Wang, P., & Bailenson, J. (in press). Virtual reality as a research tool. In T. Reimer, L. van Swol., & A. Florack (Eds.), *The Routledge Handbook of Communication and Social Cognition.* New York, NY: Routledge/Taylor and Francis.

Virtual reality as a research tool

Portia Wang
Stanford University
Stanford, CA
Email: portiaw@stanford.edu

Jeremy N. Bailenson
Stanford University
Stanford, CA
Email: bailenso@stanford.edu

*** To appear in T. Reimer, L. van Swol., & A. Florack (Eds.), *The Routledge Handbook of Communication and Social Cognition* ***

Abstract

This chapter provides an overview of the research possibilities of studying social cognition and communication using virtual environments. We begin by giving an overview of the related technology, specifically the hardware and software used to develop and support virtual reality (VR) experiences. Then, we review and contextualize three methodological problems of experimental social psychology outlined by Blascovich and colleagues in 2002, namely the experimental control-mundane realism trade-off, lack of replication, and the use of nonrepresentative samples, and specifically focus on how VR can mitigate the three problems. We next give examples of research topics social scientists have studied using the framework provided by Fox and colleagues' 2009 work. We then lay out the current landscape of large-scale virtual reality studies with a review of 34 studies, focusing on their setting, recruitment methods and implementations of the VR experiences. Finally, we discuss implications for future research.

Introduction

Virtual reality (VR) has the ability to transport users to immersive environments, potentially with the presence of others. The introduction of commercial hardware such as the Meta Oculus Quest 2 and the Apple Vision Pro and social VR platforms such as ENGAGE, RecRoom, Horizon Worlds, and VRChat accelerated adoption of this technology, and further opened up novel opportunities for social science research (Jonas et al., 2019). By leveraging this immersive medium, research scientists can place study participants into highly controllable and customizable virtual worlds, where their interactions with the space and other individuals can be recorded and later analyzed in great detail.

One possibility VR enables is large-scale user studies beyond the physical confines of lab spaces. For example, researchers were able to leverage portable and commercially available VR devices to set up studies in high school classrooms (Makransky et al., 2021), ship headsets to individual students to investigate longitudinal VR usage in university courses (Han et al., 2023), and administer experiences remotely without supervision through recruiting participants with existing VR equipment (Huber & Gajos, 2020; Mottelson et al., 2021). The portability of VR setups allowed some of these studies to be conveniently administered at locations frequented by the target demographics, while the ability to facilitate controllable and repeatable immersive experiences further helped researchers run multiples subjects in parallel without compromising the quality of the study and its data. These benefits of using VR as a research tool are echoed by a growing body of social science research in VR and are topics we will examine throughout the chapter.

In this chapter, we provide an overview of the research possibilities of studying social cognition and communication using virtual environments. We begin by giving an overview of the related technology, specifically the hardware and software used to develop and support VR experiences. Then, we review and contextualize three methodological problems of experimental social psychology, namely the experimental control-mundane realism trade-off, lack of replication, and the use of nonrepresentative samples, outlined by Blascovich and colleagues (2002), focusing on how VR can mitigate the three problems. We next give examples of research topics social scientists have studied using the framework provided by Fox and colleagues (2009). We then lay out the current landscape of large-scale virtual reality studies with a review of 34 studies published after 2015 with at least 100 participants, focusing on their setting, recruitment methods and implementations of the VR experiences. Finally, we discuss implications for future research.

Technology Overview

VR experiences are immersive, in that users tend to respond in similar ways to virtual stimuli than they do to real stimuli, and are also fairly portable and shareable once built given the content is digital and the hardware is readily available. The hardware typically includes a head-mounted display (HMD) worn by a user or a stereoscopic display device that renders content in 3D. Additionally, hand-held controllers or devices for stimulating modalities such as haptic feedback are often used to complement the visual sensory experience. The software component is responsible for rendering the virtual environments, simulating interactions, and updating the user's viewpoints, gestures, and other body movements within the VR experience. Collectively, the two facilitate a cycle of three key technical elements. The first of which is tracking, where fine-grained movements of head and hands are typically recorded through the headset, controllers, and external tracking systems. The second element is rendering, which refers to constantly regenerating the immersive content after taking into account user movement and actions (e.g., head tilt, controller actions). The final element is display, where the hardware such as the headset or projection screens is used to display the content that the user reacts to, oftentimes accompanied by spatialized audio from speakers.

Another categorization breaks down VR systems into PC-based VR and standalone VR. While PC-based VR refers to systems that are tethered to personal computers and rely on their computational power and other sensors such as motion trackers and camera systems to track and render the virtual experiences, standalone VR systems are self-contained units that integrate all the necessary hardware for tracking, rendering and display to provide the immersive experiences. As typically wireless and more consumer-friendly, standalone VR tends to have lower processing power, quality of graphics, and precision of tracking when compared to PC-based VR.

Relatedly, there are two trends in the recent development of VR technologies that are helping transform the research landscape for social scientists. The first is the proliferation of standalone commercial VR headsets. Because standalone headsets are more portable, researchers can administer studies in locations outside their laboratories, for example in public spaces such as museums, schools, and hospitals. They may also conduct remote user studies by shipping the headset and controllers to individual participants and having them complete the study in the comfort of their homes. Given the low cost of these commercially available standalone headsets, researchers may also recruit from the increasing pool of participants who already own headsets, and run studies by sharing the VR programs needed to complete the study. The increasing affordability of VR setups presents another advantage as researchers can purchase and use a large number of VR systems (e.g., hundreds instead of handfuls of headsets given historically traditional sized budgets for VR projects), and run large-scale studies where participants are interacting with others synchronously.

The second trend revolves around the development of social VR software. Popular social VR software such as VRChat and ENGAGE allow users to create personalizable avatars, embody them, and finally interact with others in high-customizable virtual environments. This software lowers the technical barriers and cost for designing and executing social psychology experiments in VR and further opens up the possibility of conducting remote experiments with participants who own hardware that is compatible with this software. Additionally, software such as ENGAGE also allows researchers to record the tracking data (e.g., head and head motion, avatar movement), and replay recordings of participant interactions as if they were real-time, and social scientists can then observe the scene from any angle and distance as the virtual camera can be placed anywhere within a rendering. The ability to observe recorded interactions as if they were in real-time, combined with the granular VR tracking data, introduces new ways to conduct ethnographic research and analyze social behavior such as non-verbal and verbal communication, collaboration, and turn-taking.

Three Challenges within Social Psychology

Researchers have studied social psychological processes through manipulating stimuli that are actual, imagined, or implied (Allport, 1985). Under the assumption that the three types of human stimuli can elicit similar social psychological processes, many have used VR as a novel tool to generate simulated scenarios to study these processes. Blascovich and colleagues (2002) further argued that the three methodological problems for studying social psychology–the experimental control-mundane realism trade-off, lack of replication, and the use of nonrepresentative samples–can be mitigated if not solved using immersive virtual environment technologies. We now delve into each of the three problems, focusing on how VR technology can alleviate each, supplementing each with an example.

The experimental control-mundane realism trade-off refers to the balancing act between having independent variables that are representative of real-life scenarios and those that are more precisely-manipulated within the confines of a highly-controlled research setting. In laboratory settings, this typically meant either sacrificing mundane realism in exchange for more easily controlled stimuli, such as verbal and written social scenarios, or incurring the high costs of training and recruiting confederates to act out intricate interactions in a confined lab environment. VR mitigates this trade-off by allowing researchers to immerse study participants in realistic virtual environments, anywhere from small lecture halls to large marketplaces and reducing the cost and effort of confederates acting out the scenarios repeatedly, as interactions and dialogues can be programmed or recorded and re-enacted using computer programs. Further, without the constraints associated with real-world and laboratory environments, VR can instrument realistic experiences that are dangerous (e.g., firefighting), impossible (e.g., embodying an older avatar), counterproductive (e.g., high-risk training), and expensive (e.g., field trips) in the real world (Bailenson, 2023). While producing realistic VR experiences can be costly and time-consuming, emerging creative tools are leveraging technologies such as Generative Artificial Intelligence to translate text and image prompts into 3D objects and scenes, which can potentially lower the barriers associated with creating virtual environments (Brown et al., 2023). Researchers have also found that improvements on perceived realism may not be necessary for eliciting natural human behaviors and improving the immersive experience (van Gisbergen et al., 2019). This understanding allows social scientists to leverage VR as a tool for studying human behavior across a wide range of possible stimuli while retaining a high degree of control over the experimental setting.

By studying the role of context in virtual social interactions, Han and colleagues (2023, Study 2) leveraged this exact opportunity in their large-scale longitudinal field experiment. In their second study, a total of 137 university students were recruited for a 10-week course about VR. Students were given Meta Oculus Quest 2 headsets, which they used to participate in weekly sessions hosted by the social VR platform ENGAGE. Each week, students participated in discussions and activities in different virtual environments, which varied in their spaciousness (panoramic vs. constrained) and setting (indoors vs. outdoors). Using the VR platform, the authors controlled and manipulated the amount of moving area and spatial height to create a total of 192 unique environments, ranging from spacious event halls to enclosed forest areas. By placing groups of students in controlled yet realistic virtual environments, the authors found that greater amounts of visible space leads to higher values in measurements such as nonverbal synchrony, perceived restorativeness, entitativity, pleasure, arousal, self and spatial presence, enjoyment, and realism. The results also showed that outdoor environments are related to higher perceived restorativeness and enjoyment, although panoramic and outdoor environments tended to yield lower enjoyment and realism.

The second problem is that of the lack of replication in social psychology. The authors attributed one of the key reasons to the difficulty of implementing the exact procedures used in past studies, possibly due to a "paucity of detailed information" provided in publications and the mere fact that "researchers do not share physically identical laboratories" (Blascovich et al., 2002, p. 105). Again, VR mitigates this problem as researchers can design, control, and later share their experimental setups and interactive study programs in great detail (e.g., utterances, dialogues, gestures, and appearances of confederates, timing of events). Since VR has the unique affordance of placing participants in similar or identical virtual scenarios, perfect replications of past studies are now possible despite participants being in physically different locations.

Ma and colleagues (2018) investigated this affordance by conducting a remote study demonstrating the feasibility of replicable Web-based VR experiments. In it, the authors sought to replicate previous in-lab studies on three VR illusions: place illusion (i.e., the sense of being transported into a virtual environment), embodiment illusion (i.e., the sensation of experiencing the virtual environment as an avatar), and plausibility illusion (i.e., the feeling that events in the virtual environment are real). The authors first recruited from the Amazon Mechanical Turk and assembled a VR panel with 242 crowdsourced workers. Following this, the researchers administered a survey on VR headset ownership and decided to design for the Samsung Gear VR headset given its highest ownership percentage among the respondents. After building three VR experiments using the React VR framework, the authors conducted the three experiments by first recruiting from the VR panel, providing study instructions, administering the web-based experiment, and finally asking each participant to provide feedback through an exit survey. With each experiment studying one of the three illusions respectively, the remote studies replicated the original findings for one of the three studies. The authors attributed the lack of replication to unjustified hypotheses or failed manipulations. Nevertheless, this work highlighted how VR, specifically open-sourced code, can facilitate replications of past studies with different demographics in remote settings.

The final problem is that of nonrepresentative samples, as participants for lab experiments are oftentimes recruited through convenience sampling. This leads to samples consisting mostly of participants in the same region or university community, oftentimes made up mostly of undergraduate university students. As the sample of participants is typically not representative of the population, it is unclear whether research findings can be generalized with external validity. Once again, VR's ability to allow researchers to conduct “experiments" remotely provides a solution to this problem. Radiah and colleagues (2021) described a spectrum of ways for conducting remote VR studies, where on one end lies hosting studies entirely through existing platforms (e.g., ENGAGE, Mozilla Hubs, VRChat), and on the other end creating and sharing standalone programs using development software (e.g., Unity, Unreal) to carry out the user studies. With VR, the channels for recruitment and distribution also expanded, as researchers can now directly leverage the VR platforms, App Stores (e.g., Steam, Oculus Quest Store), and pre-owned devices for both purposes. This enables researchers to include a more representative participant demographic in their samples, thereby addressing some of the limitations associated with convenience sampling. Furthermore, given that VR experiences are controllable and repeatable over time, another way to assemble a representative sample is by examining multiple studies across time.

Martingano and colleagues (2023) leveraged this latter affordance to study how demographics affect presence by aggregating study results from seven independent studies, which culminated in a sample size of 1145. As measurements of presence are subjective, an understanding of how user characteristics influence presence is crucial to developing immersive experiences that achieve the desired outcomes across different demographics. The authors focused on two types of presence, namely social presence, which refers to the sense of being together with other social entities, as well as spatial presence, which concerns the sense of being situated within a digital environment. Collectively, the seven studies employed two types of experiences, either the VR Buffet in which parents select food for their children or one of several VR clinical simulations where users embody healthcare providers or patients in medical exam rooms. Between the years of 2009 and 2020, the authors recruited participants from the local community and conducted all seven studies in the same controlled laboratory setting using either the Nvisor SX 60 or HTC Vive headset, all while amassing a wide variation of participant age, gender, and race over time. Then, through a meta-analysis, the results showed that the sense of presence is not related to age and gender but is, however, affected by racial groups for both social and spatial presence measurements. With the large-scale sample covering a wide range of demographics revealing these insights, the authors further highlight the necessity of evaluating how demographics are related to presence and motivate future work to mitigate these inequities in experiencing immersive content.

While VR has shown promise in mitigating the issue of nonrepresentative samples, the sampling population for user studies can remain subjected to additional sources of biases. For example, recruitment through digital channels for distribution may be limited to those who own compatible VR devices. The recruited population may also be biased towards users who have access to and a fluency in navigating certain digital software (e.g., VR platforms, App Stores).

Studying VR as an Object, Application, and Method

Fox and colleagues (2009) provided a useful framework for categorizing the role VR plays in social science research. Specifically, the authors distinguished between three categories, where VR is studied as an *object*, *application*, and *method.* The study of VR as an object refers to the body of work where the effects of the medium itself are studied. When researchers study VR as an application, they study the effects of real-world deployment of VR applications outside of the laboratory setting. Finally, using VR as a method refers to the field of work where researchers use VR as a tool to study social scientific phenomena. Using this framework, we next discuss past works within each category. Our goal here is not to provide an exhaustive list covering all potential topics, but rather a snapshot of how VR can be used to investigate social cognition and communication.

Studying VR as an object, many researchers have investigated how experiences in the immersive medium differ from those in the physical world (Fox et al., 2009). Although virtual environments and experiences can be built to mimic those in the physical environments, does VR elicit the same psychological effects?

One example of these concepts is that of presence, the subjective experience of the "phenomenon of behaving and feeling as if we are in the virtual world created by computer displays" (Sanchez-Vives & Slater, 2005). To elicit a sense of presence, Slater and colleagues (2009) argued that there are three necessary conditions, namely that of low latency between sensory data and proprioception, statistical plausibility, and behavior-response correlations where the environment responds correspondingly to participant actions. In a review of 239 user studies investigating presence in VR experiences, Souza and colleagues (Souza et al., 2021) similarly noted the wide range of factors that are related to the sense of presence in immersive environments and further binned them into four categories – engagement (e.g., attention, inclusiveness), personal characteristics (e.g., personality), interaction fidelity (e.g., travel, manipulation), and display fidelity (e.g., body-ownership, field of view). To measure presence, works have utilized both subjective measurements and objective measurements such as Functional Magnetic Resonance and Electroencephalography (Souza et al., 2021).

In addition to evoking similar psychological processes in physical environments within VR, researchers have also studied phenomena unique to VR. One of which is VR sickness. Similar to motion sickness, VR sickness can cause symptoms such as disorientation, drowsiness, fatigue, and nausea and poses a barrier to mass adoption of the medium as it can "cause intense discomfort, shorten the duration of a VR experience and create an aversion to further use of VR" (Fernandes & Feiner, 2016). With this in mind, researchers have studied different ways for mitigating it. In a longitudinal study investigating triad interactions over a ten-week period, Bailenson and Yee (2006) showed that simulator sickness decreased over time as users became more acquainted with the immersive medium. Many have also studied the efficacy of restricting the field of view (Fernandes & Feiner, 2016; Norouzi et al., 2018), reducing optical flow in peripheral vision (Buhler et al., 2018) in mitigating VR sickness. Additionally, a large body of work has also studied the disparate impacts that VR sickness has across individuals who differ in their motion sickness susceptibility, gender, real-world experience, technological experience, assessment of neurological disorders and relevant phobias (Howard & Van Zandt, 2021).

Researchers have also studied VR's ability to prompt prosocial behavior. Rosenberg and colleagues (2013) gave participants the superpower to fly and tasked them to either find a diabetic child in need of insulin or tour the virtual city. Upon comparing this condition with one where the participants were not gifted this superpower, the authors found that those with "super-flight" abilities were more likely to help experimenters after the virtual experience. The authors hypothesized that the "super-flight" abilities may have primed concepts associated with being a superhero, which later yielded the helping behaviors outside of VR. Kandaurava and Lee (2019) examined the impact of VR experiences in the social marketing context by having participants watch cinematic content or participate in a ball-tossing game either in VR or through two-dimensional screens. Compared to participants who experienced the stimuli on two-dimensional screens, the authors found that those in the VR conditions reported higher levels of empathy, sense of responsibility, and willingness to donate time and money. Oh and colleagues (2016) studied the effects of perspective-taking, the action of perceiving a scenario from an alternative point of view, on ageism. Specifically, over the course of two studies, the authors investigated whether perspective-taking diminishes the threat of intergenerational attitudes and whether such effects differ between those who embodied an elderly person in VR and those who took part in a mental simulation for the perspective-taking exercise. The results showed that while perspective-taking in an immersive virtual environment is more effective than mental simulation when the threat is not present during the intergroup contact, it does not have the same effect when the threat is present during the intergroup contact. The authors offered one possible explanation, pointing out that intergenerational tension often stems not from hostile intergenerational contact but rather the perception that the elderly is inconveniencing the younger generation (North & Fiske, 2012).

Given VR's unique immersive nature and ability to provoke psychological effects, another category of VR research focuses on evaluating the effects of VR applications in the real-world. While researchers have studied the use of VR in domains such as military and medical use cases, in this following section we take a deeper dive on the field of education.

When considering VR as an educational tool, many have highlighted its potential benefits, and also noted the criticality of proper implementation. In a study investigating how an educational VR experience on ocean acidification can influence learning and perception of climate change, researchers found that when compared to a seated experience, the ability to move around in an immersive environment increased the feelings of self-efficacy but impeded learning (Queiroz et al., 2023). Similarly, through two experiments conducted with high school students interacting either with a gamified simulation of crime-scene investigation involving the collection of DNA samples in a virtual laboratory environment or a video covering the same material, Makransky and colleagues (2021) found that that the use of VR increased presence but did not necessarily improved learning. Rather, it is the combination of the VR experience with enactment, allowing students to participate in physical activities with concrete objects, that improves learning. Conversely, the authors found that the combination of video with enactment did not yield comparable benefits. Both works suggested that VR can be beneficial to learning, yet its efficacy depends heavily on how the medium is interwoven into the educational materials.

The final body of work uses VR as a method for studying human behavior and communication. Under this category, researchers leveraged the ability to create diverse, realistic yet well-controlled stimuli and exploited the rich tracking data to study phenomena such as group dynamics, and remote collaborations. In a study investigating social interactions in virtual spaces, Williamson and colleagues (2021) built a customized space using the VR platform Mozilla Hubs to host an academic workshop. By leveraging the open-sourced virtual environment, the authors used instrumented tracking to log the positions and orientations of 26 registered attendees across four different virtual spaces. Using this data to analyze group formation, personal space, and shared attention, the results showed that participants stood closer to each other in smaller spaces and that larger spaces discouraged small group formations but enabled more flexible personal space. Miller and colleagues (2021) investigated how turn-taking and gaze are related to synchrony, which refers to “individuals' temporal coordination during social interactions” (Delaherche et al., 2012, p. 349). To do this, the authors asked three-person teams to collaborate on four different design tasks in either a traditional conference room or informal garage over a two-hour period and tracked the positions and orientations of the head and two hands at a rate of 20Hz for each individual participant. In an analysis of the tracking data, the authors showed that synchrony can be affected by virtual environments and that synchrony is likely to be lower when a user is looking at another user. Given these findings, the authors highlighted the need to consider virtual context as a crucial component in modeling and understanding human interactions.

The State of Large-scale Virtual Reality Research

The vision proposed by Blascovich and colleagues (2002) of using immersive virtual environment technology as a tool to study social psychology is now transitioning into a tangible reality. Technological advancements, for example the improvements of hardware capabilities and introduction of consumer-level devices, along with the changes in social norms such as the widespread adaptation to remote working and learning, have played a crucial role in bringing this idea to fruition. To assess the progress made towards realizing this vision and present an overview of how researchers conduct large-scale VR studies, the reminder of the chapter will review recent large-scale VR studies, with a focus on their setting, recruitment methods and implementations of the VR experiences. The examined studies cover a wide range of topics, for example education and learning outcomes, spatial navigation performance, and emotions. While we aimed to include a representative sample of large-scale VR research, the works reviewed here are far from exhaustive as we did not perform a formal meta-analysis and may have missed works during the examined time frame.

There are several inclusion criteria to the presented set of works. We limited our search to works accessible through the ACM Digital Library, APA PsycNet, Frontiers, MDPI Journals, Oxford Academic, PLOS Journals, SAGE Journals, Science Direct, and Wiley Online Library. We then limited our search to works published after 2015 with the phrase "virtual reality", "virtual environment" or "virtual world" in either the title or abstract.

Additionally, the papers must also have user studies with at least 100 participants. As the definition of large-scale user studies is also context- and field-dependent, we chose the arbitrary cutoff threshold of 100 participants with the aim of providing an estimation of recent large-scale works. For works that explicitly framed the work into multiple studies and drew from different participant pools, we report them separately and again only include them if the number of participants exceeds 100. Though this choice may have filtered out relevant research with narrower target demographics and study designs that warrant smaller sample sizes (Caine, 2016; Onwuegbuzie & Collins, 2007), we focus on understanding how scholars have insofar leveraged VR to conduct research at scale.

Finally, the works must contain some VR components using HMDs. Although this criterion excludes works that only use desktop VR and other display technologies such as CAVEs, we believe that the selected works offer valuable insights into the research landscape. When analyzing these works, we focus on the recruitment methodology as well as the technology used for the VR experiences. Specifically, we report seven metrics, namely the venue of publication, sample size, setting, recruitment method, participant population, VR hardware used, and development platform for the VR experiences. For setting, each study can fall into one or more of three categories based on how the VR portion of the study is conducted: in-lab where the study subjects participate in a controlled lab environment, out-of-lab where the experiment is held in locations under the supervision of research personnel, and remote where the experiment is administered without the in-person presence of a research personnel. For the development platforms, each study is categorized in one or more of three categories: customized experiences using existing social VR programs, existing experiences, and self-constructed experience. If mentioned in the work, we also included the exact platforms, tools, and name of existing experiences used.

In total, we identified 34 studies that covered a wide range of recruitment settings, participant demographics, HMD devices and hardware setups, and approaches to presenting VR experiences, depicted in Table 1. Participants were recruited in many different ways, ranging from pavilion on the festival grounds (van Gelder et al., 2019) to museums, aquariums, arcades across 17 different countries (Queiroz et al., 2023). The demographics of the participants varied, with the majority of the papers focused either on students or the entire population, and two focusing on more specific populations such as parents (Hagerman et al., 2020) and female students (Riem et al., 2019). The selected works used various HMDs such as the Google Cardboard, HTC Vive, Oculus Quest and Rift, Sony HMZ-T1, Samsung Gear VR and NVIS nVisor SX60. Additional hardware such as camera systems and physiological equipment were also used to obtain additional tracking and physiological data (Hildebrandt et al., 2016; McCall et al., 2015). Finally, when facilitating VR experiences, researchers made use of existing experiences available through VR games (Kandaurova & Lee, 2019) and educational tools (Makransky et al., 2019; Queiroz et al., 2023). Many leveraged other platforms and tools to create new immersive experiences, with some researchers using 360-degree and multiple camera system (Bramley et al., 2018; van Gelder et al., 2019) and development tools such as Unity, 3ds Max, and Vizard (McCall et al., 2016), and others utilizing existing social VR platform to customize virtual environments (Han et al., 2023) and social interactions (Wang et al., 2024). Taken together, it is clear that researchers are leveraging VR technology to conduct large-scale studies and did so while tailoring their approaches towards their target participant demographics and use-cases.

The reviewed studies also revealed points of friction in deploying experiments in the remote setting, interestingly echoing two of the three challenges of social psychology. For example, Ma and colleagues (2018) reported facing difficulties in collecting valid and replicable data remotely, which corresponded to the problem of lack of replication discussed earlier in the chapter. Other researchers pointed to the challenge of recruiting a large and representative sample (Huber & Gajos, 2020; Mottelson et al., 2021), which parallels the issue of nonrepresentative samples in social psychology. One recent initiative that seeks to mitigate these challenges is the Virtual Experience Research Accelerator (VERA), a community resource supported by researchers, paid staff, and volunteers that seeks to facilitate high-quality remote studies. VERA envisioned a novel way for conducting remote VR studies by allowing researchers to submit study proposals, where those approved are further distributed to a "carefully curated large and diverse VERA participant pool" (*Planning a Virtual Experience Research Accelerator (VERA)*, n.d.). With VERA, researchers may more easily conduct studies that are large-scale, longitudinal, and diverse in their demographics, thereby circumventing the issues of studies being underpowered and not generalizable to the external population. The prospects of conducting remote VR user studies through VERA and analogous efforts to further mitigate the three challenges in social psychology is novel and promising, though its true impact remains to be fully realized.

Conclusions and Future Work

There are several directions for future research. In addition to developing toolkits and methodology for conducting remote, large-scale studies, we imagine more works leveraging the granular tracking data afforded by the technology such as eye gaze, hand gesture, facial expression, and audio. Another avenue of future work is in building and investigating the effects of systems that transform social interactions beyond what is possible or has actually occurred in the real world. One example is a system that transformed the tracking data around proxemics and eye gaze to acclimate new users into recorded social interactions in VR (Wang et al., 2023). With the increasing adoption and accessibility of VR technology, we also envision more work to be done in evaluating real-world deployments of applications in domains such as design, education, healthcare, and media.

In this chapter, we provide an overview of VR technology, discuss how it can be used to alleviate problems faced by social psychologists, and what topics past researchers have addressed. We then give an overview of the current state of large-scale VR research, with a focus on their recruitment methods, target population, VR hardware, as well as the development process of the immersive experiences. Being a helpful tool, virtual reality enables researchers to study the psychological processes underlying social interactions. Through creating tangible and immersive experiences, virtual reality empowers scholars to unravel the intricacies of social phenomena and uncover insights that may elude traditional research approaches.

Table 1. Results from the review of large-scale VR papers (2015-2024)

Authors	Journal	N	Setting	Recruitment Method	Population	VR Hardware	Development for VR experience
Ammann et al., (2020)	Food Quality and Preference	100	In-lab	Online advertisements and experimental panel	All	HTC Vive	Self-constructed experience (Unity)
Bramley et al., (2018)	International Journal of Market Research	486	Remote	Populus' proprietary online panel	All	Google Cardboard	Self-constructed experience (360-degree video using 360-degree camera)
Chan et al., (2022)	Education and Information Technologies	125	In-lab	University	Students	HTC Vive	Self-constructed experience (Unity, Autodesk 3ds Max)
Chittaro et al., (2017)	International Journal of Human-Computer Studies	108	In-lab	University	Students	Sony HMZ-T1	Self-constructed experience
Felnhofer et al., (2015)	International Journal of Human-Computer Studies	120	In-lab	University	Students	Sony HMZ-T1	Self-constructed experience (Blender 3D, OGRE3D, and GIMP)
Hagerman et al., (2020)	Health Psychology	190	In-lab	Online advertisements, flyers, and word of mouth	Parents	HTC Vive	Existing experience (VR Buffet)
Han et al., (2023): Study 1	Journal of Computer-Mediated Communication (JCMC)	101	Remote	University course	Students	Oculus Quest 2	Customized experiences using existing social VR program (ENGAGE)
Han et al., (2023): Study 2	Journal of Computer-Mediated Communication (JCMC)	137	Remote	University course	Students	Oculus Quest 2	Customized experiences using existing social VR program (ENGAGE)
Herrera et al., (2018): Study 1	PLOS ONE	117	In-lab	University and surrounding region	All	Oculus Rift DK2	Self-constructed experience (Becoming Homeless)
Herrera et al., (2018): Study 2	PLOS ONE	439	In-lab	University and mobile sites	All	Oculus Rift DK2	Self-constructed experience (Becoming Homeless)
Hildebrandt et al., (2016)	Psychophysiology	274	In-lab	Existing participant pool	All	NVIS nVisor SX60 with additional tracking software; devices for tracking physiological data (e.g., heart rate, skin conductance, electromyography, respiration)	Existing experience (Room 101)
Huber & Gajos (2020): Study 1	PLOS ONE	311	Remote	Online experiment platform (i.e., LabintheWild.org)	All	Head-mounted (model not specified), mobile, desktop	Self-constructed experience
Huber & Gajos (2020): Study 2	PLOS ONE	1334	Remote	Online experiment platform (i.e., LabintheWild.org)	All	Head-mounted (model not specified), mobile, desktop	Self-constructed experience
Kandaurova & Lee, (2019): Study 3	Journal of Business Research	122	In-lab	University	Students	Oculus Rift	Existing experience (Cyberball)
Lin (2017)	Computers in Human Behavior	145	In-lab	University	Students	HTC Vive	Existing experience (The Brookhaven Experiment)
Lin et al., (2018)	New media & society	102	In-lab	University	Students	HTC Vive	Existing experience (The Brookhaven Experiment)
Ma et al., (2018)	World Wide Web Conference (WWW)	242	Remote	VR-AMT Panel created using Amazon Mechanical Turk	All	Samsung Gear VR	Self-constructed experience (React VR)
Makransky et al., (2019)	Journal of Computer Assisted Learning	105	Out-of-lab	University course	Students	Desktop VR; Samsung Gear VR	Existing experience (Laboratory Safety Virtual Lab)
Makransky et al., (2021): Experiment 1	Journal of Educational	131	Out-of-lab	High school workshop	Students	Samsung Gear VR	Existing VR program (Polymerase

	Psychology						Chain Reaction Virtual Lab)
Makransky et al., (2021): Experiment 2	Journal of Educational Psychology	165	Out-of-lab	3 High schools	Students	Samsung Gear VR	Existing VR program (Polymerase Chain Reaction Virtual Lab)
Martínez-Navarro et al. (2019): Phase 1	Journal of Business Research	178	In-lab	Lab database	All	HTC Vive	Self-constructed experience
McCall et al., (2015)	Consciousness and Cognition	306	In-lab	Existing participant pool	All	NVIS nVisor SX60 with additional tracking software; devices for tracking physiological data (e.g., skin conductance, heart rate)	Existing experience (Room 101)
McCall et al., (2016)	Computers in Human Behavior	324	In-lab	Existing participant pool	All	NVIS nVisor SX60 with additional tracking software	Existing experience (Room 101); Self-constructed experience (Vizard 4.0, Autodesk 3ds Max, Photoshop, Audacity)
Mottelson et al., (2021): Study I, Part 1	Frontiers in Virtual Reality	161	Remote, out-of-lab	Social media	All	Oculus Quest (1st gen)	Self-constructed experience (Unity, SideQuest, Python-based backend application for tracking data)
Mottelson et al., (2021): Study I, Part 2	Frontiers in Virtual Reality	185	In-lab	University	Students	Oculus Quest (1st gen)	Self-constructed experience (Unity, SideQuest, Python-based backend application for tracking data)
Oh et al., (2016): Study 1	Computers in Human Behavior	148	In-lab	University	Students	Oculus Rift DK2	Self-constructed experience (Vizard 5.0)
Queiroz et al., (2023)	Sustainability	305	Out-of-lab	17 locations across the U.S., the U.K., Canada, and Denmark (e.g., museums, aquariums, arcades)	Students, visitors	HTC Vive	Existing experience (Stanford Ocean Acidification Experience)
Riem et al., (2019)	Psychoneuroendocrinology	180	In-lab	University	Female Students	Oculus Rift DK2	Self-constructed experience (Unity)
Roettl & Terlutter (2018)	PLOS ONE	237	In-lab	University	Students	Oculus Rift	Self-constructed experience (Unity)
Shi et al., (2019)	Automation in Construction	126	In-lab	University	Students, staff	Oculus Rift CV1	Self-constructed experience (Unity)
Siamionava et al. (2018)	International Journal of Hospitality Management	139	In-lab	University	Professors, students	Oculus (model not specified)	Self-constructed experience (Unity)
Tcha-Tokey et al., (2018)	Hindawi Advances in Human-Computer Interaction	152	In-lab	Not specified	Professors, students	Oculus Rift DK2	Self-constructed experience (Unity)
van Gelder et al., (2019)	Journal of Research in Crime and Delinquency	145	Out-of-lab	Pavilion on the festival grounds	All	Samsung Gear VR	Self-constructed experience (360-degree video created using GoPros)
Wang et al., (2024)	CHI conference on Human Factors in Computing Systems	128	In-lab	University	All	Oculus Quest 2	Customized experiences using existing social VR program (ENGAGE)

Note. Papers are ordered alphabetically by the lead authors' last names. VR hardware other than the HMDs are also included if mentioned in the papers.

References

Allport, G. W. (1985). The historical background of social psychology (Vol. 1). *The Handbook of Social Psychology*.

Ammann, J., Stucki, M., & Siegrist, M. (2020). True colours: Advantages and challenges of virtual reality in a sensory science experiment on the influence of colour on flavour identification. food quality and preference, 86, 103998.

Bailenson, J. (2023, March 16). *Here's why virtual reality should not be used every day*. World Economic Forum. https://www.weforum.org/agenda/2023/03/metaverse-virtual-reality-ignore-the-hype/

Bailenson, J. N., & Yee, N. (2006). A Longitudinal Study of Task Performance, Head Movements, Subjective Report, Simulator Sickness, and Transformed Social Interaction in Collaborative Virtual Environments. *Presence: Teleoperators and Virtual Environments*, *15*(6), 699–716.

Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry*, *13*(2), 103–124.

Bramley, I., Goode, A., Anderson, L., & Mary, E. (2018). Researching in-store, at home: Using virtual reality within quantitative surveys. *International Journal of Market Research*, *60*(4), 344–351.

Brown, J., Bailenson, J., & Hancock, J. (2023). Misinformation in virtual reality. Journal of Online Trust and Safety, 1(5).

Buhler, H., Misztal, S., & Schild, J. (2018). Reducing VR Sickness Through Peripheral Visual Effects. *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, 517–519.

Caine, K. (2016, May). Local standards for sample size at CHI. In *Proceedings of the 2016 CHI conference on human factors in computing systems* (pp. 981-992).

Chan, C. S., Bogdanovic, J., & Kalivarapu, V. (2022). Applying immersive virtual reality for remote teaching architectural history. Education and Information Technologies, 1-33.

Chittaro, L., Sioni, R., Crescentini, C., & Fabbro, F. (2017). Mortality salience in virtual reality experiences and its effects on users' attitudes towards risk. International Journal of Human-Computer Studies, 101, 10-22.

Delaherche, E., Chetouani, M., Mahdhaoui, A., Saint-Georges, C., Viaux, S., & Cohen, D. (2012). Interpersonal Synchrony: A Survey of Evaluation Methods across Disciplines. *IEEE Transactions on Affective Computing*, *3*(3), 349–365.

Felnhofer, A., Kothgassner, O. D., Schmidt, M., Heinzle, A. K., Beutl, L., Hlavacs, H., & Kryspin-Exner, I. (2015). Is virtual reality emotionally arousing? Investigating five emotion inducing virtual park scenarios. International journal of human-computer studies, 82, 48-56.

Fernandes, A. S., & Feiner, S. K. (2016). Combating VR sickness through subtle dynamic field-of-view modification. *2016 IEEE Symposium on 3D User Interfaces (3DUI)*, 201–210.

Fox, J., Arena, D., & Bailenson, J. N. (2009). Virtual Reality: A Survival Guide for the Social Scientist. *Journal of Media Psychology Theories Methods and Applications*, *21*(3), 95–113.

Hagerman, C. J., Ferrer, R. A., Klein, W. M. P., & Persky, S. (2020). Association of parental guilt with harmful versus healthful eating and feeding from a virtual reality buffet. *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association*, *39*(3), 199–208.

Han, E., Miller, M. R., DeVeaux, C., Jun, H., Nowak, K. L., Hancock, J. T., Ram, N., & Bailenson, J. N. (2023). People, places, and time: a large-scale, longitudinal study of transformed avatars and environmental context in group interaction in the metaverse. *Journal of Computer-Mediated Communication: JCMC*, *28*(2), zmac031.

Herrera, F., Bailenson, J., Weisz, E., Ogle, E., & Zaki, J. (2018). Building long-term empathy: A large-scale comparison of traditional and virtual reality perspective-taking. PloS one, 13(10), e0204494.

Hildebrandt, L. K., McCall, C., Engen, H. G., & Singer, T. (2016). Cognitive flexibility, heart rate variability, and resilience predict fine-grained regulation of arousal during prolonged threat. *Psychophysiology*, *53*(6), 880–890.

Howard, M. C., & Van Zandt, E. C. (2021). A meta-analysis of the virtual reality problem: Unequal effects of virtual reality sickness across individual differences. *Virtual Reality*, *25*(4), 1221–1246.

Huber, B., & Gajos, K. Z. (2020). Conducting online virtual environment experiments with uncompensated, unsupervised samples. *PloS One*, *15*(1), e0227629.

Jonas, M., Said, S., Yu, D., Aiello, C., Furlo, N., & Zytko, D. (2019). *Towards a Taxonomy of Social VR Application Design*. https://doi.org/10.1145/3341215.3356271

Kandaurova, M., & Lee, S. H. (mark). (2019). The effects of Virtual Reality (VR) on charitable giving: The role of empathy, guilt, responsibility, and social exclusion. *Journal of Business Research*, *100*, 571–580.

Lin, J. H. T. (2017). Fear in virtual reality (VR): Fear elements, coping reactions, immediate and next-day fright responses toward a survival horror zombie virtual reality game. Computers in Human Behavior, 72, 350-361.

Lin, J. H. T., Wu, D. Y., & Tao, C. C. (2018). So scary, yet so fun: The role of self-efficacy in enjoyment of a virtual reality horror game. New Media & Society, 20(9), 3223-3242.

Makransky, G., Andreasen, N. K., Baceviciute, S., & Mayer, R. E. (2021). Immersive virtual reality increases liking but not learning with a science simulation and generative learning strategies promote learning in immersive virtual reality. Journal of Educational Psychology, 113(4), 719.

Makransky, G., Mayer, R. E., Veitch, N., Hood, M., Christensen, K. B., & Gadegaard, H. (2019). Equivalence of using a desktop virtual reality science simulation at home and in class. *PloS One*, *14*(4), e0214944.

Martínez-Navarro, J., Bigné, E., Guixeres, J., Alcañiz, M., & Torrecilla, C. (2019). The influence of virtual reality in e-commerce. Journal of Business Research, 100, 475-482.

Martingano, A. J., Duane, J. N., Brown, E., & Persky, S. (2023). Demographic differences in presence across seven studies. Virtual Reality, 1-17.

Ma, X., Cackett, M., Park, L., Chien, E., & Naaman, M. (2018). Web-Based VR Experiments Powered by the Crowd. *Proceedings of the 2018 World Wide Web Conference*, 33–43.

McCall, C., Hildebrandt, L. K., Bornemann, B., & Singer, T. (2015). Physiophenomenology in retrospect: Memory reliably reflects physiological arousal during a prior threatening experience. *Consciousness and Cognition*, *38*, 60–70.

McCall, C., Hildebrandt, L. K., Hartmann, R., Baczkowski, B. M., & Singer, T. (2016). Introducing the Wunderkammer as a tool for emotion research: Unconstrained gaze and movement patterns in three emotionally evocative virtual worlds. Computers in human behavior, 59, 93-107.

Miller, M. R., Sonalkar, N., Mabogunje, A., Leifer, L., & Bailenson, J. (2021). Synchrony within Triads using Virtual Reality. *Proc. ACM Hum.-Comput. Interact.*, *5*(CSCW2), 1–27.

Mottelson, A., Petersen, G. B., Lilija, K., & Makransky, G. (2021). Conducting unsupervised virtual reality user studies online. *Frontiers in Virtual Reality*, *2*. https://doi.org/10.3389/frvir.2021.681482

Norouzi, N., Bruder, G., & Welch, G. (2018). Assessing vignetting as a means to reduce VR sickness during amplified head rotations. *Proceedings of the 15th ACM Symposium on Applied Perception*, Article Article 19.

North, M. S., & Fiske, S. T. (2012). An inconvenienced youth? Ageism and its potential intergenerational roots. Psychological bulletin, 138(5), 982.

Oh, S. Y., Bailenson, J., Weisz, E., & Zaki, J. (2016). Virtually old: Embodied perspective taking and the reduction of ageism under threat. *Computers in Human Behavior*, *60*, 398–410.

Onwuegbuzie, A. J., & Collins, K. M. (2007). A typology of mixed methods sampling designs in social science research. *Qualitative report*, *12*(2), 281-316.

Planning a virtual experience research accelerator (VERA). (n.d.). Retrieved May 20, 2023, from https://sreal.ucf.edu/vera-discussion/

Queiroz, A. C. M., Fauville, G., Abeles, A. T., Levett, A., & Bailenson, J. N. (2023). The Efficacy of Virtual Reality in Climate Change Education Increases with Amount of Body Movement and Message Specificity. *Sustainability: Science Practice and Policy*, *15*(7), 5814.

Radiah, R., Mäkelä, V., Prange, S., Rodriguez, S. D., Piening, R., Zhou, Y., Köhle, K., Pfeuffer, K., Abdelrahman, Y., Hoppe, M., Schmidt, A., & Alt, F. (2021). Remote VR Studies: A Framework for Running Virtual Reality Studies Remotely Via Participant-Owned HMDs. *ACM Trans. Comput.-Hum. Interact.*, *28*(6), 1–36.

Riem, M. M. E., Kunst, L. E., Steenbakkers, F. D. F., Kir, M., Sluijtman, A., Karreman, A., & Bekker, M. H. J. (2019). Oxytocin reduces interpersonal distance: Examining moderating effects of childrearing experiences and interpersonal context in virtual reality. *Psychoneuroendocrinology*, *108*, 102–109.

Roettl, J., & Terlutter, R. (2018). The same video game in 2D, 3D or virtual reality–How does technology impact game evaluation and brand placements?. PloS one, 13(7), e0200724.

Rosenberg, R. S., Baughman, S. L., & Bailenson, J. N. (2013). Virtual superheroes: using superpowers in virtual reality to encourage prosocial behavior. *PloS One*, *8*(1), e55003.

Sanchez-Vives, M. V., & Slater, M. (2005). From presence to consciousness through virtual reality. *Nature Reviews. Neuroscience*, *6*(4), 332–339.

Shi, Y., Du, J., Ahn, C. R., & Ragan, E. (2019). Impact assessment of reinforced learning methods on construction workers' fall risk behavior using virtual reality. Automation in Construction, 104, 197-214.

Siamionava, K., Slevitch, L., & Tomas, S. R. (2018). Effects of spatial colors on guests' perceptions of a hotel room. International Journal of Hospitality Management, 70, 85-94.

Slater, M., Lotto, B., Arnold, M. M., & Sanchez-Vives, M. V. (2009). How we experience immersive virtual environments: The concept of presence and its measurement. *Anuario de Psicología*, *40*(2), 193–210.

Souza, V., Maciel, A., Nedel, L., & Kopper, R. (2021). Measuring Presence in Virtual Environments: A Survey. *ACM Comput. Surv.*, *54*(8), 1–37.

Tcha-Tokey, K., Christmann, O., Loup-Escande, E., Loup, G., & Richir, S. (2018). Towards a model of user experience in immersive virtual environments. Advances in Human-Computer Interaction, 2018.

van Gelder, J.-L., de Vries, R. E., Demetriou, A., van Sintemaartensdijk, I., & Donker, T. (2019). The Virtual Reality Scenario Method: Moving from Imagination to Immersion in Criminal

Decision-making Research. *The Journal of Research in Crime and Delinquency*, *56*(3), 451–480.

van Gisbergen, M., Kovacs, M., Campos, F., van der Heeft, M., & Vugts, V. (2019). What we don’t know. the effect of realism in virtual reality on experience and behaviour. Augmented Reality and Virtual Reality: The Power of AR and VR for Business, 45-57.

Wang, P., Miller, M., Queiroz, A., & Bailenson, J. (2024). Socially Late, Virtually Present: The Effects of Transforming Asynchronous Social Interactions in Virtual Reality. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery.

Wang, P., Miller, M. R., & Bailenson, J. N. (2023). The Belated Guest: Exploring the Design Space for Transforming Asynchronous Social Interactions in Virtual Reality. *2023 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, 617–618.

Williamson, J., Li, J., Vinayagamoorthy, V., Shamma, D. A., & Cesar, P. (2021). Proxemics and Social Interactions in an Instrumented Virtual Reality Workshop. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, Article Article 253.