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RESEARCH ARTICLE

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Virtual reality expands the toolkit for conducting health psychology research

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Abstract

Virtual reality (VR) has become a readily available consumer technology, strengthening its promise as a research tool for health psychology. We identify five key strengths of VR-based research: data collection, realism, experimental control, adaptability, and mobility (DREAM). We review how these advantages allow researchers to investigate behavioral, psychological, and social processes related to health and well-being in novel ways, by using VR as both a stimulus and a measurement tool. We also describe challenges facing VR research and potential strategies researchers can use to mitigate them. In addition to reviewing existing research, we hope to inspire researchers to consider ways in which VR might be used in future to augment their own research programs or answer currently impracticable research questions in health psychology.

KEYWORDS
health psychology, methodology, virtual reality

1 | INTRODUCTION

Health psychologists are challenged with understanding the complex influences of behavioral, psychological, and social factors on health and well-being. The traditional research measures in our arsenal have brought us a long way; however, there remain many crucial questions that could benefit from methodological advances, such as understanding the triggers of unhealthy behaviors, including the influence of psychological states and the broader social environment. Here we will consider how virtual reality (VR), an emerging communication technology, could be used as a research tool to enable novel and improved research projects across the discipline. The potential benefits of VR as a research tool have been noted in other related fields (e.g., Blascovich et al., 2002; Pan &

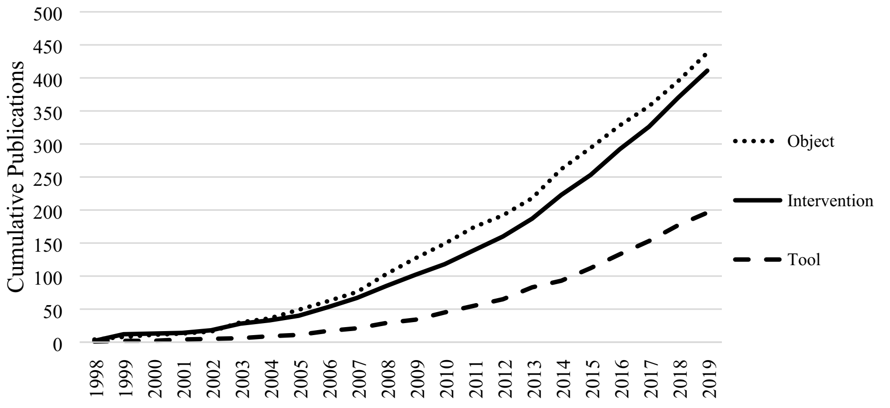

FIGURE 1 Use of VR as a research tool in health psychology publications. *Note*: A search of the database PsychINFO was performed in August 2020 using the search terms "Virtual Reality" AND "Health." Irrelevant articles, duplicates, and articles that did not report empirical data were excluded. The remaining 1084 articles were coded based on Fox et al.'s (2009) tripartite distinction between objects, interventions, and tools. Articles coded as "objects" evaluate the form or content of VR and how variations in each affect the user, this includes measuring if an experience creates presence, evokes emotions, creates motion sickness as well as users' opinions about VR. Articles coded as "interventions" explore VR's viability as an application for content delivery outside of the laboratory, for example, for increasing empathy, physical rehabilitation and any other effects that persist beyond VR exposure. Articles coded as "tools" use VR to study other physical or psychological phenomena, this includes using VR as a stimulus or as a measure, to test hypotheses unrelated to VR. PsychINFO does not index whitepapers or industry projects and therefore these are not depicted in this figure. These projects normally aim to develop new VR experiences and so are likely to be classified as interventions or objects and therefore this graph may underestimate the prevalence of this type of work.

Hamilton, 2018; Ventura et al., 2018; Wilson & Soranzo, 2015), but an exploration of the promise of VR for health psychology is overdue.

Over the last 3 decades, research using VR has steadily grown, aided by major developments in consumer availability of VR hardware in recent years. However, despite the myriad ways in which VR could be used as a research tool in health psychology, its application in this manner is rare compared to other uses. Figure 1 depicts the different applications of VR within health psychology since 1998. This figure relies on Fox et al.'s (2009) tripartite distinction between VR as an object of study, VR interventions, and using VR as a research tool.

Research that studies VR as an object evaluates the form or content of VR and how variations in each affect the user, this can include measuring whether a VR experience creates presence, evokes emotions, or creates motion sickness. Through research on VR as an object, we have learned that virtual humans can exert real social influence and that responses to this influence look similar in VR and real life (Blascovich et al., 2002). This work has also provided recommendations for best practices, including identifying features of VR environments that are more likely to make users feel a sense of presence during use (i.e., a feeling of "being there" within the VR environment) (Cummings & Bailenson, 2016). Research on VR as an object will continue to be important for health psychology as it points to areas in which VR is a useful and valid tool for our work.

VR interventions use VR for clinical or practical purposes. We are currently in the "clinical era" of VR research (Cipresso et al., 2018) and VR health interventions span a wide range of areas (see A. S. Rizzo & Koenig, 2017 for review). Examples include distraction-based pain reduction (Eijlers et al., 2019; Indovina et al., 2018; Kenney & Milling, 2016); exposure therapy and anxiety reduction (Carl et al., 2019; Morina et al., 2015; Opris et al., 2012; A. Rizzo et al., 2019); physical rehabilitation (Howard, 2017); neuropsychological assessment (Neguț et al., 2016), and healthcare provider training (Kyaw et al., 2019). In many cases, VR interventions compare favorably to existing treatments and VR as an intervention has been declared "ready for primetime" (A. S. Rizzo & Koenig, 2017).

In this article, we will focus on the third category: using VR as a research tool to test research questions unrelated to the technology itself. Given the apparent underutilization of VR as a research tool (see Figure 1), we will first outline the benefits of using VR in this manner, then showcase existing VR-based research and describe potential possibilities for future use. Although this review is not comprehensive, we hope to inspire researchers to consider the ways in which VR could be used to augment their existing research protocols or answer currently impracticable research questions.

2 | THE BENEFITS OF VR AS A RESEARCH TOOL (DREAM)

VR technology is an overarching term for a collection of computer hardware and software designed to immerse users in artificial environments. One common VR setup is a head mounted display-based system where users view three-dimensional computer-generated images within a headset. While wearing this system, a user's movements and orientation are tracked and fed back into the system to adapt the presentation of the virtual environment. As a user turns their head, for example, it may appear as though they are looking around a virtual room. Researchers may choose to combine a virtual stimulus, such as a virtual patient, with more traditional measurement techniques such as questionnaires or in-person observation (VR as a stimulus delivery platform). VR can also be used to measure the behavioral consequences of real-world interventions such as clinical training. For example, by testing how participants act with a virtual patient (VR as a measurement tool).

Perhaps the most innovative research is when VR simultaneously fulfills the role of stimulus and measurement tool. Unlike traditional methodology, in which researchers must typically tradeoff between the external validity of conducting research in field settings and the internal validity of conducting it in the controlled clinic or lab setting, when using VR as a research tool it is possible to gain the benefits of both. For example, Persky and Eccleston (2011) used VR to evaluate medical students for signs of antifat bias using a virtual patient designed to present with or without obesity. The virtual patient with obesity triggered more negative clinical judgments and interpersonal behaviors compared to the patient without obesity. There were several benefits of using VR for this project including automated *data collection*, along with heightened *realism*, *experimental control*, *adaptability*, and *mobility* (see Table 1). This study was successfully able to elicit naturalistic behaviors from participants due to the psychological and mundane *realism* that was created by the simulated clinical environment. The VR environment can feel real, despite computer generated graphics, because VR can mimic perceptual and psychological elements of the real world (Riva et al., 2019). At the same time, the researchers precisely manipulated patient weight status digitally, within a context of great *experimental control*, wherein all other physical features and all verbal and nonverbal behavior of the patient were held constant across conditions. As such, the causal effect of patient weight status was isolated. Quantifying the specific effect of weight status was a key aim of this experiment and would have been difficult to achieve without the control possible in a VR environment, as natural confounds abound in reality. Automated *data collection* allowed precise, covert, and continuous measurement of subtle indicators of antifat bias such as patterns of reduced eye-gaze toward the virtual patient with obesity.

Health psychologists may also wish to use VR in their research because the virtual environment can be *adapted* to simulate any situation, constrained only by researchers' imagination. The *realism* of VR allows participants to become immersed, even into situations that are impossible or infeasible to create in real life (Bailenson, 2018a). Finally, multisite research teams and those desiring to study difficult-to-reach populations may appreciate the *mobility* of VR, which allows standardized research to be conducted across various locations or in the community. The five advantages of VR we identify make up the acronym "DREAM" (*data collection*, *realism*, *experimental control*, *adaptability*, and *mobility*). These characteristics apply to VR as a research tool in general and have been leveraged by health psychologists to varying degrees in previous work. In this review, we will describe research that has benefited from, or could benefit from, these advantages of VR. We will highlight elements of DREAM by italicizing them throughout the paper.

TABLE 1 Potential advantages of using VR as a research tool for health psychology research

	Advantages	Example
Experimental control	• A VR stimulus is presented in exactly the same format every time, ensuring standardization. • Control over almost all sensory input reduces impact of extraneous variables and noise in data collection. • By allowing manipulation of only the variable of interest, concerns about possible systematic confounds are reducedz.	*To evaluate medical professionals' medical decision-making for signs of anti-fat bias providers could interact with a virtual patient programmed to present with or without obesity. The only difference in the interaction is the apparent weight of the patient; other physical features, as well as all verbal and nonverbal behavior is the same.*
Adaptability	• Researchers can create any situation as needed even if it is rare or impossible in real life. • Includes ability for perspective-taking (participants can virtually 'walk in another person's shoes).	*In a virtual interaction, a digital patient could be programmed to differ on any desired characteristic including rare anatomical features, or even allowing healthcare professionals to take a virtual trip within the patient's body to examine organ function. Alternatively, healthcare professionals could experience what it is like to be on the other side of this interaction, virtually taking on the patient's, weight and health problems.*
Mobility	• Once a VR-based experiment is created, it can be directly replicated anywhere including in hard to reach settings and populations. • Physical lab or clinic space is not required for VR-based research. • Ease of multi-group collaborations across various research sites using the same VR software.	*VR research can be replicated anywhere by sending the software to other research sites around the world. Research sites would not necessarily even need a research lab or clinic to perform the experiment in, the participant can be located in any convenient space and still inhabit the same virtual clinic. The portability of VR gives it the ability to reach greater diversity of healthcare professionals in different settings.*
Realism	• Immersive nature of VR allows users to feel a sense of presence. • VR stimuli can elicit ecologically valid behaviors. • Largely unconstrained responses are possible by participants. • Dangerous or harmful scenarios can be simulated without placing participants at risk. • Healthcare can be investigated without manipulating real patient medical care.	*Interaction with a medical student can occur in a visually realistic clinic room with a behaviorally realistic patient. The fully immersive headset makes the participants feel as if they were really there. Participants' bias, if any, can manifest in this interaction in the same way it might in a real-life scenario, including through treatment decisions, speech and body language. This design avoids potential concern about using real patients or actors as target for potential bias. Participants' full attention is on the clinical setting, similar to real life medical care, they cannot be easily distracted (e.g., by mobile phones)*

TABLE 1 (Continued)

	Advantages	Example
Data collection	• Precise measurements of physical movements are taken covertly, automatically, and continuously over time, eliminating the requirement for resource-intensive human observation. • Captures subtle indicators of variables participants are unable or unwilling to verbalize. • Can be source of "big data." • Designers can create any scenario as needed to measure participant behavioral response.	*Every aspect of what participants say and do in a virtual patient interaction can be recorded for later analysis. Interpersonal bias could be evaluated by coding healthcare decisions, content analysis of speech, analysis of tone and pitch, and non-verbal behavior such as visual or eye contact and interpersonal distance from the patient, etc. These data could be combined in multi-variate analyses or explored individually as* per *the researchers' hypotheses. If researchers were interested in exploring new research questions, such as how participants conduct a physical exam, or how they respond to a patient who faints during their visit, these scenarios can also be created and behavior tracked.*

Note: Some examples loosely based on Persky and Eccleston (2011).

3 | VR AS A RESEARCH TOOL IN HEALTH PSYCHOLOGY: PAST, PRESENT, AND FUTURE

VR has been and could continue to be used to investigate three broad areas in health psychology: the antecedents of health behaviors, the impact of psychological processes in health, and broader social processes in health. Within each, we describe how VR can serve as a tool for stimulus presentation and for measurement within the research process.

3.1 | Health behaviors

Health behaviors include activities, intentional or unintentional, undertaken by individuals that subsequently influence their own health or the health of others (Short & Mollborn, 2015). Unsurprisingly, there are a plethora of actions that can be classified as health behaviors including substance use, diet, physical activity, sleep, sexual activity, healthcare-seeking behaviors, and adherence to prescribed medical treatments. Using VR to study health behaviors has not yet become widespread, but existing work can provide a glimpse into future possibilities.

3.1.1 | VR as a stimulus for studying health behaviors

VR can be used to immerse participants in *realistic* simulations of real-world environments to investigate health behaviors. For example, a realistic virtual bar scene, complete with beer taps and patrons, was used to induce cravings for alcohol in research on heavily drinking college students (Simon et al., 2020). Similar environments have been used to trigger cravings for cocaine (Saladin et al., 2006), nicotine (de Bruijn et al., 2020; Ferrer-Garcia et al., 2010), and other substances to aid in substance use research. Taking it a step further, such VR experiences have been used to evaluate the efficacy of experimental treatments and interventions for addiction. For example, Kotlyar et al. (2020) used a VR environment with smoking cues to test the efficacy of a nicotine lozenge. Building upon such work, VR simulations are ripe for testing a wider array of behavioral and social interventions.

Because they are virtual, these environments can be modified in systematic ways to investigate how individual elements of the environment influence the precursors of health behavior. For example, social pressure in the form of a virtual drinking companion significantly increased alcohol cravings in a virtual bar (Ghiţă et al., 2017). VR thereby allows researchers the *experimental control* needed to disentangle the relative influence of various environmental factors in ways difficult to achieve in the field. In VR, naturally occurring covariates, such as the presence of other people and alcohol in a bar setting, can be easily separated, allowing the relative importance of each to be evaluated. Taking this logic to the extreme, in a project investigating satiation and eating behavior, Li and Bailenson (2018) used VR to disentangle the relative influence of smell and touch on donut consumption; research that is not just difficult, but probably impossible to perform using real-world stimuli. The authors ultimately found that experiencing either scent or texture, but not both together, led participants to subsequently eat fewer real donuts due to a proposed satiation effect. Future research using VR in health psychology could endeavor to disentangle a variety of variables that tend to naturally co-occur, such as the influence of different senses on drug cravings, or the relative contribution of verbal and nonverbal aspects of the placebo effect.

To date, most VR research has utilized the *realism* and *experimental control* that accompanies VR stimuli to investigate potential triggers of unhealthy behavior. However, other advantages of VR methodology could also be used in this area, specifically, taking advantage of the *adaptability* of VR to simulate experiences that differ from real life. For example, VR can be adapted to simulate the consequences of unhealthy behaviors using body illusions. For example, VR could be used to create the illusion that the users' own physical appearance or abilities have changed in response to their health behaviors. Researchers in other domains have already altered users' apparent weight (Ferrer-Garcia et al., 2017), height (Freeman et al., 2014), and visual acuity (Boumenir et al., 2014) to give users a taste of what it may be like to have different characteristics and restrictions. These experiences have mostly been used as interventions to increase empathy or reduce stigma (see Matamala-Gomez et al., 2020 for review), but researchers have also used simulated physical changes to motivate healthy behaviors. For example, Fox and Bailenson (2009) demonstrated that virtually simulating changes in body size in accordance with the amount of exercise that participants completed led to greater subsequent voluntary exercise. Similarly, future studies in VR could examine potential motivational mechanisms, such as visualizing the beneficial physical effects of treatment adherence, or the negative consequences of unmitigated sun exposure. How and under what conditions these aspirational and/or threatening imagined future-selves influence health behaviors remains an open question.

3.1.2 | VR as a measure of health behavior

Within *realistic* simulated environments, health psychologists can record a variety of health-oriented choices and behaviors such as research participants' treatment adherence (Kurtz, et al., 2007), alcohol choice (van der Vorst et al., 2014), and unhealthy food selection (Hagerman et al., 2019; Riches et al., 2019). This provides a new avenue for direct measurement of health choices given that self-reports are notoriously unreliable (Baumeister et al., 2007), and real-world observation is often burdensome.

Although the choices are virtual, evidence is mounting that health behaviors in VR are similar to those made in the real world (Cheah et al., 2020; Persky, et al., 2018; Ung et al., 2018; Waterlander, et al., 2015). Choices made in VR have also predicted real-world behavior change. Following an intervention to promote reduced alcohol consumption, participants who chose a virtual water, rather than a virtual alcoholic beverage, were more likely to report reduced real-life alcohol consumption 6 months later (Wang et al., 2019).

VR environments may be particularly suited to measuring risky choices, such as drug-use or sexual-health choices because researchers can capture rapid, emotion-based choices (de-Juan-Ripol et al., 2018). Risky decisions are typically impulsive and reactive and therefore difficult to capture with traditional self-report measures. VR environments also allow risky behaviors to be evaluated without placing participants in real danger. Researchers have used VR to measure risky pedestrian behaviors (Davis et al., 2013), and even participants' willingness to take their own life (Franklin et al., 2019).

Current research has generally exploited the *realism* of VR to measure explicit health choices. However, to date, relatively little research has utilized VR's potential for automatic *data collection* of subtle physical movements that can be a proxy for intentions or beliefs in relation to health behaviors. Where participants look and move, or how they interact with objects, may provide researchers with information about the mechanisms behind their health choices. There is much room for further exploration of subtle behavioral tracings and the psychological states they might index (Yaremych & Persky, 2019). For example, in an intervention study, researchers had adolescents practice several healthy behaviors in VR, such as asking a pharmacist for an HIV test, refusing drugs at a party, and negotiating condom use with a partner (Hadley et al., 2019). Although the authors were interested in participants' self-reported outcomes (which improved), future work could scrutinize participants' behavior within these virtual role-play scenarios to investigate whether behavioral movement patterns could provide a window into unconscious thought. For example, researchers could consider whether a participant's gaze lingers on drug paraphernalia during the party or whether their posture indicates shame while asking for an HIV test. By analyzing how participants make health choices in addition to choices they make, health psychologists may gain a better understanding of the underlying processes leading to unhealthy behaviors.

3.2 | Psychological processes in health

Health psychology often considers how specific, contextual beliefs may influence health outcomes (e.g., beliefs about treatment efficacy), as well as how habitual ways of thinking influence health through behaviors or lifestyle choices. VR can provide a way of quantifying these psychological processes as well as inducing specific psychological states to evaluate their effect.

3.2.1 | VR as a stimulus for studying psychological processes in health

VR can be used to manipulate participants' cognitive or emotional state to experimentally determine effects on health-oriented outcomes. For example, researchers asked older adults to cross a virtual street under a distraction induction to study the influence of cognitive load on pedestrian safety (Nagamatsu et al., 2011). Participants who were busy talking on a cell phone or listening to music were more likely to have a collision with a virtual car. This study demonstrates the blatantly dangerous consequences of reduced cognition that would be impossible to directly investigate outside of VR. However, more subtle research on psychological processes is also possible. For example, stress, which is associated with deleterious effects on health throughout the lifespan (Lupien et al., 2009; O'Connor et al., 2020), can be readily manipulated in VR. *Realistic* virtual scenes depicting heights, spiders, combat, public speaking, and other stressful situations are most commonly used for exposure therapy (see Kothgassner et al., 2019; Opriş et al., 2012). However, these stressful experiences can also be used to investigate the impact of acute stress on health processes such as weight gain. For example, Padilla et al. (2019) measured participants' stress levels during a public speaking task, where the virtual audience looked progressively bored and disappointed. Stress reduced executive function and attention (both implicated in overeating) most among adolescents with excess weight, suggesting a potential mechanism by which stress influences weight gain. Although this research could have technically been conducted in the real world, a large audience with standardized behavior in a high-stakes environment (i.e., an auditorium) is far more practical to create virtually. Health psychologists may likewise be interested in using VR for research in cases where it conveys such practical advantage.

VR can be put to use inducing a variety of other emotional states in order to study their influence on health. While emotions can be induced through other means, VR-based induction has the potential to be especially powerful (Susindar et al., 2019). Although little research has used this approach to date, in one unusual study, researchers used VR to induce disgust in participants, then measured their willingness to eat a real piece of chocolate (Ammann et al., 2020). Work along this vein could give insight into emotional influences on eating, treatment decision-making, and other health behaviors. Health psychologists may rely on pre-existing, validated, emotion induction stimulus sets such as Li et al.'s (2017) database, or develop their own, topic-relevant, emotional VR stimuli (e.g., involving fear-inducing medical procedures) as required by the research. Regardless of the emotional trigger, the *realism* of VR is a key advantage for inducing emotional states.

In the realm of cognition, the *adaptability* of VR is an area of relative strength. VR can be used to present information in ways that are not possible in the real world. VR has shown promise as a route for influencing knowledge, opinions, and thinking styles. This may be especially useful when the investigation benefits from experiential approaches or when complex health information is better displayed in three dimensions or through multiple perceptual channels. Along these lines, a study used VR to portray the "caloric weight" of unhealthy foods using 3D food models and haptic feedback. This experience was associated with higher perceived risk and selection of snacks with lower calorie density (Ahn et al., 2019). In a similar way, VR experiences could prompt different thinking styles, supporting the investigation of *how* people think about health. For example, participants' construal level could be manipulated by encouraging focus on concrete details versus larger abstract aspects of their virtual environment depending upon how it is rendered. By focusing participants on the larger picture, a more abstract construal level may be induced, which has been associated with self-control (Fujita, 2008). Construal level may also influence outcomes like treatment adherence or acceptance of the end of life. There are a great many areas of untapped potential for using the adaptability of VR to interrogate the relationship between psychological processes and health outcomes.

3.2.2 | VR as a measure of psychological processes in health

VR can provide enhanced measures of pre-existing differences in individuals' psychological processes. Researchers have already used VR to measure a variety of cognitive skills and characteristics with important relationships to health, such as attention (Rodríguez-Barranco et al., 2016), memory (Neguț et al., 2016), and propensity to feel stress (Rodrigues et al., 2020). Many of the most popular cognitive VR measures test participants' ability to perform in *realistic* real-world scenarios, which differs from traditional versions of these tasks. For example, the *SeeMe* virtual interactive shopping environment measures executive function by asking participants to purchase specific products and stay within an allocated budget (Nir-Hadad et al., 2017). Other real-world scenarios include driving (Liu et al., 1999), street crossing (Janouch et al., 2018), and classroom performance (Mühlberger et al., 2020). Many of these VR measurements have been validated in comparison with more traditional assessments, and in some cases outperform traditional tests (Diaz-Orueta et al., 2020). The proliferation of these assessments speaks to the advantages of VR *realism*.

VR assessments can also collect a great deal of data related to the process by which participants perform required tasks (e.g., body movement, gaze direction, order, and timing). Future work could take advantage of this *automatic data collection* to elucidate the mechanisms by which trait and state individual differences in cognitive processes influence health behaviors. One notable piece of research used VR to investigate the mechanism through which temperamental fear in children leads to increased injury likelihood as pedestrians. In a VR street-crossing scenario, more fearful children hesitated before initiating crossing, leading to a smaller gap between themselves and the oncoming virtual vehicle, thus increasing the likelihood of collision (J. Shen et al., 2015). By understanding mechanisms through which fear influences safety, researchers can more effectively target interventions. Many other possible mechanisms are ripe for exploration using VR simulations, including impulse-control and food choice, or surgeons' attention levels and their surgical precision. In this way, VR can be used not just to quantify individual differences, but also to determine how they influence health outcomes.

Assessments of individual differences could also be fed back into healthcare decision-making. In an exciting example, the ENGAGE study investigates whether measuring regulation of emotion, cognition, and self-focused reflection in VR, in combination with traditional lab-based measures and self-reports, could be used to predict the most efficacious intervention strategies for people with comorbid depression and obesity (Williams et al., 2018). Given widespread agreement that one size does not fit all in healthcare and given recent investments in personalized medicine, VR should be further evaluated as an approach for phenotyping individuals to direct treatment plans.

3.3 | Social processes in health

Health not only reflects an individual's physical and psychological state, but the social context a person inhabits as well. Research on the social determinants of health has grown markedly in the last decade, reflecting a broad consensus that health and health disparities are shaped by nonmedical factors; such as an individual's social support, family connectedness, workplace and neighborhood characteristics, and their position in a larger political-economic hierarchy that can enable or constrain health (Short & Mollborn, 2015). VR environments show promise for examining research questions around social influences on a micro level, such as investigating physician bedside manner, communication strategies, and interpersonal biases. VR may also hold promise for research at a more macro level, such as investigating how social norms, policies, and laws influence health processes and outcomes.

3.3.1 | VR as a stimulus for studying social processes in health

When investigating social interactions, experiments often require confederate actors to play a role—such as simulated patients. It is almost impossible to ensure that different actors, or even the same actor on multiple occasions, acts in a standardized manner for each participant. In contrast, virtual humans can play roles like patients or healthcare providers to examine a range of social and interpersonal research questions with total *experimental control*. For example, Persky and Street (2015) investigated whether patients' health attitudes were influenced by the communication approach (supportive vs. directive) of a virtual physician. Flipping the script and having real providers interact with a virtual patient, research has investigated how expression of pain by virtual patients influences judgments of pain and prescription of opioids (Hirsh et al., 2009). VR can be used to examine other social influences on health, such as peer pressure on drinking or smoking (Ghiţă et al., 2017), or the importance of social support for effective patient communication during physician visits (McDonald et al., 2013). These studies allow researchers to focus on only the social variable of interest, holding constant extraneous variables and confounds.

It is now commonplace to manipulate specific physical characteristics of virtual humans. Researchers have consistently found that healthcare providers treat virtual patients differently depending on a variety of characteristics, including race, gender, age, and weight (Hirsh et al., 2008, 2009; Persky & Eccleston, 2011). Again, all other aspects of presentation can be held constant, so it is possible to determine how exactly a single characteristic such as race, gender, or weight triggers bias directly. The concordance of characteristics like gender and race between patient and physician can also be systematically modified using VR to match participant demographics. Demographically discordant interactions have been shown to negatively impact patient satisfaction and patient comprehension of health risks when studied in VR (Mast et al., 2007; Persky et al., 2013) as well as in real clinical visits (M. J. Shen et al., 2018). These discoveries would have been difficult, if not impossible, to achieve, without the *experimental control* that VR simulations provide.

Most of the research to date on social health factors has used VR to investigate one-on-one interactions between patients and providers; however, future work could take advantage of the *adaptability* of VR to simulate the larger social environment. For example, VR could be used to simulate differences in healthcare settings such as quality of equipment, wait-times, friendliness of the office staff, diversity of patients and staff, and so forth. This kind of macro-focused virtual environment would allow exploration of how systematic differences in healthcare environments, beyond interpersonal bias, might influence patient health processes. From a macro perspective, researchers can also manipulate the VR environment to trial prospective health policy and legislation on the ground. For example, in a virtual convenience store, researchers investigated the impact of banning tobacco displays. When tobacco products were enclosed in a virtual cabinet, youth participants were less aware they were for sale and were less likely to try to purchase them (A. E. Kim et al., 2013). Given the clear implications of the broader environment for health, VR provides a simple way to manipulate and evaluate potential systemic variations that could lead to health improvements.

3.3.2 | VR as a measure for studying social processes in health

The incidence of specific social behaviors can be directly assessed using VR. For example, Jouriles et al. (2016) used a simulated dating violence situation to measure rates of bystander intervention. Within healthcare interactions specifically, the behaviors of both patients and healthcare providers can be evaluated using VR, including the questions they ask, the actions they take, and the decisions they make. Automatic *data collection* also allows subtle aspects of social interactions to be evaluated for signs of interpersonal bias. This has included interpersonal distance (Simões et al., 2020) and eye contact (H. Kim et al., 2018). These implicit measures have been used to better understand patient–provider interactions and interpersonal bias and showcase a key advantage of VR research (*data collection*). For example, researchers found that medical students make less visual contact with a virtual patient with obesity than a lean virtual patient (Persky & Eccleston, 2011). Measuring participants' responses to virtual humans in this manner has become increasingly well validated as a research tool because participants generally respond in similar ways to virtual and real humans (Blascovich, 2002; Blascovich et al., 2002). In a study comparing interactions with virtual patients versus real human actors portraying patients, medical students tended to ask the same questions, interact in a similar manner, and put the same effort into achieving the goals in both types of interactions (Lok et al., 2006). There are certainly differences between VR social interactions and their real-world counterparts in certain contexts, but, if well understood, we may be able to use these differences to our advantage. For example, patients may be more inclined to make honest disclosures to virtual humans because they are less motivated to make a socially desirable impression (Lucas et al., 2014).

The development of social VR in tandem with its inherent *mobility* increases possibilities for socially oriented research. In social VR, multiple people interact in the same virtual space although they are physically in different locations. Research on multiplayer digital games suggests that people in social VR can form genuine friendships and interlinked communities (Ducheneaut & Moore, 2004; Jakobsson & Taylor, 2003), and that these virtual experiences are personally meaningful (Maloney & Freeman, 2020; Maloney et al., 2020). One large untapped area of potential for VR research is utilizing its *mobility* to measure behavior within social VR. Changes in social behaviors can be mapped as they spread throughout these online communities because each person leaves a detailed digital footprint. Do healthy norms spread between those who frequently interact? Or do social influencers have the most impact? To the best of our knowledge, no research has yet used social VR to answer these kinds of questions; however, the idea is not without precedent. Epidemiologists have considered the

TABLE 2 Potential challenges of using VR as a research tool for health psychology research and mitigation strategies

	Challenges	Example and mitigation strategies
Technological limitations	• Flexible artificial intelligence programs for integration into VR experiences are not widespread or easily accessible. • While visual, auditory, and vestibular stimuli are central to most VR applications, VR simulation of other senses, particularly touch, smell, and taste are less well developed.	*AI is needed to power realistic, interactive conversations with virtual humans, and sensory immersion is important for simulating certain environmental cues, disease states, medical interventions, etc. Currently these tools are not yet easily accessible to the typical health psychology researcher. These tools are expected to become more accessible and at a lower cost over time. In the meantime, researchers have used various lower-tech solutions to compensate. For example, human experimenters can select avatar responses in virtual interactions.*
Prohibitive costs	• The cost of VR hardware has brought it within reach of most research labs • Software can range considerably in cost with custom development often being cost-prohibitive.	*In the best case, a suitable VR program to address researchers' needs may already exist. Partnerships among researchers (e.g., partnering with computer scientists), and between researchers and industry can also greatly reduce cost barriers associated with creating custom content. The field needs more matchmakers to encourage these partnerships, as well as the development of highly flexible VR research tools.*
Safety concerns	• Mundane safety issues such as tripping and colliding with real objects. • VR can cause motion sickness (or "cybersickness") among its users. • Sanitation of VR equipment. • Concerns about safety of long-term VR use include possible changes in vision and addiction; these are especially concerning among children where research and guidelines are lacking.	*Mundane safety issues such as tripping have been largely solved by digital systems and human spotters. A wealth of guidelines exist for minimizing risks of cybersickness[a,b] and there are several evidence-based sanitation regimens for VR equipment,[c] but in order for these mitigation strategies to be effective, care must be taken to follow them. Several safety questions remain related to long-term use of VR and its effects on children. More research on this topic is sorely needed. However, most research applications do not involve long-term equipment use, so concerns may be less significant in this context.*
Privacy concerns	• VR data can be associated with a user's identity, health, psychological state, attitudes, etc.,[d,e] and as such should be protected.	*Although in a research context privacy is overseen by institutional review boards, outside of the research context there are few situations in which VR user privacy is protected. VR data can reveal identifiable physical characteristics*

(Continues)

TABLE 2 (Continued)

Challenges	Example and mitigation strategies
• Challenges consenting for collection of data that may later allow for reidentification or for revealing analyses.	*as well as attitudes and behaviors. As technological development and research progress, the amount of information that can be gleaned from VR data is likely to increase. Movement data, for example, has been found capable of identifying individuals uniquely*[f] *and may have future medical diagnostic validity and behavioral data may be able to reveal attitudes that the participant may not choose to disclose (e.g. racial bias). This challenge is not unique to VR data, and approaches for consenting, data sharing, and legislation have been devised in other domains including genetics and genomics.*[g]

[a]Kemeny et al. (2020).
[b]Porcino et al. (2017).
[c]Ydo (2020).
[d]Bailenson (2018b).
[e]Yaremych and Persky (2019).
[f]Miller et al. (2020).
[g]Phillips et al. (2020).

spread of virtual illness in online games as a useful digital proxy for mapping real-world epidemics (Lofgren & Fefferman, 2007). Not only does the mobility of VR allow researchers to take headsets to their participants in various locations, it also allows them to tap into vast consumer VR markets to collect data from around the world in existing virtual communities.

4 | DREAM BIG

VR holds vast potential as a research tool for health psychology, with five key advantages (DREAM). Existing research has generally utilized the *realism* and *experimental control* inherent to VR-research to conduct ecologically valid and standardized research. Researchers are also beginning to use automatic *data collection* to measure more subtle behaviors such as eye gaze or posture. Fewer research studies appear to take advantage of the adaptability and mobility of VR, possibility due to the practical difficulties and costs associated with programming unique VR environments or purchasing VR hardware for multisite research. Nevertheless, as VR becomes cheaper and more readily available, more researchers should access these benefits of VR.

5 | LIMITATIONS AND FUTURE DIRECTIONS

Alongside the accomplishments and potential of VR for the field of health psychology come challenges and areas for development. Some researchers may find that VR technology is not yet sufficiently developed to meet their needs, or that its costs are prohibitive; and all researchers should consider the safety and privacy of their participants when using VR (see Table 2). It is crucial to avoid the pitfalls described by those already engaged in VR research. Furthermore, although many research endeavors may benefit from use of VR, there are just as many research questions whose study would not be aided by VR, and for which, in fact, the technology might detract. Thus, though VR is novel and appealing, we should thoughtfully evaluate whether it is the right tool in our toolbox before developing new applications. It is also essential to note that while researchers have explicitly validated the use of VR for research in some domains of study, it is necessary to establish that new VR paradigms do indeed manipulate, or measure, intended variables.

6 | CONCLUSION

VR is a novel tool in health psychologists' toolbox with much-untapped potential. Here, we identify five key advantages of using VR as a research tool: *data collection*, *realism*, *experimental control*, *adaptability*, and *mobility* (DREAM). It is our hope that VR will be used to tackle research questions that could benefit from one or more of these advantages. In this paper we have showcased some of the ways that VR has successfully been used in previous research and we hope that health psychologists will consider it as an option more frequently in future. Although this review is not comprehensive, we hope it will inspire researchers to consider whether and how VR might be used to augment their own research programs or answer currently impracticable research questions.

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REFERENCES

Ahn, S. J., Hahm, J. M., & Johnsen, K. (2019). Feeling the weight of calories: Using haptic feedback as virtual exemplars to promote risk perception among young females on unhealthy snack choices. *Media Psychology*, *22*(4), 626–652. https://doi.org/10.1080/15213269.2018.1492939

Ammann, J., Hartmann, C., Peterhans, V., Ropelato, S., & Siegrist, M. (2020). The relationship between disgust sensitivity and behaviour: A virtual reality study on food disgust. *Food Quality and Preference*, *80*, 103833. https://doi.org/10.1016/j.foodqual.2019.103833

Bailenson, J. (2018a). *Experience on demand: What virtual reality is, how it works, and what it can do*. WW Norton & Company.

Bailenson, J. (2018b). Protecting nonverbal data tracked in virtual reality. *JAMA Pediatrics*, *172*(10), 905–906. https://doi.org/10.1001/jamapediatrics.2018.1909

Baumeister, R. F., Vohs, K. D., & Funder, D. C. (2007). Psychology as the science of self-reports and finger movements: Whatever happened to actual behavior?. *Perspectives on Psychological Science*, *2*(4), 396–403. https://doi.org/10.1111/j.1745-6916.2007.00051.x

Blascovich, J. (2002). A theoretical model of social influence for increasing the utility of collaborative virtual environments. *Proceedings of the 4th international conference on Collaborative virtual environments*, 25–30. https://dl.acm.org/doi/pdf/10.1145/571878.571883

Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Target article: Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry*, *13*(2), 103–124. https://psycnet.apa.org/doi/10.1207/S15327965PLI1302_01

Boumenir, Y., Kadri, A., Suire, N., Mury, C., & Klinger, E. (2014). Impact of simulated low vision on perception and action. *International Journal of Child Health and Human Development*, *7*(4), 159–174.

Carl, E., Stein, A. T., Levihn-Coon, A., Pogue, J. R., Rothbaum, B., Emmelkamp, P., Asmundson, G. J. G., Carlbring, P., & Powers, M. B. (2019). Virtual reality exposure therapy for anxiety and related disorders: A meta-analysis of randomized controlled trials. *Journal of Anxiety Disorders*, *61*, 27–36. https://doi.org/10.1016/j.janxdis.2018.08.003

Cheah, C. S. L., Barman, S., Vu, K. T. T., Jung, S. E., Mandalapu, V., Masterson, T. D., Zuber, R. J., Boot, L., Gong, J., & Gong, J. (2020). Validation of a virtual reality buffet environment to assess food selection processes among emerging adults. *Appetite 153*, 104741. https://doi.org/10.1016/j.appet.2020.104741

Cipresso, P., Giglioli, I. A. C., Raya, M. A., & Riva, G. (2018). The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Frontiers in Psychology*, *9*, 2086. https://doi.org/10.3389/fpsyg.2018.02086

Cummings, J. J., & Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology*, *19*(2), 272–309. https://doi.org/10.1080/15213269.2015.1015740

Davis, A. L., Avis, K. T., & Schwebel, D. C. (2013). The effects of acute sleep restriction on adolescents' pedestrian safety in a virtual environment. *Journal of Adolescent Health*, *53*(6), 785–790. https://doi.org/10.1016/j.jadohealth.2013.07.008

De Bruijn, G.-J., de Vries, J., Bolman, C., & Wiers, R. (2020). (No) escape from reality? Cigarette craving in virtual smoking environments. *Journal of Behavioral Medicine*, *44*, 138–143. https://doi.org/10.1007/s10865-020-00170-1

De-Juan-Ripoll, C., Soler-Domínguez, J. L., Guixeres, J., Contero, M., Álvarez Gutiérrez, N., & Alcañiz, M. (2018). Virtual reality as a new approach for risk taking assessment. *Frontiers in Psychology*, *9*, 2532. https://doi.org/10.3389/fpsyg.2018.02532

Diaz-Orueta, U., Blanco-Campal, A., Lamar, M., Libon, D. J., & Burke, T. (2020). Marrying past and present neuropsychology: Is the future of the process-based approach technology-based?. *Frontiers in Psychology*, *11*, 361. https://doi.org/10.3389/fpsyg.2020.00361

Ducheneaut, N., & Moore, R. J. (2004). The social side of gaming. In *Proceedings of the 2004 ACM conference on Computer supported cooperative work* 360-369. https://doi.org/10.1145/1031607.1031667

Eijlers, R., Utens, E. M. W. J., Staals, L. M., de Nijs, P. F. A., Berghmans, J. M., Wijnen, R. M. H., Hillegers, M. H. J., Dierckx, B., & Legerstee, J. S. (2019). Systematic review and meta-analysis of virtual reality in pediatrics. *Anesthesia & Analgesia*, *129*(5), 1344–1353.https://doi.org/10.1213%2FANE.0000000000004165

Ferrer-Garcia, M., Garcia-Rodriguez, O., Gutiérrez-Maldonado, J., Pericot-Valverde, I., & Secades-Villa, R. (2010). Efficacy of virtual reality in triggering the craving to smoke: Its relation to level of presence and nicotine dependence. *Studies in Health Technology and Informatics*, *154*, 123–127.

Ferrer-Garcia, M., Porras-Garcia, B., González-Ibañez, C., Gracia-Blanes, M., Vilalta-Abella, F., Pla-Sanjuanelo, J., Riva, G., Dakanalis, A., Achotegui-Loizate, J., Talarn-Caparrós, A., Ribas-Sabate, J., Andreu-Gracia, A., Díaz-Marsa, M., Monràs-Arnau, M., Serrano-Troncoso, E., Treasure, J., & Gutiérrez-Maldonado, J. (2017). Does owning a "fatter" virtual body increase body anxiety in college students?. *Annual Review of CyberTherapy and Telemedicine*, *15*, 147–153.

Fox, J., Arena, D., & Bailenson, J. N. (2009). Virtual reality. *Journal of Media Psychology*, *21*(3), 95–113. https://psycnet.apa.org/doi/10.1027/1864-1105.21.3.95

Fox, J., & Bailenson, J. N. (2009). Virtual self-modeling: The effects of vicarious reinforcement and identification on exercise behaviors. *Media Psychology*, *12*(1), 1–25. https://doi.org/10.1080/15213260802669474

Franklin, J. C., Huang, X., & Bastidas, D. (2019). Virtual reality suicide: Development of a translational approach for studying suicide causes. *Behaviour Research and Therapy*, *120*, 103360. https://doi.org/10.1016/j.brat.2018.12.013

Freeman, D., Evans, N., Lister, R., Antley, A., Dunn, G., & Slater, M. (2014). Height, social comparison, and paranoia: An immersive virtual reality experimental study. *Psychiatry Research*, *218*(3), 348–352. https://doi.org/10.1016/j.psychres.2013.12.014

Fujita, K. (2008). Seeing the forest beyond the trees: A construal-level approach to self-control. *Social and Personality Psychology Compass*, *2*(3), 1475–1496. https://doi.org/10.1111/j.1751-9004.2008.00118.x

Ghiţă, A., Ferrer-Garcia, M., & Gutiérrez-Maldonado, J. (2017). Behavioral, craving, and anxiety responses among light and heavy drinking college students in alcohol-related virtual environments. *Annual Review of Cybertherapy and Telemedicine*, *15*, 135–140.

Hadley, W., Houck, C., Brown, L. K., Spitalnick, J. S., Ferrer, M., & Barker, D. (2019). Moving beyond role-play: Evaluating the use of virtual reality to teach emotion regulation for the prevention of adolescent risk behavior within a randomized pilot trial. *Journal of Pediatric Psychology*, *44*(4), 425–435. https://doi.org/10.1093/jpepsy/jsy092

Hagerman, C. J., Ferrer, R. A., Klein, W. M. P., & Persky, S. (2019). Association of parental guilt with harmful versus healthful eating and feeding from a virtual reality buffet. *Health Psychology*, *39*(3), 199–208. https://doi.org/10.1037/hea0000831

Hirsh, A. T., Alqudah, A. F., Stutts, L. A., & Robinson, M. E. (2008). Virtual human technology: Capturing sex, race, and age influences in individual pain decision policies. *Pain*, *140*(1), 231–238. https://doi.org/10.1016/j.pain.2008.09.010

Hirsh, A. T., George, S. Z., & Robinson, M. E. (2009). Pain assessment and treatment disparities: A virtual human technology investigation. *Pain*, *143*(1–2), 106–113. https://doi.org/10.1016/j.pain.2009.02.005

Howard, M. C. (2017). A meta-analysis and systematic literature review of virtual reality rehabilitation programs. *Computers in Human Behavior*, *70*, 317–327. https://doi.org/10.1016/j.chb.2017.01.013

Indovina, P., Barone, D., Gallo, L., Chirico, A., De Pietro, G., & Giordano, A. (2018). Virtual reality as a distraction intervention to relieve pain and distress during medical procedures. *The Clinical Journal of Pain*, *34*(9), 858–877. https://doi.org/10.1097/ajp.0000000000000599

Jakobsson, M., & Taylor, T. L. (2003). The Sopranos meets EverQuest: Social networking in massively multiplayer online games. *Proceedings of the 2003 Digital Arts and Culture (DAC) Conference*, Melbourne, Australia,81–90.

Janouch, C., Drescher, U., Wechsler, K., Haeger, M., Bock, O., & Voelcker-Rehage, C. (2018). Cognitive-motor interference in an ecologically valid street crossing scenario. *Frontiers in Psychology*, *9*, 602. https://doi.org/10.3389/fpsyg.2018.00602

Jouriles, E. N., Rosenfield, D., Yule, K., Sargent, K. S., & McDonald, R. (2016). Predicting high-school students' bystander behavior in simulated dating violence situations. *Journal of Adolescent Health*, *58*(3), 345–351. https://doi.org/10.1016/j.jadohealth.2015.11.009

Kemeny, A., Chardonnet, J.-R., & Colombet, F. (2020). Reducing cybersickness. In *Getting rid of cybersickness* (pp. 93–132). Springer.

Kenney, M. P., & Milling, L. S. (2016). The effectiveness of virtual reality distraction for reducing pain: A meta-analysis. *Psychology of Consciousness: Theory, Research, and Practice*, *3*(3), 199–210. https://psycnet.apa.org/doi/10.1037/cns0000084

Kim, A. E., Nonnemaker, J. M., Loomis, B. R., Baig, A., Hill, E., Holloway, J. W., Farrelly, M. C., & Shafer, P. R. (2013). Influence of tobacco displays and ads on youth: A virtual store experiment. *Pediatrics*, *131*(1), e88–e95. https://doi.org/10.1542/peds.2012-0197

Kim, H., Shin, J. E., Hong, Y.-J., Shin, Y.-B., Shin, Y. S., Han, K., Kim, J.-J., & Choi, S.-H. (2018). Aversive eye gaze during a speech in virtual environment in patients with social anxiety disorder. *Australian and New Zealand Journal of Psychiatry*, *52*(3), 279–285. https://doi.org/10.1177/0004867417714335

Kothgassner, O. D., Goreis, A., Kafka, J. X., Kaufmann, M., Atteneder, K., Beutl, L., Hennig-Fast, K., Hlavacs, H., & Felnhofer, A. (2019). Virtual social support buffers stress response: An experimental comparison of real-life and virtual support prior to a social stressor. *Journal of Behavior Therapy and Experimental Psychiatry*, *63*, 57–65. https://doi.org/10.1016/j.jbtep.2018.11.003

Kotlyar, M., Vogel, R. I., Dufresne, S. R., Mills, A. M., & Vuchetich, J. P. (2020). Effect of nicotine lozenge use prior to smoking cue presentation on craving and withdrawal symptom severity. *Drug and Alcohol Dependence*, *206*, 107706. https://doi.org/10.1016/j.drugalcdep.2019.107706

Kurtz, M. M., Baker, E., Pearlson, G. D., & Astur, R. S. (2007). A virtual reality apartment as a measure of medication management skills in patients with schizophrenia: A pilot study. *Schizophrenia Bulletin*, *33*(5), 1162–1170. https://doi.org/10.1093/schbul/sbl039

Kyaw, B. M., Posadzki, P., Paddock, S., Car, J., Campbell, J., & Tudor Car, L. (2019). Effectiveness of digital education on communication skills among medical students: Systematic review and meta-analysis by the digital health education collaboration. *Journal of Medical Internet Research*, *21*(8), e12967. https://doi.org/10.2196/12967

Li, B. J., & Bailenson, J. N. (2018). Exploring the influence of haptic and olfactory cues of a virtual donut on satiation and eating behavior. *Presence: Teleoperators and Virtual Environments*, *26*(3), 337–354.

Li, B. J., Bailenson, J. N., Pines, A., Greenleaf, W. J., & Williams, L. M. (2017). A public database of immersive VR videos with corresponding ratings of arousal, valence, and correlations between head movements and self report measures. *Frontiers in Psychology*, *8*, 2116. https://doi.org/10.3389/fpsyg.2017.02116

Liu, L., Miyazaki, M., & Watson, B. (1999). Norms and validity of the DriVR: A virtual reality driving assessment for persons with head injuries. *CyberPsychology and Behavior*, *2*(1), 53–67. https://doi.org/10.1089/cpb.1999.2.53

Lofgren, E. T., & Fefferman, N. H. (2007). The untapped potential of virtual game worlds to shed light on real world epidemics. *The Lancet Infectious Diseases*, *7*(9), 625–629. https://doi.org/10.1016/s1473-3099(07)70212-8

Lok, B., Ferdig, R. E., Raij, A., Johnsen, K., Dickerson, R., Coutts, J., Stevens, A., & Lind, D. S. (2006). Applying virtual reality in medical communication education: Current findings and potential teaching and learning benefits of immersive virtual patients. *Virtual Reality*, *10*(3–4), 185–195. https://doi.org/10.1007/s10055-006-0037-3

Lucas, G. M., Gratch, J., King, A., & Morency, L.-P. (2014). It's only a computer: Virtual humans increase willingness to disclose. *Computers in Human Behavior*, *37*, 94–100. https://doi.org/10.1016/j.chb.2014.04.043

Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews Neuroscience*, *10*(6), 434–445. https://doi.org/10.1038/nrn2639

Maloney, D., & Freeman, G. (2020). Falling asleep together: What makes activities in social virtual reality meaningful to users. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 510–521. https://doi.org/10.1145/3410404.3414266

Maloney, D., Zamanifard, S., & Freeman, G. (2020). Anonymity vs. familiarity: Self-disclosure and privacy in social virtual reality. *26th ACM Symposium on Virtual Reality Software and Technology*, 1–9. https://doi.org/10.1145/3385956.3418967

Mast, M. S., Hall, J. A., & Roter, D. L. (2007). Disentangling physician sex and physician communication style: Their effects on patient satisfaction in a virtual medical visit. *Patient Education and Counseling*, *68*(1), 16–22. https://doi.org/10.1016/j.pec.2007.03.020

Matamala-Gomez, M., Maselli, A., Malighetti, C., Realdon, O., Mantovani, F., & Riva, G. (2020). *Body illusions for mental health: A systematic review*. https://psyarxiv.com/mk69x/download?format=pdf

McDonald, D. D., Walsh, S., Vergara, C., & Gifford, T. (2013). Effect of a virtual pain coach on pain management discussions: A pilot study. *Pain Management Nursing*, *14*(4), 200–209. https://doi.org/10.1016/j.pmn.2011.03.004

Miller, M. R., Herrera, F., Jun, H., Landay, J. A., & Bailenson, J. N. (2020). Personal identifiability of user tracking data during observation of 360-degree VR video. *Scientific Reports*, *10*, 17404. https://doi.org/10.1038/s41598-020-74486-y

Morina, N., Ijntema, H., Meyerbröker, K., & Emmelkamp, P. M. G. (2015). Can virtual reality exposure therapy gains be generalized to real-life? A meta-analysis of studies applying behavioral assessments. *Behaviour Research and Therapy*, *74*, 18–24. https://doi.org/10.1016/j.brat.2015.08.010

Mühlberger, A., Jekel, K., Probst, T., Schecklmann, M., Conzelmann, A., Andreatta, M., Rizzo, A. A., Pauli, P., & Romanos, M. (2020). The influence of methylphenidate on hyperactivity and attention deficits in children with ADHD: A virtual classroom test. *Journal of Attention Disorders*, *24*(2), 277–289. https://doi.org/10.1177/1087054716647480

Nagamatsu, L. S., Voss, M., Neider, M. B., Gaspar, J. G., Handy, T. C., Kramer, A. F., & Liu-Ambrose, T. Y. L. (2011). Increased cognitive load leads to impaired mobility decisions in seniors at risk for falls. *Psychology and Aging*, *26*(2), 253–259. https://doi.org/10.1037%2Fa0022929.

Neguț, A., Matu, S. A., Sava, F. A., & David, D. (2016). Virtual reality measures in neuropsychological assessment: A meta-analytic review. *The Clinical Neuropsychologist*, *30*(2), 165–184. https://doi.org/10.1080/13854046.2016.1144793

Nir-Hadad, S. Y., Weiss, P. L., Waizman, A., Schwartz, N., & Kizony, R. (2017). A virtual shopping task for the assessment of executive functions: Validity for people with stroke. *Neuropsychological Rehabilitation*, *27*(5), 808–833. https://doi.org/10.1080/09602011.2015.1109523

O'Connor, D. B., Thayer, J. F., & Vedhara, K. (2021). Stress and health: A review of psychobiological processes. *Annual Review of Psychology*, *72*, 663–688. https://doi.org/10.1146/annurev-psych-062520-122331

Opriş, D., Pintea, S., García-Palacios, A., Botella, C., Szamosközi, Ş., & David, D. (2012). Virtual reality exposure therapy in anxiety disorders: A quantitative meta-analysis. *Depression and Anxiety*, *29*(2), 85–93. https://doi.org/10.1002/da.20910

Padilla, M. M., Fernández-Serrano, M. J., Verdejo García, A., & Reyes del Paso, G. A. (2019). Negative social evaluation impairs executive functions in adolescents with excess weight: Associations with autonomic responses. *Annals of Behavioral Medicine*, *53*(4), 383–391. https://doi.org/10.1093/abm/kay051

Pan, X., & Hamilton, A. F. D. C. (2018). Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. *British Journal of Psychology*, *109*(3), 395–417. https://doi.org/10.1111/bjop.12290

Persky, S., & Eccleston, C. P. (2011). Medical student bias and care recommendations for an obese versus non-obese virtual patient. *International Journal of Obesity*, *35*(5), 728–735. https://doi.org/10.1038/ijo.2010.173

Persky, S., Goldring, M. R., Turner, S. A., Cohen, R. W., & Kistler, W. D. (2018). Validity of assessing child feeding with virtual reality. *Appetite*, *123*, 201–207.https://doi.org/10.1016%2Fj.appet.2017.12.007

Persky, S., Kaphingst, K. A., Allen, V. C., Jr, & Senay, I. (2013). Effects of patient-provider race concordance and smoking status on lung cancer risk perception accuracy among African-Americans. *Annals of Behavioral Medicine*, *45*(3), 308–317. https://doi.org/10.1007/s12160-013-9475-9

Persky, S., & Street Jr, R. L. (2015). Evaluating approaches for communication about genomic influences on body weight. *Annals of Behavioral Medicine*, *49*(5), 675–684. https://doi.org/10.1007/s12160-015-9701-8

Phillips, M., Molnár-Gábor, F., Korbel, J. O., Thorogood, A., Joly, Y., Chalmers, D., Townend, D., & Knoppers, B. M. (2020). Genomics: Data sharing needs an international code of conduct. *Nature*, *578*(7793), 31–33. https://doi.org/10.1038/d41586-020-00082-9

Porcino, T. M., Clua, E., Trevisan, D., Vasconcelos, C. N., & Valente, L. (2017). Minimizing cyber sickness in head mounted display systems: Design guidelines and applications. *IEEE 5th International Conference on Serious Games and Applications for Health (SeGAH)*, 1–6.

Riches, S. P., Aveyard, P., Piernas, C., Rayner, M., & Jebb, S. A. (2019). Optimising swaps to reduce the salt content of food purchases in a virtual online supermarket: A randomised controlled trial. *Appetite*, *133*, 378–386.https://doi.org/10.1016%2Fj.appet.2018.11.028

Riva, G., Wiederhold, B. K., & Mantovani, F. (2019). Neuroscience of virtual reality: From virtual exposure to embodied medicine. *Cyberpsychology, Behavior, and Social Networking*, *22*(1), 82–96. https://doi.org/10.1089/cyber.2017.29099.gri

Rizzo, A., Thomas Koenig, S., & Talbot, T. B. (2019). Clinical results using virtual reality. *Journal of Technology in Human Services*, *37*(1), 51–74. https://doi.org/10.1037/neu0000405

Rizzo, A. S., & Koenig, S. T. (2017). Is clinical virtual reality ready for primetime? *Neuropsychology*, *31*(8), 877–899.

Rodrigues, J., Studer, E., Streuber, S., Meyer, N., & Sandi, C. (2020). Locomotion in virtual environments predicts cardiovascular responsiveness to subsequent stressful challenges. *Nature Communications*, *11*, 5904. https://doi.org/10.1038/s41467-020-19736-3

Rodríguez-Barranco, M., Gil, F., Hernández, A. F., Alguacil, J., Lorca, A., Mendoza, R., Gómez, I., Molina-Villalba, I., González-Alzaga, B., Aguilar-Garduño, C., Rohlman, D. S., & Lacasaña, M. (2016). Postnatal arsenic exposure and attention impairment in school children. *Cortex*, *74*, 370–382.

Saladin, M. E., Brady, K. T., Graap, K., & Rothbaum, B. O. (2006). A preliminary report on the use of virtual reality technology to elicit craving and cue reactivity in cocaine dependent individuals. *Addictive Behaviors*, *31*(10), 1881–1894. https://doi.org/10.1016/j.cortex.2014.12.018

Shen, J., McClure, L. A., & Schwebel, D. C. (2015). Relations between temperamental fear and risky pedestrian behavior. *Accident Analysis & Prevention*, *80*, 178–184. https://doi.org/10.1016/j.aap.2015.04.011

Shen, M. J., Peterson, E. B., Costas-Muñiz, R., Hernandez, M. H., Jewell, S. T., Matsoukas, K., & Bylund, C. L. (2018). The effects of race and racial concordance on patient-physician communication: A systematic review of the literature. *Journal of Racial and Ethnic Health Disparities*, *5*(1), 117–140. https://doi.org/10.1007/s40615-017-0350-4

Short, S. E., & Mollborn, S. (2015). Social determinants and health behaviors: Conceptual frames and empirical advances. *Current Opinion in Psychology*, *5*, 78–84. https://doi.org/10.1016/j.copsyc.2015.05.002

Simões, M., Mouga, S., Pereira, A. C., de Carvalho, P., Oliveira, G., & Castelo-Branco, M. (2020). Virtual reality immersion rescales regulation of interpersonal distance in controls but not in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *50*, 4317–4328. https://doi.org/10.1007/s10803-020-04484-6

Simon, J., Etienne, A. M., Bouchard, S., & Quertemont, E. (2020). Alcohol craving in heavy and occasional alcohol drinkers after cue exposure in a virtual environment: The role of the sense of presence. *Frontiers in Human Neuroscience*, *14*, 124. https://doi.org/10.3389%2Ffnhum.2020.00124.

Susindar, S., Sadeghi, M., Huntington, L., Singer, A., & Ferris, T. K. (2019). The feeling is real: Emotion elicitation in virtual reality. *Proceedings of the Human Factors and Ergonomics Society*, *63*(1), 252–256.https://doi.org/10.1177%2F1071181319631509.

Ung, C.-Y., Menozzi, M., Hartmann, C., & Siegrist, M. (2018). Innovations in consumer research: The virtual food buffet. *Food Quality and Preference*, *63*, 12–17. https://doi.org/10.1016/j.foodqual.2017.07.007

van der Vorst, H., Schuck, K., Engels, R. C. M. E., & Hermans, R. C. J. (2014). Children's responses towards alcohol in virtual reality: Associations between parental alcohol use, drinking selections and intentions to drink. *Journal of Substance Use*, *19*(6), 429–435. https://doi.org/10.3109/14659891.2013.852257

Ventura, S., Baños, R. M., Botella, C., & Mohamudally, N. (2018). Virtual and augmented reality: New frontiers for clinical psychology. In *State of the art virtual reality and augmented reality knowhow* (pp. 99-118). IntechOpen. https://doi.org/10.5772%2Fintechopen.74344

Wang, L., Christensen, J. L., Jeong, D. C., & Miller, L. C. (2019). Virtual prognostication: When virtual alcohol choices predict change in alcohol consumption over 6-months. *Computers in Human Behavior*, *90*, 388–396. https://doi.org/10.1016/j.chb.2018.08.025

Waterlander, W. E., Jiang, Y., Steenhuis, I. H. M., & Ni Mhurchu, C. (2015). Using a 3D virtual supermarket to measure food purchase behavior: A validation study. *Journal of Medical Internet Research*, *17*(4), e107. https://doi.org/10.2196/jmir.3774

Williams, L. M., Pines, A., Goldstein-Piekarski, A. N., Rosas, L. G., Kullar, M., Sacchet, M. D., Bailenson, J., Lavori, P. W., Dagum, P., Wandell, B., Correa, C., Greenleaf, W., Suppes, T., Perry, L. M., Smyth, J. M., Lewis, M. A., Venditti, E. M., Snowden, M., Simmons, J. M., & Ma, J. (2018). The ENGAGE study: Integrating neuroimaging, virtual reality and smartphone sensing to understand self-regulation for managing depression and obesity in a precision medicine model. *Behaviour Research and Therapy*, *101*, 58–70. https://doi.org/10.1016/j.brat.2017.09.012

Wilson, C. J., & Soranzo, A. (2015). The use of virtual reality in psychology: A case study in visual perception. *Computational and mathematical methods in medicine*, *2015*, 151702. https://doi.org/10.1155/2015/151702.2015

Yaremych, H. E., & Persky, S. (2019). Tracing physical behavior in virtual reality: A narrative review of applications to social psychology. *Journal of Experimental Social Psychology*, *85*, 103845. https://doi.org/10.1016/j.jesp.2019.103845

Ydo, E. (2020). *VR hygiene and safety: Everything you need to know. Serious VR*. https://www.linkedin.com/pulse/vr-hygiene-safety-everything-you-need-know-evelien-ydo/

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