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How Remote-Controlled Avatars are Accepted in Hybrid Workplace

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Abstract Due to Covid-19 outbreak, more people in workforce started working from home. Especially, hybrid work style is widely accepted at workplace as more flexible and inclusive way. However, a challenge of the satellite side of hybrid meeting has also gradually recognized, namely being easily ignored by co-located participants. Regarding the issues that hinder the participation and collaboration of hybrid participants, only a limited study has been made with no clear solutions. Hypnotizing physical *embodiment* in hybrid work as one of the potential solutions for avoiding satellite participants being neglected in remote work environment, this work has implemented remote-controlled avatars as physical embodiment of a remote participant and investigated its impact on communication and collaboration in hybrid meetings. Our preliminary analysis of the field experiments indicated that the Avatar with physical embodiment increased satellite participant's social presence, and interestingly, the subjective satisfaction level of the satellite participant was significantly higher than the remote participation with typical meeting tools, such as Zoom. In this paper, two observed effects of avatars with physical embodiment on participating at remote work are discussed; firstly, acceptance of satellite participants through embodiment and, second, social presence and potential collaboration between AI and Human. Since the hybrid work is expected to increase further in our society, there are a lot of potentials for improvements to design better remote work environment through avatar as physical embodiment.

Keywords: Remote Work, Hybrid Work, Satellite Participant, Embodiment, Avatar.

1 Introduction

Due to Covid-19 outbreak, more people in the workforce started working from home. This remote work became a daily practice at workplace. Since remote work has accepted as common practice as a part of the future work style after the pandemic, the potential of new working style is expanding drastically beyond our initial expectations.

The remote work not only reduces travel time, improve work-life balance and flexibility, but also eliminates barriers for people with anxiety and disabilities who had limited opportunities to participate in workplace previously [1]. Research on remote work after the pandemic has just begun, however, a shift of implementing a hybrid work model from traditional co-located work has already been observed as one of the prominent emerging phenomena even among the limited number of preliminary research. This shift has accelerated especially among leading digital societies, such as Denmark [2], where digital infrastructure of remote work has already established.

Hybrid work has potentials not only to limit some of the disadvantages of remote work [2], but also to increase diversity and inclusion [1] at work contexts. Hybrid work style, by providing workers freedom to choose a place to work, more flexible and inclusive emerging work style for many reasons. For families with small children, it is easy to accommodate to sudden illnesses. If workers are allowed to work at home several times a week, they will have more options where to live. Some wish to live in an area surrounded by nature, and others with their old parents in suburb cities, regardless of distance from their office.

Due to drastic technological progress of remote collaboration and communication tools such as Zoom, Teams, Slack, and Miro [3], and its upwards learning curves among people across nations through intensive mandate experience, people accumulated their skills and knowledge of remote work drastically. This created a unique global condition of equality of participation.

However, this participatory equality seems to be applied only when everyone is on remote condition. We have witnessed and gradually recognized a challenge of the satellite side of hybrid meeting, namely a challenge being easily ignored by co-located participants.

In hybrid work, a special consideration must be paid for equal participation because, it is extremely challenging to keep up social presence of the satellite participants in hybrid work settings. The more the co-located workers become concentrated and devoted to their work, the lower the social presence of the satellite participants in the team becomes, which undermine remote workers' participation at work. Regarding the issues that hinder the participation and collaboration of hybrid participants, only a limited study has been made with no clear solutions.

2 Preliminary Works: What We Found So Far

What is a key to support remote work? How can we resolve imbalance on the satellite side, especially in hybrid meetings? Based on the challenging agenda, we set our research question as follows: *How can the satellite participants in hybrid work avoid being neglected with the help of physical embodiment?*

At Future Living Lab (<https://futurelivinglab.org/>), a two year's research collaboration with a telecom company, NTT Techno Cross and two universities, Tokyo Institute of Technology and Roskilde University, a design project for future of remote work was initiated. Among distinct topics of inclusion and wellbeing on remote work, this re-

search focuses the effect of physical *embodiment* [4] in hybrid work as one of the potential solutions for avoiding satellite participants being neglected in remote work environment. In this research, diverse styles of remote-controlled avatars are implemented as physical embodiment of remote participants and investigate its impact on communication and collaboration in hybrid meetings.

A research design of the experiment introduced in this paper was inspired by a series of small studies on hybrid work conducted over the past years by one of the authors. Before introducing the experiment in Section 3, the two previous studies, a literature review [2] and three-months field experiment [5], will be briefly introduced as a trajectory to the targeted study.

2.1 Prospects of Hybrid Work

One of the author's first study on hybrid work is a literature review conducted in 2020-2021 [2], which clarified understandings of advantages and disadvantages in remote work during the first year of the global Covid-19 outbreak, 2020. In 2020, many people around the world had experienced semi-forced remote work. Some people lived in countries such as the Netherlands and Denmark, where remote work has already moderately being introduced, while countries like Japan where the Internet installation rate is high, but the condition for remote work were immature. Note that the remote work settings in this context cover wide range from remote access to the corporate network or database (technical constraints) to practical agreements of working from home (social constraints).

The literature review, covering the first year of COVID-19 experience, handled 39 academic papers, which revealed advantages, and disadvantages of remote work. According to the study, the three most common advantages are 1) reduced travel time, 2) improved work-life balance, and 3) improved flexibility, while the disadvantages are 1) damaging mental health, 2) harming physical health, and 3) declining of work-relationships. One of the final remarks of the literature review presented a view that remote work would increase globally even after the pandemic and expected that many organizations would be preparing in implementing a hybrid work model as new normal. The preliminary conclusion of the work is that the hybrid model at workplace is promising as it expects to keep advantages and to limit some of the disadvantages of remote work.

This introduced preliminary view of the remote work in 2020 has also been supported by the most recent research from 2021 onwards. Rather than introducing complete remote work or returning to the pre-pandemic workstyle, more and more companies are shifting to hybrid work [6]. Some companies that haven't implemented remote work, have also explored possibilities of hybrid work environment [7, 8].

2.2 Potentials of Avatar

A three-month field experiment conducted in the spring of 2022 by one of the author's research group, indicated potentials of remote work from different angles. The experiment investigated effects of using avatars in business meetings between the managers and their co-workers [5]. This study explored effects of using digital avatar robots in

virtual meeting environment, specifically, focusing on the perception of social presence and co-presence between workers and their managers. The experiment result indicated that in using digital avatar for the meetings, significant number of participants felt an improvement in social presence, co-presence, and overall virtual meeting experience.

The impact was greater especially to those who has a first meeting or has a meeting with persons from the higher corporate hierarchy. Our study suggested that remote work through digital avatar could be easier accepted and would increase social presence in remote work. Embodiment of the remote participants would facilitate collaboration due to its amplified social presence.

3 Experiment

3.1 Avatar at Hybrid Workshops

Most recently, authors have conducted a series of experiments on influence and acceptance of avatars in hybrid work context as a part of Future Living Lab. An ultimate purpose of the experiments is to conduct a test implementation, *living lab* [9] of embodied avatar and its social presence, to understand potentials of hybrid work supported by Avatar.

We conducted a successive four hybrid design workshops during March to August 2022. The number of participants of the workshops were five or six including one satellite participant, *Participant A*. The participants had diverse backgrounds such as university students, professionals at industries and non-profit organisations, and researchers. The participants were invited to the workshops through the authors’ personal connections and advertisements put on the public space of authors’ home university. **Table 1** shows a formation of participants in each workshop session.

Duration of the workshops was approximately three hours each, and the participants received one design task to achieve in three hours, such as ideation and concept creation based on the workshop agenda. Typically, the workshop offers data set, paper templates, post-it and pens for working on specific ideation, creation, and discussion among group members.

Table 1. A formation of participants in each workshop session

Workshop# (Month)	Co-located Participants	Satellite Participant	Total Participants
1 (March)	5	1	6
2 (May)	4	1	5
3 (June)	4	1	5
4 (August)	4	1	5

While one member joined the workshops as a satellite participant, other participants were co-located and co-worked at workshop sites. The satellite *Participant A* joined the workshops through an embodied avatar, which *Participant A* controlled and spoke through. A remote avatar, *Avatar Bear*, with physical embodiment at co-located stage

was presented as shown in **Fig. 1**. Avatar Bear can be interpreted as a substitute body of the satellite *Participant A* and equipped with fictitious AI functions. The AI functions were deployed based on the Wizard of Oz technique [6] mediated by a human operator, *Operator K* at the workshop site.



Fig. 1. Avatar Bear in Wizard of Oz method.

In order to test communicative and collaborative effects of Avatar Bear, diverse conditions of participation were designed (**Table 2**). Among four workshops, the first workshop used ordinary online meeting tool, *Zoom*, with a tablet screen, while the rest three sessions used the Avatar Bear. The *Zoom* in the first workshop was set up with a tablet on the movable table with wheels (**Fig. 2**) so that the remote participant's view can be easily adjusted with its display angle. Among three Avatar Bear sessions, a condition of the last session was slightly different from the two other sessions. In the second and third sessions, AI functions of the Avatar Bear was activated so that the Avatar Bear, by recognizing environment, conducted autonomous actions such as waving hands, nodding, and facing to the speakers without direct manipulation by the satellite *Participant A* from the distance. In **Table 2** this setting is described as AI Avatar Bear *with Intelligence*, differentiating from *without automated behaviour* of the fourth session.

Table 2. Design of hybrid participation in four workshops

#	Avatar Participation
1	Zoom in the tablet set on the movable table with wheels
2	AI Avatar Bear with intelligence
3	AI Avatar Bear with intelligence
4	AI Avatar Bear without automated behavior



Fig. 2. Zoom in the tablet set on the movable table with wheels

On the other hand, in the fourth session, the Avatar Bear could act only when the satellite *Participant A* explicitly commanded actions. For this session, the three action buttons were prepared as shown in **Table 3**. The satellite *Participant A* send a command to the Avatar Bear and the commanded action was activated by Avatar Bear AI (*Operator K*) with a few second's delay.

Table 3. Three actions operated by the satellite *Participant A*.

#	Operation button	Meaning
1	I want to share	Preliminary operation for waiting to speak up
2	I have something to say	Waiting for the turn to speak
3	I feel neutral	Not moving, no need to get attention

3.2 Data Collection

To investigate the impact on communication and collaboration of AI Avatar Bear with embodiment, questionnaires were distributed to participants after the workshops. The collected answers were analyzed and qualitative interview as a semi -structured interview [10]) was conducted within one week after the workshops, referring to the answers of the questionnaire.

Table 4. A brief overview of the questionnaire.

#	Questions	Measurement
1	Easy to talk to the Avatar Bear	7 Likert Scale
2	Easy to understand the Avatar Bear	7 Likert Scale
3	Easy to discuss with the Avatar Bear	7 Likert Scale
4	How did you think about an appearance of the Avatar Bear as a workshop member?	Open answer
5	How did you think about behavior of the Avatar Bear at the workshop?	Open answer
6	Feel free to leave your comments regarding the Avatar Bear	Open answer

The questionnaire consisted of six questions (see **Table 4**), which are to ask about impacts and impressions about AI Avatar Bear's workshop participation, satisfaction in communication and collaboration with the Avatar. The questionnaire was sent also to *Participant A*. In this case, *Participant A* answered about impacts and impressions about AI Avatar Bear's workshop participation, satisfaction in communication and collaboration with the co-located participants. All responses to question 1-3 were made on a 7-point Likert scale (from "1 strongly disagree" to "7 strongly agree"). The answers to the question four to six were open answers, which were later investigated in the in-depth interviews.

4 Preliminary Findings

The workshop participants were, as shown in **Table 5**, six, five, five and five each in total. A few participants joined four times consecutively, but overall members of the participants were different in every workshop. A satellite participant, *Participant A*, and *Operator K* were always the same person.

Table 5. Participants and their participation record.

Participants Name	W-1	W-2	W-3	W-4
<i>Operator K</i>	●	●	●	●
Participant A	●	●	●	●
Participant W	●	●	●	●
Participant I	●	●	●	●
Participant T	●	●		●
Participant H	●	●		
Participant F	●		●	
Participant Y			●	●
Total Participants	6	5	5	5

The original motivation of this study is to clarify whether the satellite participants in hybrid work can avoid being neglected with the help of physical embodiment. Specifically, the question was whether AI Avatar Bear with a physical embodiment would achieve participation, being recognized and accepted its presence by co-located participants in the work context. In this results section, a few noteworthy results related to recognition and acceptance of the Avatar Bear will be presented.

4.1 Recognition of Avatar Bear

The data from the questionnaires and the interviews clearly showed that the participants recognized and paid attentions to Avatar Bear during workshops. The co-located participants looked and turned to Avatar Bear, and frequently talked to the avatar.

First, let's review questions one to three. The first three questions direct and indirectly relate to the recognition of the Avatar Bear, which are 1) Easy to talk to the Avatar Bear, 2) Easy to understand the Avatar Bear, 3) Easy to discuss with the Avatar Bear. The overall average of the collected answers, for example, in the second session are 4.4, 2, 3.4 respectively. An evaluation of the question 2 was relatively low, which were explained by a few interview comments as potentially solvable technical problem.

The audio setup was important. It was hard to hear when the surroundings were noisy. I found it also difficult because of the time lag and not knowing what the Bear was watching. (Participant I)

Intriguingly, Participant A's view was somewhat different. In the interview, *Participant A* also made a remark that there were technical challenges such as voice volume setting and auto-mute setting. For example, auto-mute setting was a cause of prompt utterance not being heard on time and lost timing to speak. *Participant A* felt timely conversation as a team member, and any interventions of discussion among co-located discussion were difficult to make. As such, *Participant A* also expressed its dilemma that the Avatar was not always included to the discussion.

However, at the same time, the satellite *Participant A* recognized that the other participants were more attentive and occasionally approached or directed an eye on to the Avatar, comparing the past experiences as satellite participants. *Participant A* was confident that the Avatar Bear was recognized and accepted its presence by co-located participants, For example, the satellite *Participant A* commented;

I kept having and increased feeling of participation in the workshop as other participants looked at and talked to me (*Participant A*).

Even though there were obvious discrepancies in communication, it seems the satellite *Participant A* externalised rather satisfied view as a satellite participant. Although this is a subjective view, the satellite participant at least felt highly likely to be listened and recognized by other co-located participants. Next, we will investigate further in this subjectivity aspect.

4.2 Participant Subjective Satisfaction

Both co-located participants and the satellite *Participant A* evaluated similarly with questions 1 and 3 of the questionnaires. Overall rating among participants including the satellite *Participant A* have not clearly changed overtime. However, the interview revealed that the satisfaction of the participants who continued to participate and *Participant A* are rather high in the 2nd and 3rd workshops.

According to subjective self-report in the interview, the satellite *Participant A*'s satisfaction is higher in the 2-4th workshops than in the first session. Furthermore, among 2nd to 4th workshops, *Participant A* is more satisfied in the 2nd and 3rd than the 4th workshop. In the last interview, *Participant A* reflected the 4th workshop as with extra burdens since every behaviour of Avatar had to be commanded all the time. What's worse

was *Participant A* felt there was little feedback such as eye contacts from other participants, despite of the heavier burden than before. This experience hindered the Participant A's motivation of participation.

I was too busy, giving commands and deciding Avatar Bear's next action without return of investment. I could not concentrate on discussion, which ended up not much participation at the workshop. (*Participant A*).

This subtle mood change of *Participant A* was not externalised in Likert scale nor not recognized by any other participants. However, *Participant A* affirmed that the 2nd and 3rd workshop were more satisfactory. *Participant A* reflected the 3rd workshop was most included and participated one.

4.3 Group Dynamics and Human Relations in the Workplace

Among the four workshops, Zoom was used in the 1st workshop, and Avatar Bear was used in the 2nd to 4th workshops. Avatar Bear was always a same stuffing bear, while the AI function specifications were, to iterate, changed in the 4th session, in which Avatar Bear's actions were substantially reduced compared to the 2nd and 3rd workshops. The specification change was made to increase a degree of freedom of the satellite *Participant A's decision*, and to improve overall satisfaction. This decision was made since the increase of the autonomous actions of the Avatar Bear was observed in the 2nd and 3rd workshops. Thus, the research design team evaluated that AI intervention was excessive. In order to improve its Avatar function, behavior buttons were introduced (See **Table 3**)

However, as a result, the satisfaction of the satellite *Participant A* was mitigated. Less movements of the Avatar Bear reduced Avatar Bear's social presence among the co-located participants. The co-located participants paid less attention to Avatar Bear overtime, and gradually Avatar Bear presence disappeared. This is at least how *Participant A* felt. The satellite *Participant A's* view felt being ignored by co-located participants in spite of all the efforts of sending commands for better collaboration and participation.

In all workshops, condition was same. Sometimes I couldn't hear co-located participants, and I couldn't see description of point-it notes on the table. But this time, it was worse. I experienced that the Avatar was disappeared from the participants' consciousness. (Participants A)

I kind of forgot the Avatar occasionally. Probably without movement of the Avatar, I was not sure if the remote participant was away from the desk or just to keep quiet. (Participants I)

From the co-located participants' point of view, it would be easier to talk or take actions to the Avatars, who are sure to present, while the co-located participants hardly dared to do so when the remote participant's presence was not guaranteed. It is not

surprising that the co-located participants hardly take any affirmative actions toward the Avatar. The discussion would involve people in presence while remote participants without social presence are easily ignored from the co-located group discussion. This would be a natural reaction of group dynamics towards human relations in the workplace.

5 Discussion

It has hinted several potential effects of avatars with physical embodiment on participating at remote work, such as increasing satellite participant's social presence. Some of the most prominent preliminary findings are recognition of Avatar and the satellite participant, and subjective satisfaction among both co-locate and satellite participants and group dynamics towards human relations in the workplace.

Findings from our data indicates that small tuning of the Avatar Bear behavior settings might bring big differences in acceptance of the satellite participant, psychologically and practically. In this section, two aspects indicated by our preliminary findings are discussed.

5.1 Acceptance of Satellite Participant through Embodiment and Social Presence

Our preliminary data showed the subjective satisfaction of the satellite *Participant A* as well as co-located participants were satisfactory in the 2nd to 4th workshops with the Avatar Bear than the 1st remote participation with a typical meeting tool, Zoom. Looking at this single result alone, an implication that embodiment can increase social presence and reduce the sense of exclusion of satellite participants seems to be valid or at least worth mentioning. Furthermore, since the overall subjective satisfaction of the participants has increased, it is tempting to conclude that the Avatar's social presence would contribute to include satellite participants in the hybrid work setting. However, our data also show that embodiment is not simply a matter of achieving social presence and inclusion of satellite participants.

Interestingly, throughout the four workshops, there were always a few occasions that co-located participants hardly showed clear recognition to the satellite participant's presence according to the interview of the satellite *Participant A*, meaning the satellite participant was not included to the discussion, simply being neglected. However interestingly, the subjective satisfaction level of the satellite *Participant A* was not correlated with the facts reported by the participants. The satisfaction of satellite *Participant A* was high in the 2nd to 4th workshops with Avatar Bear than the first remote participation with the typical meeting tool, Zoom, and this satisfaction was commented directly by the satellite *Participant A*.

In other words, having embodiment and achieving social presence might give a relative sense of participation of the remote participant, while the person can still be ignored occasionally. The satellite participant seems content, even sometimes ignored.

This phenomenon leads us to hypothesize that what's more important for remote participants is to have a sense of physical participation through avatar, while being ignored or not is less matter. Also, it seems important for co-located participants to recognize a physical presence of all participants in the same place, even if they know that satellite participants behind Avatars are, in reality, located far away.

5.2 Collaboration between AI and Human

The satellite *Participant A* was often unable to provide timely response due to slight network delays. Also, occasional troubles in understanding the situation of co-located site made the remote participant reaction delayed. This situation activated AI based automated decisions of Avatar Bear more frequently than originally planned. Thus, in the 2nd and 3rd workshops, more automated action of the avatar were activated independently and autonomously over time by Avatar Bear AI (*Operator K*), assuming the intentions and feelings of the satellite participant. To our surprise, our data hinted that the avatar in the 2nd and 3rd workshops was accepted better by all participants than the last workshop when the Avatar Bear acted entirely only by the satellite participant's commands. Comparing the second and third sessions with the fourth session, in the fourth session when the Avatar Bear's AI decisions were restricted, not only was the recognition of the other participants lowered, but the satisfaction of *Participants A* was also decreased.

As mentioned previously, the command function was implemented just before the 4th workshop. The research design team considered the Avatar Bear should have been controlled by the satellite *Participant A*. Thus, the team considered the unexpected autonomous action of the Avatar Bear should be terminated. As a result, the satisfaction of *Participant A* was damaged as mentioned before.

Previous research introduced and implemented automation of avatars [11, 12]. Ogawa et.al.[8] implemented automated gesture function in their avatar so that avatars waves hands and nodding head while talking and listening to others.

Beyond predefined automated actions introduced by the previous research, our preliminary experiments indicate importance of active intelligent collaboration between AI and human. With current technology, it is still difficult for remote and satellite participants, to fully grasp local context and to follow conversation flow. Apart from technological challenges such as voice volumes or stable network connection, there exists challenges of human relations. Through tablet screen or avatar, it is still difficult to understand conversations and gestures from subtle body languages or tone of voices among co-located participants. The technological advancement made us possible to participate online work as closer to physical participation than ever, but online participation is not perfect enough to substitute with co-located participation. Our data indicated a potential of AI and human collaboration and co-creation under the current technological condition.

In our experiment, a human *Operator K* played a role of future AI using the Wizard of Oz method. Going beyond the currently implemented auto-generated Avatar actions such as waving and nodding, collaboration and co-creation between AI and human

might open new stage of hybrid participation. The avatar has a potential not only automated remote support but also amplify potentials and capability of remote participants as well as improving overall quality of satellite participant social presence among co-located participants.

6 Conclusion and Implications

Satellite work is becoming an easier choice after Covid-19 at workplace, but we are also witnessed that the satellite side on remote work is unconsciously and unintentionally neglected and eliminated in hybrid meetings, which gives satellite workers' negative experience.

Our preliminary research indicates the satellite participants cannot avoid being neglected. However, AI Avatar bear with a physical embodiment helps providing social presence and occasionally achieve participation, being recognized, and accepted its presence by co-located participants. More notably, the satellite participant's satisfaction was higher than Zoom participation, especially when physical ability of satellite participant was amplified with the collaboration with AI functionalities of Avatar.

Based on the preliminary results introduced in this paper, we are currently exploring three potential research directions of our original research question; how can the satellite participants in hybrid work avoid being neglected with the help of physical embodiment?

One is to improve the quality of physical presence of avatars to provide the best hybrid work experience. In our experiment, we observed prompt collaboration between the remote operator as satellite participant and the Avatar Bear as AI mediated by human operator. The remote operator, *Participant A* and the Avatar Bear acted as one as if the Avatar possessed by human [7]. This collaboration amplified the satellite participant's capabilities and overall quality of satellite participant social presence. As exemplified in the experiment, we are interested in improving quality of interaction between satellite and co-located participants through establishing satellite participants and avatar collaboration. Currently, quite a few remote-controlled avatars have been starting to play active roles in our society. However, the existing usage of avatar is limited. In future, avatars can support remote operators by providing decision supports based on the on-site context judgment. This possibility of man-machine or human-avatar collaboration can extend human capability, which could result better acceptance and higher satisfaction of satellite participants in hybrid work.

Another possible direction is to increase and improve subjective satisfaction of collaborative work in hybrid environment as one of the indirect approaches to solve challenges of being neglected. Different from co-located work and remote work, in hybrid work, satellite participants tend to be less satisfied because less accepted by the co-located workers. We would like to work on such a challenge as to improve the satisfaction and fulfillments of not only one side of participants, but also both remote and co-located participants in hybrid work.

It is expected that the hybrid work will increase and widely accepted in our society. In such context, we imagine a role of avatar, physical embodiment as substitute of physical self, will increase drastically due to its physicality and social presence. Considering its high potential to deploy avatar as physical embodiment in hybrid work environment, further unsolved challenges will be identified – how remote-controlled avatars can support hybrid work and improve the overall work environment? How can avatar help be increasing worker satisfaction and wellbeing in hybrid work? We would like to contribute designing better remote work environment from such avatar-human collaboration perspectives.

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References

1. Takeuchi, K., Yamazaki, Y., Yoshifuji, K.: Avatar work: Telework for disabled people unable to go outside by using avatar robots “orihime-d” and its verification. *ACM/IEEE Int. Conf. Human-Robot Interact.* 53–60 (2020). <https://doi.org/10.1145/3371382.3380737>.
2. Rønneknamp, C.: Working from Home in a COVID-19 World, (2021).
3. Molla, R.: The pandemic was great for Zoom. What happens when there’s a vaccine?
4. Jung, Y., Lee, K.M.: Effects of physical embodiment on social presence of social robots. *Proc. Presence*, 2004. 80–87 (2004).
5. Yasuoka, M. and Zivko, M.: Effects of Digital Avatar Robots on perceived social presence and co-presence in business meetings between the managers and their co-workers.
6. Fayard, A.L., Weeks, J., Khan, M.: Designing the hybrid office. *Harv. Bus. Rev.* 2021, 1–11 (2021).
7. Grzegorzczak, M., Mariniello, M., Nurski, L., Schraepen, T., Grzegorzczak, M., Mariniello, M., Nurski, L.: Blending the physical and virtual: A hybrid model for the future of work Standard-Nutzungsbedingungen: is a Research Assistant at Bruegel Blending the physical and virtual: a hybrid model for the future of work. *Bruegel Policy Contrib.* (2021).
8. Bloom, N., Han, R., Liang, J.: How Hybrid Working from Home Works Out. (2023).
9. Yasuoka, M., Akasaka, F., Kimura, A., Ihara, M.: Living labs as a methodology for service design - An analysis based on cases and discussions from a systems approach viewpoint, (2018). <https://doi.org/10.21278/idc.2018.0350>.
10. Wood, L.E.: Semi-Structured Interviewing for user-centered design. *Interactions.* 4, 48–61 (1997).
11. Ogawa, K., Nishio, S., Koda, K., Balistreri, G., Watanabe, T., Ishiguro, H.: Exploring the natural reaction of young and aged person with Telenoid in a real world. *J. Adv. Comput. Intell. Informatics.* 15, 592–597 (2011). <https://doi.org/10.20965/jaciii.2011.p0592>.
12. Tanaka, K., Nakanishi, H., Ishiguro, H.: Comparing video, avatar, and robot mediated communication: Pros and cons of embodiment. *Commun. Comput. Inf. Sci.* 460, 96–110 (2014). https://doi.org/10.1007/978-3-662-44651-5_9.