Socially Distanced: Have user evaluation methods for Immersive Technologies changed during the COVID-19 pandemic?

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Abstract

Since the emergence of COVID-19 in late 2019, there has been a significant disturbance in human-to-human interaction that has changed the way we conduct user studies in the field of Human-Computer Interaction (HCI), especially for extended (augmented, mixed, and virtual) reality (XR). To uncover how XR research has adapted throughout the pandemic, this paper presents a review of user study methodology adaptations from a corpus of 951 papers. This corpus of papers covers CORE 2021 A* published conference submissions, from Q2 2020 through to Q1 2021 (IEEE ISMAR, ACM CHI, IEEE VR). The review highlights how methodologies were changed and reported; sparking discussions surrounding how methods should be conveyed and to what extent research should be contextualised, by drawing on external topical factors such as COVID-19, to maximise usefulness and perspective for future studies. We provide a set of initial guidelines based on our findings, posing key considerations for researchers when reporting on user studies during uncertain and unprecedented times.

Index Terms: Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods—User studies

1 Introduction

The COVID-19 pandemic has had a remarkable impact on human-to-human interaction, changing the way we work and interact [56]. Communities from all walks of life have been forced to adapt their strategies and behaviours, to ensure the safety and well-being of our societies. This, in turn, has affected how research is conducted in the field of Human-Computer Interaction (HCI); particularly surrounding user studies with extended reality (XR) technologies. COVID-19 has caused a suspension of studies across the globe, researchers reporting an overall drop in the number of studies being conducted, with no clarity on how long suspensions would last [46].

As studies surrounding XR are predominantly conducted in a controlled environment, and require novel, non-ubiquitous hardware and software; notably wearables like head-mounted displays [56], the procedures that are needed to ensure health and safety are arguably more complex to implement, ethically questionable and practically difficult in many locales [50]. This is emphasized by a survey conducted in response to the pandemic [46], which further highlights the uncertainty that COVID-19 has presented for user experience researchers; many revealing they were unsure on how to make XR equipment sharing safe, or how to make facilities suitable for testing.

With the knowledge that COVID-19 has forced change, we seek to understand how researchers have adapted and reported their methods throughout the pandemic. Consequently, a corpus of 951 papers were considered from A* ranked conferences, 250 of which included a user study. These 250 papers were reviewed based on the technologies used, number of participants, the type of studies included (co-located or remote), the state of ethical approval and the details included surrounding COVID-19. By considering these factors and using the same events from 2019 as a baseline, this review provides an insight into how research has been able to continue, whilst highlighting to what extent study adaptations were reported throughout the pandemic.

2 Method

The methods that were applied to filter, collect, and prepare the data for analysis are further defined in the following subsections.

2.1 Data Collection

A sample of papers were collated from CORE[1] 2021 A* ranked conferences relevant to immersive technologies. We selected A* conferences with submission deadlines in 2020, during the COVID-19 pandemic, thus IEEE ISMAR'20 (May 18th 2020, Q2), ACM CHI'21 (September 17th 2020, Q3) and IEEE VR'21 (November 13th 2020, Q3) were included. For ACM CHI, the papers were scanned based on Title and Abstract, to select those related to AR/VR technologies. For IEEE ISMAR and IEEE VR, full papers and journal tracks were included within the sample. AR/VR submissions that did not include a user study were excluded from the sample. Where Abstracts were ambiguous, the paper was searched for key words such as 'participant', 'user' and 'study'. As a baseline, we reviewed the same three conferences for 2019 following the same methods, notably considering the study type (remote or in person), state of ethical approval and number of participants.

2.2 Data Analysis

After screening the papers, information was captured based on the following factors (each conference coded within a separate matrix):

- **Study Type:** Studies were classified as *remote* when conducted with no test instructor present in the same physical location and *local*, when directly supervised by an instructor (co-located).
- **COVID-19 Considerations:** If methodology and/or protocol related adaptations were considered, and implemented due to COVID-19, they were noted and reported.
- **Ethical Approval:** If the paper stated that the study had been subject to some form of ethical review process, i.e. gained IRB (Institutional Review Board) approval, we noted and discussed the details provided.
- **Participants:** The number of participants was calculated as the total number of users recruited in the paper. If the study was composed of an initial pilot study and a user evaluation, or multiple user studies, the total number of participants of all studies combined was considered.

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[1] http://portal.core.edu.au/conf-ranks/

- **Studies Conducted Prior to COVID-19:** If the paper stated when the data was collected, or the date that the study took place, we captured this information and reported on it.

3 Analysis

This section provides a summary of the data captured and highlights the trends that were identified, drawing on key examples of study methods and adaptations. In total, 951 papers published during the pandemic were considered for review (Q2=87, Q3=746, Q4=118), as well as 880 in the baseline sample from 2019 (Q1=49, Q2=703, Q3=128). Of the papers published during COVID-19, 701 were excluded as they 1) did not focus on XR technologies (N=642) and 2) not include a user study (N=59; Q2=24, Q3=12, Q4=23). In total, 250 papers that focused on XR and included a user study were highlighted for further review. Using the same exclusion criteria, 207 accepted submissions were also assessed from the 2019 conferences.

3.1 Study Type: Remote vs Local

When considering Q2 submissions, few papers (N=3) implemented studies remotely, with 2 separate papers reporting on mixed-method approaches; conducting both a co-located and remote study. These studies were based on understanding emotional and/or psychological factors, by presenting video clips or scenes to participants and asking them to provide subjective responses (i.e. based on perception [7, 14, 34]). Data was collated via ratings on industry-standard questionnaires, such as Likert-scales [7,34,65], or through delivering a personalised application where input (i.e selection data [14]) was captured. Video conferencing software was also used to stream live images and communicate with participants [34], with some studies opting for a more scripted, web-based approach [7, 65]. Although there were variations in the procedures, hardware and software employed, these methods were common with remote studies across the 3 quartiles.

Even though the majority of studies conducted during Q3 were co-located (N=60), three papers reported on studies that used a mixed-methods approach, and a substantial increase in remote studies was found when compared to Q2 (N=25). One of these papers reported to deliver specialist equipment to participants, for synchronous, remote communication whilst flying drones [49]. The remaining studies employed participants with access to equipment, which; for the most part (N=14), involved desktop-based set ups. Several studies (N=6) recruited participants with access to HMDs, with 3 studies requiring mobile equipment (tablet or smartphone). A single study allowed participants to use any of these devices [66].

Desktop-based remote studies in Q3 were notably made up of perception studies [16,57], surveys [39,59,68], walkthroughs [13,42] and interviews with experts [8, 20, 59] and/or amateurs [42, 49]; as well as one distributed elicitation study [2]. Similar to Q1, studies that used mobile technologies (HMD, phone or tablet) were generally web based [15, 57], or required the user to download an application [44, 50].

In Q4, only a single method applied both a lab-based and remote study [10]. Studies were again predominantly co-located (N=53), with 16 papers reporting on remote studies. These remote studies predominantly involved participants with access to personal equipment; with 8 methodologies reporting to use head-worn displays, and 8 desktop-based set ups. The mixed-methods study [10] employed a monitor-based set up for the lab-based elicitation, and researchers delivered google cardboard headsets to participants for the remote study. As well as using participants who owned equipment, 2 of the studies testing with HMD owners also provided some participants with headsets [23, 36]. Equipment was also provided to participants in 3 other papers to aid with remote testing. Again, remote studies were mostly made up of perception studies [6, 47], surveys [30, 36, 61], task-based applications [58, 61] and interview/walkthrough-based video-conferencing sessions [10, 23].

3.2 COVID-19 Considerations: Reported vs Not Stated

For submissions in Q2, 6 papers including user studies explicitly stated method adaptations. Do et al. [14] explained that the pandemic forced them to deliver a remote study, and Krosl et al. [34] had to quickly implement a mixed-methods approach; as their planned lab-based testing had to stop prematurely. 3 other papers conducting co-located studies also stated that testing had to end abruptly due to COVID-19 [3, 19, 28], however researchers did not conduct supplementary studies. Although the study presented by Gesslein et al. [22] was directed in lab, the authors noted that choices for the experimental designs were influenced and limited by institutional COVID restrictions. A total of 40 papers did not state any changes in relation to the pandemic, or whether procedures received ethical approval.

In Q3, authors referenced adaptations in response to the pandemic in 13 co-located studies; as well as in the methods for 16 remote studies. There were 45 studies that did not report on any adaptations, or state ethical approval. The lab-based studies notably reported adaptions surrounding recruiting participants (N=5) and hygienic measures (N=9); i.e. providing personal protective equipment (PPE) such as face masks, sanitizer, cleaning wipes, latex gloves and single-use VR Eye mask coverings [45], or introducing three-day quarantine periods for AR/VR equipment [33]. There were also reports of changes to equipment and/or procedures. This included not using headphones for audio output and scheduling sessions at least a day apart [4], or adapting the primary measure in order to ensure social distancing [45]. In one study [31], all experiments were performed in the two first authors' homes, and by the authors only, due to logistic constraints caused by the pandemic. For remote studies during Q3, researchers most commonly justified their methods by referring to current restrictions in place; meaning they had limited accessibility to shared facilities, equipment and users [37, 42], and had to adhere to COVID safety measures [8, 26, 37].

Of the 95 papers considered in Q4, there were 17 lab-based studies that stated adaptations, as well as 10 remote studies. Much in line with Q3, 41 studies did not report on any adaptations due to COVID-19 or state ethical approval. Where changes to methodologies were highlighted, they were again predominantly based on factors surrounding participants (N=8), and hygiene/ disinfection protocols (N=8), with another study waiting 72 hours between sessions to provide HMDs [18].

Corresponding to Q3, equipment and procedures during Q4 were adapted to fulfill safety requirements. For example, when exploring proxemics, Medeiros et al. [41] recorded movement scripts as opposed to using real people as bystanders. As well as this, Englmeier et al. [17] were limited by the time allowed for the study (30 minutes), leading them to reduce the number of experimental conditions and opt for a shorter questionnaire.

Given the constraints following COVID-19 testing protocols, Gagnon et al. [21] were unable to calibrate or make adjustments to their HMD system for individual participants. In one study [52], researchers also delivered instructions from a separate room via loudspeaker, adapting the hardware set up to comply with regulations.

3.3 Ethical Approval

Out of the 63 papers reviewed in Q2, 20 explicitly stated that they received ethical approval; 2 papers being those reporting on mixed-method approaches. This number was slightly less during Q3 (N= 18). Of these 18 approved studies, 4 were remote; 2 of which explicitly stated ethical approval and method adaptations due to the pandemic, as well as four of the 13 lab-based studies. Likewise, many papers failed to explain whether studies received ethical approval in light of the pandemic within Q4. There were a total of 30 papers found to report on formal ethical approval, 4 of which were remote studies. 7 studies (Remote=3) reported on adapting methods, as well as attaining ethical approval.

3.4 Participants

In Q2 (IEEE ISMAR'20), the 63 papers including a user evaluation had an average number of 31.70 (SD=21.39) participants. In ISMAR'19, 37 user evaluations were accepted, the average number of participants being 37.19 (SD=34.15). Out of the 63 user evaluations accepted in 2020, 3 were conducted remotely, with an average number of 63.33 participants (SD=43.65). Two studies employed mixed methods approaches with a mean value of 27.50 participants (SD=31.81). The remaining 58 studies were co-located, with an average of 30.09 participants (SD=19.00). For the 20 studies reporting IRB approval, the average was 32.31 participants (SD=14.37).

Of the accepted submissions in Q3 (ACM CHI'21), 92 papers included some form of user evaluation, with an average number of 55.89 participants (SD=149.35). This compares to ACM CHI'19 where 106 user studies were gathered, with an average number of 35.41 participants (SD=29.72). 28 out of the 92 papers accepted in 2020 included a remote evaluation, with an average number of 126.92 participants (SD=264.65). This is a notable increase from CHI'19, where only 3 XR user evaluations included a remote study. The 32 papers reporting some form of COVID adaptation had an average number of 26.87 participants (SD=29.12), with the 18 studies reporting IRB approval averaging 52.70 participants (SD=29.87).

In Q4 (IEEE VR'21), 95 of the papers included showcased some form of user evaluation, with an average number of 44.15 participants (SD=69.62). This compares to the 106 user studies accepted in IEEE VR'19, with an average number of 35.42 participants (SD=29.72). 16 out of the 97 papers were remote studies, with an average number of 25.58 participants (SD=157.22); an increase from IEEE VR'19, where only 1 user evaluation was conducted remotely. The 27 studies reporting some form of COVID adaptation had an average number of 55.45 participants (SD=62.36), with the 30 studies reporting IRB approval averaging 37.03 (SD=70.65).

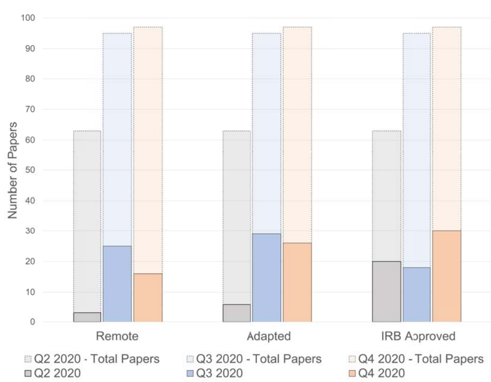

Figure 1: A representation of papers by category, showcasing number of accepted papers reporting remote, adapted and IRB approved studies against the total number of user evaluation studies accepted.

3.5 Studies Conducted Prior to COVID-19

The number of papers stating that studies were conducted prior to COVID-19 for Q2, Q3 and Q4 were 1, 5, 5, respectively; with 1 paper from Q4 stating IRB approval.

4 Discussion

This paper has reviewed 951 accepted papers related to user evaluation for immersive technologies, from CORE 2021 A* conferences during the pandemic, uncovering to what extent researchers have modified their experiments. The primary findings presented within our analysis are further discussed in the following subsections.

4.1 Study Type: Remote vs Local

When comparing the number of remote studies conducted before and during COVID-19, it becomes clear that a primary tool utilised to continue user studies was online mediums. In response to the pandemic, online tools have recently been developed to consolidate XR study participant recruitment; such as the XR Distributed Research Network [50], which; as well as online communications like audio and video broadcasting platforms [10,62], have been employed to effectively deliver studies remotely. Experiments were delivered both with [14, 37] and without [51] AR/VR equipment. Studies were predominantly made up of perception studies [6,47], surveys [30,36,61], task-based applications [58, 61] and interview/walkthrough-based video-conferencing sessions [10, 23], which were most often conducted to justify, or inform the design of an application or system. Studies which required participants to explicitly interact with an application often captured input data, i.e. through logging the values of HMD sensors [50, 66], or selection decisions in a handheld AR environment [14].

As previously discussed, remote studies were found to be ideal for running studies with a large sample of participants [25, 39]. One reason for this is because remote experiments can effectively be conducted without researcher supervision [24, 58]. This is arguably beneficial for both participant and experimenter, as participants are able to conduct the study at their own leisure [58], and researchers are not required to oversee each study.

Although software was sometimes used to screen device specifications [54], participants were often asked to conduct the experiment under controlled conditions, i.e. standing in a room without distractions [58], or using a monitor of a certain size [12]. However, if experimenters were not present to observe participants, these requests could not be enforced. Therefore, although remote studies have proven to be a reasonable alternative to lab-based studies, sessions could be more difficult to moderate; especially when researchers are not screening and overseeing sessions [30].

Participants were found to be less committed during remote studies when compared to co-located sessions [39]. Consequently, it should either be ensured that participant screening is robust and effectively removes any compromising data [30], or that users are walked through remotely and moderated via video-conferencing software; using tools such as screen sharing with remote mouse control [20]. Online platforms that were commonly utilised included Crowdlicit [2], Prolific [39, 48], Mechanical Turk [15, 47], Zoom [10, 42], social media sites such as Reddit [37] and web-based Unity applications [51] or simulations [37, 57].

4.2 COVID-19 Considerations: Reported vs Not Stated

Where adaptations were reported they were predominantly in relation to the participants involved [63, 67], the space used [52, 62], equipment employed [52, 61], the procedure (i.e. the distribution of testing sessions [60] and hygienic practices [18, 33] over a specified period of time) and the type of study; whether it was adapted to meet health and safety guidelines in lab [41, 60], or altered to be conducted remotely due to COVID-19 [20, 64]. There were a few notable papers that researchers used to inform adaptations. The most common was that of Steed et al. [56], which outlines the steps required to provide community support for distributed experiments in response to COVID-19. Hygiene measures implemented in previous experiments were also referred to by Kocur et al. [33], whereas others followed local government/institutional guidelines [**?**,27]. When noting adaptations to lab-based user studies, some papers also referred to their local infection rates to justify their approaches [4, 43].

Due to limitations surrounding COVID-19, some researchers opted to use VR technologies to simulate AR experiences [26], with Schott et al. [52] unable to test their AR set up with multiple users.

Although it can be assumed that the increase of remote studies is due to the pandemic, many did not explicitly state adaptations in relation to COVID-19, meaning this is not conclusive. The lack of clarity has made it difficult to understand the methods some researchers followed to make studies COVID compliant. However, based on figures that show participants in PPE [53, 68], and some researchers using the pandemic as justification [32], several papers suggest that adjustments were made for any restrictions in place.

4.3 Ethical Approval

Many papers did not state formal ethical approval. Although it could be assumed standard in the field of HCI, it is arguably important to note this information, especially during abnormal periods. Whereas some papers provided detailed information of their ethical approval, as well as the adaptations required [17], many did not mention the procedure. In some cases, researchers stated that guidelines were followed but did not give further details [45], others briefly mentioned acting based on human research protection protocols; however referring to standard principles such as informed consent [29].

Although it is likely that many studies were following ethical guidelines at their institutions, with some methods and figures indicating that COVID-safe practices were implemented [32, 68], it could be argued that approval status is as important as other details reported as standard; such as participant demographics and the equipment involved, yet it is a detail that was often disregarded.

4.4 Participants

When considering the number of participants included across the assessed quartiles, the samples used for remote studies were substantially larger than included for co-located studies. This was emphasized by several papers reporting on lab-based studies, which stated that; due to COVID-19, they experienced difficulties either accessing a specific group of participants e.g. over a certain age [67], a varied range of participants [40], or a large number of participants [11, 40, 63]. Some researchers resorted to conducting their studies amongst themselves [31] or with colleagues in their institute [9]; as they were unable to recruit external users.

In several remote studies, participants were also restricted based on the hardware they owned. For example, in an online study conducted using Unity WebGL3 (with desktop-only set-ups), to simulate AR visualisations on virtual globes, hardware screening criterion was used to ensure memory requirements [51]. Similarly, for HMD based studies, technical parameters of participants personal devices were screened [5, 24, 35]. For example, Lilija et al. [35] quality checked personal Oculus Quest headsets for tracking fidelity, using jitter as a proxy for quality.

Despite researchers sometimes conducting studies across multiple AR/VR headset platforms, with Marrinan and Papka [38] developing a WEB-XR application capable of running on all HMDs with a compatible browser, in many instances, recruiting methods were restricted to a single device. For example, HMD-based studies were often limited to Oculus HMDs [5,35,44,58], or; on a single occasion, a Magic Leap One [36]). Although limiting and screening participants personal devices will likely improve accuracy and consistency of the data captured, it may also reduce the number and variation of participants that can be included in the study.

Other studies chose to widen their sample pool by delivering equipment to their participants [10]. For example, as opposed to targeting drone-owners, Sabet et al. [49] opted to recruit users with no experience; by providing them with the hardware required. Although such methods are often impractical, especially when COVID-19 restrictions are in place with limited access to lab equipment [46, 55]; or due to the cost of AR/VR hardware [61], providing users with devices or targeting non-crowdsourced participants, is likely a preferable approach; especially if an in-depth user study is desired.

Even though remote methodologies were found to provide an effective way to conduct large-scale user studies [39], with opportunities to recruit a wide range, or a targeted group of participants [56], some researchers highlighted the dishonesty [30] and lack of effort [39] that can be experienced when testing with crowdsourced participants; emphasising the importance of filtering responses [30, 39]. Ensuring participants are legitimate and committed is key when conducting remote user studies; with dishonesty found to be higher among Amazon Mechanical Turk participants [30].

As well as effective participant screening methods, when testing with equipment owners remotely, it is also important to understand the factors being assessed and how familiarity with these devices may skew results. For example, when measuring discomfort in VR with frequent HMD users, Hirzle et al. [25] note that the chosen sample may have led to a lower overall increase in symptom values. On the other hand, it could be argued that the 'in the wild' nature of remote methods may make the results more valid, as they are capturing data within a more realistic environment, with those who are already using the targeted technologies [44].

4.5 Studies Conducted Prior to COVID-19

A small percentage of papers were found to explicitly state that studies were conducted prior to the pandemic (N=11). As many papers did not state any adaptations, ethical approval or the date that the study was conducted, it is difficult to ascertain whether more studies were using data captured prior to COVID-19. As we found a study conducted in 2018 being reported in conference proceedings published in 2021 [1], it could be argued that failing to provide a date for when the study was conducted could be misleading, especially if it was not conducted directly before a submission deadline. The lack of information makes it difficult to contextualise the work; not only surrounding COVID-19, but also for factors such as the technologies (hardware/software) available at the time of the study.

5 Conclusions

Overall, we found that remote studies have become more prevalent during COVID-19 and that a range of adaptations have been applied to co-located methodologies to make them compliant. Despite this, many studies still failed to make reference to any changes in methods, provide information on ethical approval, or the date that the study was conducted. Although it is not always a requirement for researchers to state adaptations in their papers, and it could be assumed from some papers that adaptations were in place to ensure health and safety, i.e. from figures and descriptions provided, methodologies would be further contextualised; and more valid and reliable, if study details and adaptations were explicitly highlighted and discussed.

5.1 Guidelines

Based on our findings, we provide the following initial guidelines to consider when reporting on methodologies; especially during influential topical events such as COVID-19. If planning on conducting a study remotely, key considerations include;

- **Moderated or unmoderated studies:** Although remote studies can effectively be conducted without experimenter supervision, this limits the data that can be captured and makes it difficult to ensure suitable testing conditions.

- **Screening/limiting personal devices:** Although this will likely improve accuracy and consistency of data, it may also reduce the number and variation of participants eligible.

- **Crowdsourcing platforms:** Even though crowdsourcing platforms provide scope for large-scale user studies, some researchers highlighted the dishonesty and lack of effort from participants. Therefore, if opting for this method, extra screening measures should be carried out to ensure reliability.

If planning on conducting a lab-based study:

- **Explicitly stating adaptations:** If the study has been tailored to meet demands of external factors i.e. incorporating additional hygiene practices and/or adapting apparatus and procedures, state original plans and how they have been changed. This will provide the reader with context and could spark ideas on how to adapt future studies.
- **Study date:** State the date in which data was captured. This provides context and eradicates doubt, especially when considering the methods applied in times of change or uncertainty.

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