‘Can you Set It Up On Your Own?’ – Investigating Users’ Ability To Participate in Remote-Based Virtual Reality Studies

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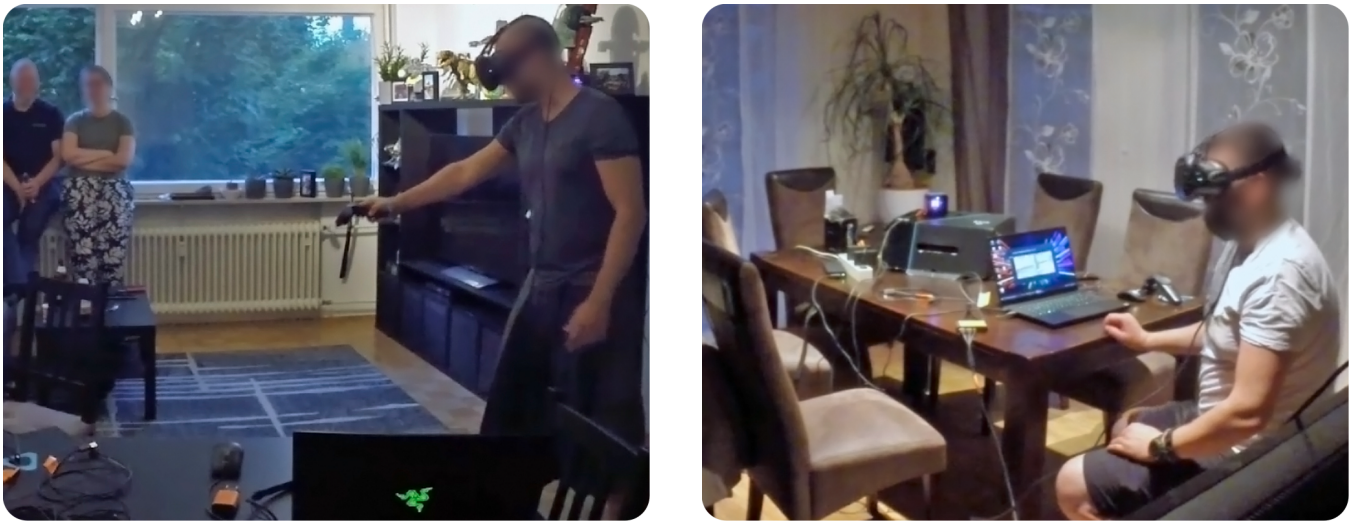

Figure 1: In an at-home user study, we investigated the challenges users face when instructed to set up and run a remote VR user study on their own.

ABSTRACT

The availability of consumer-grade virtual reality (VR) devices allows user studies to be conducted remotely, that is in users’ homes. In this way, diverse populations can be reached and studies using virtual reality can be conducted in settings characterized by high ecologic validity. In this study (N=21) we investigate challenges participants face as they are required to set up and calibrate a virtual reality system in their home without assistance from experimenters. This allowed us to identify key reasons why participants struggle with this task. Our findings suggest that providing illustrative instructions and additional assistance on request can notably increase the success rate of setting up a VR environment for participating in a remote study. Interestingly, we also find that it is harder to recruit participants who do not have prior VR experience to participate in remote VR studies. We derive suggestions on how to support this task based on our findings.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

KEYWORDS

Virtual Reality, Remote User Study

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1 INTRODUCTION

Virtual Reality (VR) has become a powerful tool for researchers to study a broad variety of research questions. In particular settings that are difficult to explore in the real world can benefit from this approach. This includes settings putting users at risk (e.g., automotive research [5]), environments that are difficult to access (mountaineering [6], safety-critical areas [27]) or phenomena difficult to observe in the real world (e.g., shoulder surfing [1]).

While for many years such VR studies have primarily been conducted in lab settings, the availability of affordable, commercial VR systems has made it possible to move research beyond the lab, conducting what is commonly referred to as out-of-the-lab virtual reality studies [9, 16, 18]. This provides an ample opportunity to involve more diverse samples and larger numbers of participants. We expect these types of studies to become more popular among researchers in the future. It has already become a frequent practice as a result of the COVID-19 pandemic, which made it challenging for researchers around the globe to invite participants into research labs due to social distancing. In the future, we expect widespread usage of head mounted displays making it easier in some context to conduct out-of-the-lab studies.

Prior research so far has primarily focused on cases in which *participants own a VR headset*. Rivu et al. [15] investigated how many users own a VR headset and their demographics. The result show that such owners are generally rather young and tech savvy. While involving this target group avoids issues related to the setup of a VR environment, it limits research to this specific target group.

In our work we are interested in cases in which *participants do not own a VR headset* [25], allowing researchers to more broadly reach out to specific target groups and to specifically investigate VR research questions related to novice VR users. In such cases, one option is to ship the VR equipment to the users' homes [9]. However, setting up VR equipment may be challenging for users, in particular for older participants [2, 4] or less tech savvy users.

The objective of our work is to understand which challenges participants face as they are trying to set up a VR system and run VR applications on their own. Identifying and understanding these challenges is valuable as it allows researchers to better support VR novices in participating in future studies, in particular, during setting up the hardware and completing the study independently.

We conducted a study with 21 participants who were required to set up a VR system (HTC VIVE) and run a VR application using Unity. Most users successfully set up the hardware but struggled to follow lengthy instructions. In addition, many participants had difficulties in setting up tracking hardware and needed assistance for locating the VR HMD in the environment.

Our paper is beneficial for researchers who wish to conduct VR studies with remote participants where participants may be required to set up the study and participate without any assistance.

2 RELATED WORK

Using new technology is often difficult for users due to lack of familiarity [7] and complex interface design [21]. We review work investigating the challenges of adapting to VR technology and the challenges faced while participating in remote VR studies.

2.1 Challenges of Adapting VR Technology

Researchers looked at how novice users can be supported in adapting to VR technology. Syed-Abdul et al. investigated adaptation and acceptance of VR technology among older users [26]. Results show that older people generally perceive VR technology positively and find it useful. Silva et al. [20] provide a systematic literature review of the state of the art of virtual and augmented reality and applications for elderly users (60 years or more). They identified aspects that should be considered in VR experiments and applications, for example, using light equipment and accounting for mobility issues among older people. Reis et al. [14] provides a summary of usability problems of older people (55-65 years) in participating in user studies. In particular, they found that as people get older, perceptual and cognitive capabilities decrease, making it particularly important to design appropriate warnings. When designing virtual environments for the elderly, a particular focus should be on engagement, health, and safety.

2.2 Challenges of Remote VR Studies

Most prior remote studies were conducted in participants' homes using their own HMDs [13, 16, 17, 24]. Other out-of-lab studies include cases in which researchers setup VR settings in public spaces, recruiting participants on the spot [8, 28]. The latter approach slightly increases the chances of obtaining a more diverse sample but the equipment is still provided and setup by experimenters.

In 2017, Mottelson et al. [10] conducted a comparative VR study (in-the-lab and out-of-lab). For the out-of-lab sessions, participants were recruited who had to physically come to the lab to pick up Google Cardboard VR glasses. In this study, data from four participants were discarded. One participant failed to set it up properly, two faced control issues, and one took too long to complete the study. In 2021 Mottelson et al.[11] conducted an unsupervised remote VR study with participants who owned an HMD. This resulted in a gender imbalanced population. In this study, the authors focused on challenges such as mobility issues, lack of representative samples, and data collection.

Researchers have looked into challenges of remote VR studies using participant-owned hardware [23] and how research methodology has changed for remote studies [3, 22]. At the same time, there are only a few studies in which participants who do not own VR equipment had to set up a VR environment themselves. One example is the work of Siltanen et al. [19] who, as a result of the pandemic, had to conduct a study remotely with participants at home. Though their work did not focus on participants' ability to setup the environment, they report that instructions are an important part of such remote studies.

Summary. From our review of prior work we learn that remote VR studies are getting increasingly popular. Many such remote studies are designed to run unsupervised (i.e in the absence of the experimenter). But there is little knowledge about the challenges occurring as participants are asked to take part in a VR study all on their own. We provide the first investigation of such challenges,

specifically related to the setup of a VR environment and subsequently solving a task with it.

3 USER STUDY

We planned and carried out an observational user study to assess and comprehend the challenges users may face when provided with VR equipment to be set up on their own. Therefore, we delivered VR equipment to participants at home and asked them to (a) set up a VR system and (b) perform a remote VR user study.

3.1 Apparatus

We provided the participants an HTC Vive VR headset as packed by the manufacturer, a separate VR-ready Razer Blade laptop, a Logitech mouse, and a multi-outlet power strip. Besides the quick start guide that comes with the hardware box, we provided a physical copy of the detailed user guide[1].

3.2 Task

Participants had to accomplish a simple task in VR (see Figure 2). They were asked to use the VR controllers to build a virtual pyramid from orange cubes before ultimately throwing red balls and successfully destroying the pyramid again.

As previously mentioned, we did not provide an assembled and calibrated VR setup. Participants were allowed to browse the Internet and provided manuals to obtain additional information. They had to solve the task independently.

Figure 2: After successfully setting up the VR apparatus, participants experienced a VR environment where they were instructed to build and destroy a pyramid.

3.3 Study Procedure

To conduct the study, we visited the participants' households[2] and brought all required hardware. After welcoming the participants, we asked them to sign the consent form. Next, we collected their demographics as well as prior experience with VR. To video-record the sessions for post-hoc analysis, we set up a GoPro Hero 3+. We then introduced the participant to the study task. During the study, the experimenter was in a separate room and participants performed the tasks independently.

[1]https://developer.vive.com/documents/719/VIVE_Pro_HMD_User_Guide.pdf
[2]We followed all local hygiene protocols to ensure a safe environment for the study participants and experimenter

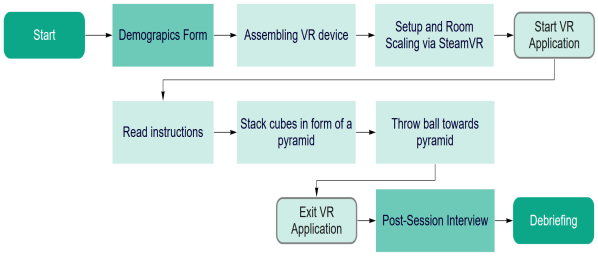

Figure 3: Study Procedure

After participants finished the task, we continued with semi-structured interviews. We used a smartphone to audio record the interviews for post-hoc analysis. We focused on the challenges they faced during the hardware setup and experiencing the VR application. Furthermore, we inquired about the manual quality, whether the provided manual was helpful, and whether they preferred assistance while setting up the hardware. We inquired how technology providers and researchers could make technology more accessible and usable. The study session lasted on average 55 minutes. The study procedure is illustrated in figure 3.

3.4 Limitation

We acknowledge the following limitation. We only tested one particular headset. However, the HTC Vive is among the most common headsets, hence well representing state-of-the-art VR headsets. In prior work, we have seen a few examples where low-weight cardboard VR glasses have been shipped to the participants which are easier to set up. Contrary to this, we used a high end VR apparatus with an external tracking system. Despite a high end system being harder to assemble, we chose this system because such equipment is still required when performing VR studies that need low latency, high precision, and resolution to ensure ecological validity. We also argue that our results are generalizable because not only do we observe challenges about the given hardware but also learn about participant behavior which can apply to different types of hardware. In addition, our study design is beneficial to aid researchers in understanding how to observe participant behavior in remote studies.

4 RESULTS

Based on the video recorded sessions, we collected quantitative data such as the time taken to install the hardware correctly. In addition, throughout the semi-structured interviews, we gathered qualitative data such as the experience of setting up a professional VR system, whether the provided manuals were understandable, and to what extent people are willing to participate in home-based VR studies in the future.

4.1 Subjects

We recruited 21 participants (7 female, 14 male) aged 30 to 61 ($M = 40.5, SD = 9.9$) via social media and using leaflets distributed in a local neighborhood. Ten participants had a high school degree,

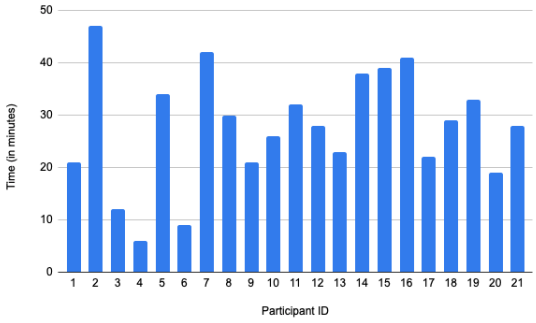

Figure 4: Participants' completion time of the task

eleven had a university degree (two B.Sc., nine M.Sc. or higher). Participants' professional backgrounds included business management, administration, information technology, social work, and sales. We also asked if participants had prior experience with VR. 16 replied they never used VR technology before, three of them used it once a month and two of them used it daily.

4.2 Overall Performance

Overall, 12 participants successfully assembled the hardware without assistance. Although we encouraged the participants to set up the hardware independently, six participants could not assemble the hardware. Participants required between 6 min and 47 min ($M = 27.6, SD = 10.9$), as shown in Figure 4. Notably, there was a visible difference between the participants (n=18) with limited technical experience ($M = 30.7, SD = 8.2$) and participants (n=3) who previously worked with VR technology ($M = 9, SD = 3$). Calculating t-test we get statistical significance with $p<0.05$. We have only collected task completion time for the hardware assembly and did not analyze the time taken to complete the VR task within the virtual world.

4.3 Strategy and Task Completion

We observed different strategies. Participants alternated between reading the provided manual and a trial and error approach.

Six participants attempted to set up the system without first consulting the manuals. Only when they could not find a suitable port for a specific cable or did not know what to do next, they consulted the manual. 12 participants attempted to successfully set up the system the other way around, where they initially took a rough idea from the manual and then carried out the assembly on their own. Only two participants strictly followed the instructions step by step. In total, 18 participants used the manual at least once. Three participants, who previously set up similar equipment, managed to complete the setup without consulting the manual at all.

4.4 Effect of Prior Knowledge

Participants who had a technical background found it easier to complete the task. Three participants had considerable experience with the setup and operation of VR devices. Thus, they carried out the setup job without consulting the manual in a very short time. In contrast, seven participants with just a little technical background expressed that they preferred to have someone at hand to help them with the task. 47 minutes was the longest time taken to set up the hardware by a participant who had no technical background and belonged in the age group of 61-65. In contrast, the shortest time taken was 6 minutes from a participant with a technical background and prior knowledge regarding VR devices.

4.5 Challenges

Overall, 12 participants managed to successfully assemble the VR hardware and were able to complete the final task in the virtual environment. All other participants (9) faced different challenges during the setup that are classified in Figure 5.

4.5.1 Manual. The majority of the participants (18 users) found the manual too extensive and complex, as it contains steps and descriptions that are not needed for the initial setup. Two participants took a brief look at the enclosed manual but, after a short time, decided that it was too extensive and confusing to comprehend; thus, they put the handbook aside. One of the main challenges for the participants was the abundance of information in the manual. Almost all participants (16 users) wanted a quick start guide with pictures and short, concise steps for assembly. P02 stated "*I was annoyed because of the long instructions that didn't show what I expected*", P04 stated, "*manual was not self-explanatory*". The quick guide that came with the hardware box contained images but did not provide text instruction thus was not very helpful to the participants.

4.5.2 Hardware Assembly. One challenge was the large number of cables involved. Users were confused about the different functions of each specific cable and where each cable must be plugged. P03 stated, "*At first it was very frustrating, where does it go - cables and how does it even start*", P15 stated, "*AC plug, didn't fit the hub, didn't know where the cable went*". Six participants incorrectly connected the cables. In addition, some participants expressed that they were afraid of tripping over a cable when using the headset.

Some participants were confused about the placement of the lighthouses. Some of them did not know exactly how to place the lighthouses. Many did not understand the precise instruction of placing the lighthouses diagonally and how that helps the setup. Few were unsure if the lighthouses would work because of a missing power switch or because they did not see the power light on the front. Two participants misplaced the lighthouses. Therefore, they could not transmit a signal. The button to turn on the controller was not found by some participants.

4.5.3 Launching Application. After the successful connection and mounting of the hardware, a room survey should be carried out. For this, the user had to log in to Steam and the SteamVR application should be started. The application window was sometimes overlooked by the participants, just like the associated burger menu to start the "Room measurement" option. For a few participants, it was not clear that the menu had to be opened to start the room survey.

4.5.4 Interaction in Virtual Environment. Some asked the experimenter to show how to switch on the controller. When first using the controller to throw the ball, some participants struggled to find the right point of time to release the grip button to release the ball.

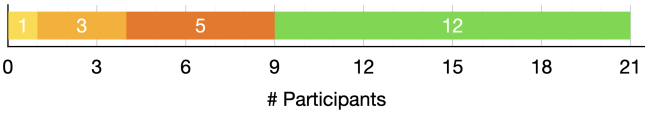

Figure 5: Participants faced different challenges during the setup. They either ■ mounted the base stations incorrectly, ■ did not know how to proceed, or ■ connected the cables falsely. Twelve participants ■ successfully completed the setup.

Two participants who never used VR technology before were afraid of getting hit by the ball in VR. Three participants were afraid of moving around because of limited physical space in the room.

5 DISCUSSION

There is still a research gap in exploring how feasible it is for users to set up a VR system independently to run VR applications and how this will scale if we recruit participants for VR studies who do not own HMDs. Identifying the difficulties would help researchers provide systematic guidance to participants who need help in setup. This would likely lead to greater remote VR participation. We believe, if we are not limited to only recruiting participants who own a VR device, we have a greater chance of obtaining a more diverse population. Currently, most remote VR studies conducted suffer from similar limitations. Examples of such limitations include a small sample size [11, 16, 17] and gender imbalance [11, 15, 16]. We believe obtaining a better representation of the population would help researchers get a more accurate outcome of the study. For example, Peck et al. [12] discuss the negative implications of conducting experiments on non-representative samples.

We found that almost all participants were eager to try out the VR system, even if they had little prior experience. The time taken for each participant to complete the initial setup varied greatly. Previous experience and knowledge affected the task completion time. Interestingly, all participants found it much harder to set up the apparatus itself than interacting in the virtual environment using a new input concept, e.g., handheld VR controllers. Our findings also show that some challenges are specific to the hardware used, therefore we find great opportunity for further research on how to provide instruction manuals that would enhance UX. We tested only one VR system but our findings are likely to affect users from similar VR-HMD systems. For future work, we would like to conduct further evaluation to compare different systems existing in the industry to obtain a comprehensive understanding of the issues participants may face. In addition, we would conduct comparative analysis between novice and expert VR users to understand how this affects performance among participants in general.

5.1 Willingness to Participate

Rivu et al. [15] conducted a survey among VR HMD owners asking their willingness to participate in user studies. Their results show that 67% agreed or strongly agreed to be willing to participate in VR studies. Unlike prior results, we had difficulty in recruiting participants. During the recruitment phase of the study, we reached out to many potential users. In this stage, we explained the user study and the task requirement briefly in the recruitment post. Surprisingly, many of the potential users declined to participate, thinking they were not tech-savvy enough or would not be able to complete the task.

We believe our experience was different from the mentioned prior work because in the published survey only HMD owners were surveyed, who are assumed to have prior experience with setting up VR systems. The difficulty we faced in recruitment indicates an inhibition threshold that the participants have to overcome in order to deal with such a new technology or to participate in technical studies. We find this interesting that non HMD owners may be unwilling to participate in remote VR studies. If researchers wish to recruit a large sample of non HMD owners for remote participation, sufficient time must be allocated for the recruitment phase.

5.2 Data Collection

Conducting out-of-the-lab studies in general are more limited than lab studies as the key concern is valid data collection. Though conducting out-of-the-lab studies allows us to reach a wider audience, data collection is still an open challenge for such studies. There may be error in data collection due to incorrect setting of the hardware. In our study, participants found it more challenging to set up the hardware than to use the application. Most of the participants didn't assemble a VR device before. The detailed handbook can be helpful if the user has time and the motivation to get to know the VR device in a detailed way. It's possible to assemble the hardware only with the handbook, but the user has to search for the first steps and know what to look for; otherwise, it will take time. Two participants even looked up at the internet for a shorter way to assemble the hardware and found a quick start guide that was used to fulfill the task. Challenges with incorrect setup may aggravate if studies require the use of additional hardware such as thermal cameras or electrodes.

5.3 Recommendations

Our exploratory study is the first step towards comprehending challenges faced by the participants. Based on our findings we provide the following recommendations for recruiting participants without affinity towards VR technology.

Provide concise instructions for the participants: We identified three different strategies followed by our participants, 1. strictly following manual, 2. trial and error approach and 3. taking brief overlook at the manual. Based on these, we can expect that in any setup, participants are likely to use different strategies. Researchers can either provide a simple illustrative manual or a short video showing how to setup the system. Manuals should have easy steps so that even if some participants use the manual from mid setup, they can get the assistance they need.

Expect participants to need additional assistance: Despite providing additional resources, expect participants to nevertheless require assistance. This may be true when the system has a complicated procedure such as having too many cables, complicated set up of HMD trackers or use of additional hardware. Even when we are using lightweight HMDs with easy instructions for setup, we should expect participants to need additional assistance. This is primarily

because different participants may employ different strategies and this is not coupled with a specific hardware. As seen in our study, many participants preferred to simply skip reading the instructions and opt for a trial and error approach. In such cases, even simple setup cannot be completed if participants do not read the manual and prefer to ask for assistance.

There are many forms of out-of-the-lab studies. A remote semi-supervised study may include an experimenter digitally present to assist in hardware assembly. In such studies, considerations need to be made to arrange a time when both the experimenter and participant can be connected. Semi-supervised study may not be feasible in many cases. For example, in the remote study conducted by Rivu et al. [16] in Rec Room, the experimenter had difficulty connecting to participants who live in different time zones. This primarily meant that the experimenter had to conduct studies in the time frame of 2-4am in the morning in the local time zone of the experimenter. When it is difficult for the experimenter to be present real-time, it is even more important to understand the potential participants and their ability to participate asynchronously.

A fully independent study without the experimenter would require participants setting up the hardware themselves. All pain points of assembling hardware must be detected to provide a positive user experience. If researchers wish to conduct unsupervised studies, one must plan ahead on how to assist participants if required. We suggest that experimenter should provide a video instruction simply showing a step by step guide of assembling the hardware. There should also be validation feedback for the participants to acknowledge that the hardware have been correctly assembled. To the best of our knowledge, all prior work advises how to help in hardware assembly with synchronous help from experimenter. We suggest that asynchronous help should be available to participants.

Be aware of participants when designing the virtual environment: In addition to requiring assistance for the hardware assembly, participants may also face difficulties within the virtual environment. As seen in our study, many participants were afraid of being hit by the virtual ball. This may be true for many first time users. When conducting a study, the sample size will not only contain expert VR users but also may include first time users and therefore researchers must be aware of this when designing the virtual environment. In addition, participants were afraid to move around due to fear of getting hit by furniture. Researchers must be aware that participants will be conducting studies at home, where they are likely to have limited space for movement. Any tasks in the virtual environment should be designed accordingly.

6 CONCLUSION

We argue that recruiting participants for remote Virtual Reality (VR) studies who do not own a head-mounted display is beneficial in obtaining a more diverse sample population. However, when conducting remote studies without the experimenter present, a participant has a greater active role in the study, such as setting up the hardware. Thus, we investigated the challenges of setting up a VR system and launching a VR application from a participant's perspective. We conducted an exploratory in-home user study with 21 participants where participants were required to set up, calibrate and run a VR apparatus on their own. Results from our study show that prior VR experience has an effect on the time taken to set up a hardware. We also found that many participants find long instructions difficult to follow and different participants use different strategies. Based on our findings, we provide a set of recommendations for researchers conducting remote supervised and unsupervised studies. We believe our findings will help researchers recruit participants not only with prior VR experience but also participants who do not own HMDs or have prior experience with VR.

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