools firsthand. To

[4]https://cs.wellesley.edu/ mobileoffice/conversations/
[5]https://chiwork.org

[6]We will cite it properly for the camera ready

facilitate its use, we designed two different activities where telepresence systems could be used for interaction: Activity 1 designed as presentation to small audience and Activity 2 was thought for group discussion; coffee breaks were utilized not only for informal networking but also as opportunities for system testing, and participant experimentation with the telepresence technologies.

- **Fostering active participation**: attendees could engage by presenting their research, submitting a position paper, or contributing a telepresence system. These options ensured diverse participation and enriched discussions. Note that these presentations were carried out testing the telepresence technologies available for the workshop. Likewise, the state of current technologies and the coordination of remote and in-person participants bring the discussion to a real-world experience outside the lab, where researchers become users of both the technologies and the experiment itself.
- **Enhancing connectivity between local and remote participants**: we sought to bridge the gap between in-person and remote attendees by enabling meaningful interactions that go beyond the limitations of traditional hybrid setups. We made a step forward by creating mixed groups of local and remote participants.

The workshop drew a diverse group of participants and contributions. Regarding participants, there were 8 in-person and 8 remote participants. Regarding contributions, 8 position papers addressing various hybrid interaction challenges, 3 organizer-provided systems, and 1 participant-submitted system were demonstrated and tested. As a result, participants tested the following system telepresence systems:

- **The Owl 2.0**[14, 23] : A 360-degree video communication system requiring participants to pre-install software on their Head-Mounted Displays (HMDs).
- **The Double 3** [5]: A mobile telepresence robot accessed via a web interface, allowing remote users to navigate physical spaces.
- **The Kubi**: A robotic tablet stand offering 300° panning and 90° tilting, accessible through a web-based platform.
- **Custom System by a Participant** [12]: A participant-submitted system, demonstrating a stereoscopic 360-degree based communications prototype.

To ensure seamless operation, we provided a Zoom session for all activities, accommodating any unforeseen issues while supporting full remote participation. Also, a miro board blackboard was set up, to gather all the feedback from participants. Different areas were assigned to gather feedback from activity 1 and activity 2.

Among the organizers, we define the following roles: *i*) Activity 1 Chair, *ii*) Activity 2 Chair, *iii*) Zoom Chair, *iv*) Local Double Chair, *v*) Remote Double Chair, *vi*) Local Owl Chair, and *vii*) Remote Owl Chair. The collaboration of so many organizers was strictly necessary for the workshop to move forward successfully (i.e., during the hybrid presentations round (the first activity), the Remote Double Chair had to ensure that the next attendant on this platform was ready, while the Remote Owl Chair had to make sure the remote presenter's application was working on his/her HMD, and the Zoom Chair had to manage the slides, etc.). It was necessary and very useful for all organizers to be constantly connected and attentive to a private channel; in this case, it was a chat group.

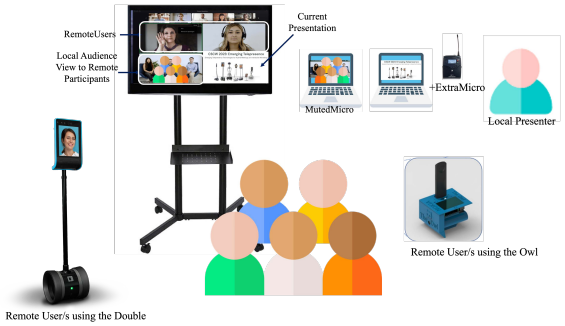


Figure 2: Activity 1. Diagram of the hardware involved to run the presentation activity in hybrid format using the Double and The Owl.

3 Activity 1- Hybrid Presentations

For the first activity of the workshop, we adapted the standard workshop activity of position paper presentations into a hybrid format. This allowed us to explore, through practice, how technologies for hybrid interaction could be used for the task of presenting to a small audience. Depending on the attendance modality, each participant could give his/her presentation in person or, using one of the two emerging systems: The Owl [14] and The Double. Participants also had the opportunity to attend the presentations using those telepresence systems, when they were not being used by the presenter. Our aim was to give each participant direct experience with at least one (and if possible both) of the telepresence systems by the end of this activity.

As can be seen from Fig. 2 for the successful execution of this activity a TV display, two laptops, one extra micro and the telepresence systems were required. The TV display was divided into smaller windows to render: current presentation, live video feed of remote participants joining the Zoom session and a view of the local participants. In the case of a local presenter two laptops were used, one used to join the Zoom call on behalf of the local audience that allows remote participants not using telepresence systems to be aware of the local audience and one used for the local presenter to present the work. An extra micro was used to ensure enough audio quality for both for the presenter or for participants raising questions. In the case of remote presenter, only the laptop for the local audience was used. The remoter presenter could potentially use a telepresence system, but she/he joint the zoom session with a laptop. Aside from all of these items, a big projector screen was used to display the presentation to the local audience at the local venue (see Fig.1 c).

3.1 Planning

Each participant was given 5 minutes to give a presentation about their position paper or about the telepresence system they were

bringing to the workshop. Participants who registered for the workshop after the position paper submission deadline gave a presentation about their current research projects. Between each presentation we scheduled an 8 minute gap. Of these, 3 minutes were allocated to Q&A and 5 minutes were allocated to switching the telepresence systems among the participants.

To facilitate the rotation of the systems and ensure that everyone was given the opportunity to use them, we had: 1) shared instructions on how to use the systems with the participants in advance, 2) planned a rotation schedule (i.e., see Table 1) and 3) assigned one in-person and one remote chair as the caretakers of each telepresence system. During the activity, it was the job of the remote caretakers of each system to look at the schedule, remind the current user to log out of the system, and help the next user log into it. This was done in the 5 minutes between the end of the Q&A and the start of the next presentation.

To ensure the session went smoothly and there was enough time to switch systems, the organizers held preliminary meetings before the workshop to assist with APK installations, if necessary, and to test the systems. Additionally, the workshop organizers arrived half an hour before the start to test the systems with remote participants to ensure everything was working properly.

3.2 Running the activity

Whilst it wasn't without challenges, the activity run fairly smoothly. Given the complexity of the technology we were bringing into the workshop, we had expected technical difficulties or delays due to participants coming to grips with the systems, so we allowed ample time for the activity. As in all workshops, it is also natural for presenters to take a bit longer than their allocated 5 minutes, or for the Q&A to evolve into a longer discussion. In our case, the 8 minute gap between presentations proved useful, as we were sometimes able to give the presenter more time for Q&A, while other participants were switching systems.

In terms of using the telepresence systems for presentations, the participants reported having an overall positive experience and liked being able to engage with each other in this way[7]. For example, during the Q&A times, **presenters using the telepresence robot moved closer to the audience, making use of the system's capabilities to mark their presence in the space**. The in-person participants liked being able to 'meet' the remote participants in this way; something which is missing from most hybrid events, where the in-person and remote attendees are treated as two separate groups or even if they are the same group, technology still offers a very limited ways of interaction.

Another issue with the current telepresence systems is the **lack of integration with general video-conferencing platforms** and with each other. In the case of delivering presentations, the presenters who joined through the telepresence systems also had to remain logged in on the Zoom call, so that they could share their screen with everyone else and present their slides. As such, they had to manage two interfaces at the same time. In addition, the video call served as a baseline where all remote participants were connected, helping organizers avoid losing track of them or creating confusion due to connection issues.

Figure 1 illustrates the overall in-person setup, with images from a) to f) depicting various situations that occurred during Activity 1. Fig. 1 a) shows the workshop room, which is very similar to the typical arrangements of regular workshops. Initially, the telepresence systems were placed in the front row, as the presentation and introduction to the workshop were given by a remote organizer. One notable aspect is that the lighting was not optimal, which did not contribute to the video quality transmitted by the telepresence systems.

Fig. 1 b) shows a gallery view of remote participants on Zoom and the slides being presented. It is important to note that remote participants connecting via telepresence technology could be presented in the local room in different ways.

If they were presenters using the Double robot, they were displayed on the Double's screen and were not visible on Zoom. This meant that the remote participants watching the presentation through Zoom could not see the face of the presenter.

If they were presenters using the Owl, they were displayed on the tablet of the prototype with an animated cartoon avatar (see Fig. 1 c,f). On the Zoom screen, they appeared wearing the HMD, as shown in Fig. 1 b). This also applied to remote participants attending a presentation using the HMD. Fig. 1 c) shows an in-person participant asking a question to the presenter connected via the Owl, positioned where an in-person presenter would typically be located. In this case, the microphone was necessary for participants connected via Zoom to hear the question. If the participant was close enough to the telepresence system, the audio could be sent and played directly through the remote attendee's HMD.

In Fig. 1 d), we can see how a in-person participant asks a question to a remote presenter. At this moment, an attendee connected via Double positions herself in front to hear the question while looking at the person asking it. In Fig. 1 g), a similar scene is shown, but this time the remote person connected via Double is looking at the Zoom presenter. This was an advantage for the remote attendee, who had the freedom to move. However, it is important to note that in some areas of the room, despite having cable covers, the cables caused the Double to get stuck, requiring assistance from local participants to help it move around. This is something to consider for this type of workshop and systems; **the rooms should have clear floors to facilitate the movement of mobile robotic telepresence systems or they will need help of in-person attendees.**

Fig. 1 g) depicts a spontaneous event that was not planned in the workshop, but it gave us the opportunity to explore: how does it work when multiple remote participants are connected with different telepresence systems and want to interact with each other? The number of participants and organizers, almost as many as the participants, allowed us to explore such situations. In this case, it was interesting, though it made the inability to move freely with one of the systems more apparent.

As can be seen in Fig. 1 f), one of the major issues with telepresence systems not being integrated with communication platforms like Zoom was also related to audio. An in-person organizer had to use an additional microphone to the Owl so that the rest of the room and Zoom participants could hear the remote person.

[7] based on lived experience and comments reported in miro

Time	Presenter	Presentation Mode	Double User	Owl User
11:00-11:05	Maria (remote)	Double	Maria (remote)	John (local)
11:05-11:13	Transition time	-	-	-
11:13-11:18	John(local)	In person	Daniel(remote)	Stuart (remote)
11:18-11:26	Transition time	-	-	-
11:26-11:31	...	...	...	...

Table 1: An example of the rotation schedule for activity 1. To preserve privacy and anomimity, names do not correspond with the real names of participants.

4 Activity 2-Group Based Activity

The second activity followed the structure of group discussions where, again, the telepresence systems were used. This allowed us to test the potential of telepresence technologies for supporting participation in hybrid group conversations. We initially planned to separate participants into one remote and one in-person group, but we realised that this would not be in keeping with the aim of creating a truly hybrid experience. Instead, we separeted participants into two groups, each of which was comprised of both in-person and remote participants (see Fig. [1 h) and j)]). In terms of the set up, the in-person participants of each group all sat on one table, with a laptop which displayed a Zoom call with the remote participants of that group[8]. In addition, each group was given one telepresence system. We made sure to group participants in such a way so that anyone who did not get to use a specific telepresence system in the first activity would be in the group given that system in the second activity.

The participants in each group then, took turns in using their assigned telepresence system, so that by the end of that activity everyone had had a chance to use it. Similarly to Activity 1, we had made a rotation schedule in advance. The activity itself was based on 6 discussion questions, so we planned for participants to pass on the system to the next person between questions. Again, the chairs of each system reminded the participants to switch, and helped them with the process. Also, the miro board was the platform used to gather all comments and answers.

4.1 Reflections on telepresence

Having heard presentations on the topic of telepresence, as well as used and observed telepresence systems ourselves, it was now time to discuss and reflect on our experiences. To spark discussions and guide the conversations, we gave participants the following discussion questions:

- **Discussion Q1** What types of hybrid meetings do you think there are? What are the main challenges of such hybrid meetings that telepresence technologies need to solve? How do we assess the success of meetings (metrics for different configurations/setups)
- **Discussion Q2** What resources and infrastructure are necessary to successfully run hybrid meetings? How could emerging technologies mitigate this?
- **Discussion Q3** What role does movement play in hybrid meetings? What forms of movement are beneficial (e.g., head movements, gesturing, full embodied movement)? How important do you consider the possibility to see/interact with real objects from the local scene (e.g.: blackboard, projector, regular object)?
- **Discussions Q4** In comparison to face-to-face, how well do the systems support communication, including non-verbal cues? Are you able to express yourself accurately? Are you able to take part in conversations comfortably (e.g., interrupting)?
- **Discussions Q5** What are the key differences you noticed between the systems? What features did you find most useful to support hybrid meetings? What was the quality of local-to-remote communication, and remote-to-remote? What has been missing from the systems?
- **Discussions Q6** Directions for future work. On what areas should future work on telepresence focus? What methodologies, modalities, and approaches should be considered?

Guided by the questions, participants discussed the various types of meetings and metrics. Being prompted to share their thoughts on the telepresence systems they had tried allowed them to identify different interaction elements that might support different hybrid meetings (e.g., use of avatars for privacy, use of camera for understanding the space, use of movement to make oneself visible to others). Participants also identified common issues with both systems, such as lack of integration with the main video-conferencing platform. Table 2 contains a summary of the topics discussed in Activity 2.

5 Conclusion and Lessons Learnt

Previous work had already identified two key sources of challenge for the success of hybrid meetings: limitations on the technology and specific design of the event dynamics and interaction [15]. This workshop aimed at gaining insight for both areas by testing emerging technologies for telepresence in an interactive workshop which was specifically designed for hybrid participation.

The usage of telepresence systems in the workshop shows that the technology is evolving in the right direction, but it still requires further development to be fully usable. Emerging telepresence technologies overcome limitations in remote-local interaction [15]: robotic telepresence (e. g. the Double) improves user agency and visibility in the physical location, while immersive telepresence (e. g. the Owl) improves space awareness and full view of the room. However, these systems do not properly address the interaction between different remote participants, mainly due to the lack of integration with videoconference platforms (e. g. Zoom). Additionally, they are limited by the battery life, which currently does not extend beyond 2-3 hours.

Emerging systems bring new challenges regarding the embodiment of remote users in the physical room. There is a general lack of self-awareness of remote users regarding how they are appearing

[8]Due to practical and convenience reason, during the execution of the activity, every participant was using their own laptop (see Fig.1 g), and h)).

Table 2: Activity 2: Hybrid Discussion

Question	Take Aways
Q1	**Meeting types** vary by task, location and number of participants. **Challenges** involve, sound quality, lack of eye contact and social cues to support turn taking [24]. **Success** depends on achieving a given task, reaching consensus, percentage of participants engaged (by counting number of active vs passive participants) and limited number of complaints.
Q2	**Resources:** time to design and think meticulously; money to buy/rent systems or virtual collaboration places, or pay fees for physical places; moderator to lead the meeting, technical moderator; **Infrastructure:** reliable technology and connectivity, and highly efficient and resilient codecs. Good illumination, clear and big spaces.
Q3	**Role of movement:** The Owl (3 DoF) and the Double have different movement (6 DoF) possibilites. Double gives you a full agency (robot embodies me). Embodied movement enables co-location. Movement can direct attention. Speed of movement is just as important as movement. Movement reduce cybersickness. **Interactivity** Both systems present lack of gestures and object manipulation (pointing, opening doors), alternative to explore: use of digital twins instead of teleoperating with real objects.
Q4	Telepresence systems give different possibilities for 'local' and 'remote' members. Differences in immersion and Social presence. **Non-verbal cues** are more difficult to read with Avatars (The Owl), rather than with real faces (The Double). Local to remote communication more straightforward with Double (faces are visible to each other). Weird experience of talking with an avatar instead of a real face. Experience is different if you known the remote person beforehand or not. Avatars can offer privacy. There is an evolving social protocol, where we learn to keep the remote members in mind. **Turn taking:** Remotes are often handicapped by delays, locals should be aware and talk more slowly.
Q5	Both systems lack a sense of awareness of how they user appears to others. The telepresence was more of a proxy than a representation of the user. In one of the groups, remote-to-remote have happened more in Zoom. **The Owl:** offered a better understanding of the space. Not reliable with wifi. There is a fear of being invisible on the Owl. The avatar could be customed at the beginning of the session. **The Double:** allows for free movement in the room, user is visible and people in the room can interact with them. Difficult to present slides whilst also driving the robot. Battery life ($90min$ in active call, 180 min in passive call). A 3D interface (stereo camera, HMD) might provide additional degrees of immersion. **Participant submitted system:** 3D (both video and audio) makes a difference, image quality (due to hard compression) not good.
Q6	**Room for improvement:** give more importance to the moderator role, and technical role in meetings, Give local members more awareness of the remote users and ways to interact with them, amplifying / adapting social signal; need for enough bandwidth or the use of ethernet cable to ensure reliable communication. **Future work:** explore many telepresence robots in a single meeting, explore multi-site arrangement, AI-based moderation

in the physical space. Remote users may have the option of being represented by cartoonish avatars, addressing privacy concerns. However, such representation, although fully accepted in virtual reality [16], results in less natural interaction in hybrid spaces. Additionally, it would create an imbalance with respect to in-person attendees, who do not have this possibility.

Successful hybrid meetings also require a good quality technical setup at the meeting venue. Microphones and cameras should be correctly positioned to cover the space, audio quality should be good ("use video when you can, but prioritize good audio" [24]), stable high-bandwidth wireless connectivity should be available, and the room should have good illumination and sufficient empty space for mobile telepresence robots to move. As experienced in the workshop, conventional conferences do not necessarily provide such setups by default. Additionally, using shared online tools, such as chats, miro boards or even discord channels, is also required.

Besides the technology and the logistics, it is key to design the meeting as hybrid from the beginning and consider the specific dynamics of hybrid communication. A key part of the workshop success had to do with the availability of sufficient organizers with dedicated roles, including a local chair, a remote chair, and sufficient technical support personnel. Beyond that, a few other aspects are worth considering.

- The meeting must be planned as hybrid. The duration of the active sessions must be controlled and sufficient breaks must be added to avoid zoom fatigue [10] and cybersickness. Planning should take into account timezone diversity and account for meal breaks across timezones. If new technologies are introduced, enough free time should be allocated for participants to test them and interact with the different systems.
- Social interaction and networking should be explicitly planned, including time for introductions and one-to-one conversations between locals and remotes.
- *Hybrid etiquette* must be established, and locals and remote chairs should remind participants to follow it. This includes established methods for remotes to request participation, as well as forcing local users to use common tools to communicate even between them (e. g. common chat or miro board). Time-zone awareness should be ensured for all participants.
- Sufficient technical support must be provided to remotes, including a pre-meeting training session, as well as backup communication channels (email, phone, messaging, ...) in case the main one fails.

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