Virtual Reality and Emotion: A 5-Year Systematic Review of Empirical Research (2015-2019)

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In popular and academic literatures, we find no shortage of use cases for Virtual Reality (VR). For example, the technology has been applied to trauma therapy (Rothbaum et al., 2001), acting (Slater et al., 2000), physical rehabilitations (Nilsson et al., 2012), learning about complex societal issues (Markowitz et al., 2018), and building empathy (Herrera et al., 2018), all with evidence that suggests VR experiences can lead to positive social and psychological outcomes (e.g., recovery from trauma, increased learning about climate change). VR provides high fidelity sensory information (Ahn et al., 2016), and encourages people to act naturally and form experiences like they would without mediation. The brain often treats a virtual experience in a similar manner to a real experience (Blascovich et al., 2002; Slater et al., 2006), which can have important implications for how we think about people, interactions with technology, and the role of VR-mediation in social and psychological processes.

The central aim of this chapter is to identify how immersive VR can be used as a tool to inform our understanding of emotion and how emotion operates as a mechanism for VR effects. To accomplish this goal, we conducted a 5-year systematic review of the VR and emotion literature (2015-2019), while also reviewing seminal pieces from outside the 5-year timeframe to provide additional perspective on the more recent work. This decision to start the review in 2015 was purposeful in order to focus our review on recent, not historical trends in VR and emotion research, and to identify empirical studies that are concerned with three types of research: (1) the connection between VR and emotion from a emotion regulation perspective (e.g., mood induction, clinical applications), (2) studies that treat emotions as a mechanism to evaluate social or psychological phenomena, and (3) studies concerned with a deeper understanding of emotions

or emotion theory. Our perspective draws on evidence from communication research, psychology, and human-computer interaction to achieve these aims. We ground our investigation in an overview of immersive VR and discuss current debates in emotion research. Finally, we attempt to make connections across fields by drawing on literature since 2015.

What is Immersive VR?

Immersive VR is a communication medium that uses specialized hardware (e.g., a head-mounted display) and sensory feedback (e.g., spatialized audio) to create a virtual experience that surrounds users, making the virtual world appear and feel comparable to the physical world. VR is qualitatively different from other media such as the mobile phone, television, or non-immersive video games, largely because one uses natural body movements to engage with a scene, and receives perceptual updates to those movements in a way that is congruent with our sensorimotor system (Loomis, 1992). From a hardware standpoint, salient features of VR include immersive VR's use of stereoscopic displays in headsets; that is, the controllers which provide various forms of haptic feedback from vibration and sometimes forced feedback, and sensors which map physical spaces in order to update one's body position during movement. Immersive VR's primary appeal, however, comes from the creation of experiences that are psychologically rich, meaningful, and often long-lasting.

Three important constructs central to understanding the psychological processes involved in a VR experience are presence, immersion, and embodiment. Presence is the psychological feeling of "being there" in a virtual environment (Heeter, 1992; Lombard & Ditton, 1997). When VR is built and conceived well, people suspend beliefs that their experience is mediated and instead, they act naturally despite wearing a head-mounted display, controllers, sensors, and other equipment. Presence can be recorded through self-report measures that indicate the degree

to which people feel psychologically attached and connected to the virtual experience, social entities in the experience, or other objects (Lee, 2004). For example, in a four-study paper, Markowitz and colleagues (2018) had participants experience a virtual ocean affected by climate change (e.g., witnessing increased algae growth and decreased marine life, acidified oceans over time). Participants rated their agreement with psychological presence questions such as "I felt surrounded by the virtual world" and measured how much people knew about ocean acidification before and after the immersive experience. In some cases, the rate of psychological presence in the underwater virtual world was linked to how much people learned about climate change in VR (Markowitz et al. 2018, Study 2). Presence, therefore, is a construct for how much people feel attached to virtual objects or experiences (Biocca, 1997; Oh et al., 2018) and how much people feel like they can act in the virtual world (Diemer et al., 2015; Lee, 2004).

A second crucial component of a virtual experience is immersion, or how well the VR technology approximates typical human actions and behaviors. For people to treat virtual experiences as real, VR technology supporting head, hand, and body movements must track actions precisely and be rendered on-screen without lag or disfigurement. When immersive VR technology fails to achieve this, people may endure simulator sickness (Kennedy et al., 1993) or doubt the fidelity of their experience. Immersion and presence are tightly linked, as research suggests immersive experiences with better tracking and stereoscopic visuals are perceived as more psychologically rich than less immersive experiences (Cummings & Bailenson, 2016). The overall medium-sized effect of the relationship, ($r = .316$, $p < .001$), indicates that immersion is a nontrivial aspect of VR and related to presence, but also clearly independent from it.

A third crucial element of an immersive VR experience is embodiment, or the ability for people to adopt the perspective and physicality of objects, entities, or figures in the virtual world.

Such objects, entities, or figures might be drastically different from a person's form in the physical world (e.g., a fantastical representation such as a coral; Markowitz et al. 2018) or certain aspects of a virtual self might be altered (e.g., height, weight, race). For example, Yee and Bailenson (2007) had people adopt an attractive (Study 1) or taller avatar (Study 2) and communicate with a partner in immersive VR. The evidence suggests that people conform to the characteristics of their avatar (called the Proteus Effect): people with more attractive avatars disclosed more intimately to partners than people with less attractive avatars, and people with taller avatars behaved more confidently and aggressively than people with shorter avatars in a negotiation game (for other evidence of body transfer, see Kilteni, Normand, Sanchez-Vives, & Slater, 2012; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). The Proteus Effect has been supported at scale in a meta-analysis of 46 experiments (*r*s between 0.22 and 0.26) (Ratan et al., 2019). As such, embodiment is an important affordance of immersive VR than can reveal social and psychological processes.

Together, presence, immersion, and embodiment are fundamental to immersive VR and allow researchers to test how people think, feel, and respond to virtual stimuli or situations. While other media, such as video games, might offer the ability to adopt an avatar in gameplay or the technology can approximate a user's movements with a joystick, these features and affordances are not instrumental for the medium's success in creating rich and meaningful experiences. People continue to play and enjoy video games that are clearly mediated (e.g., Animal Crossing), but VR experiences with low levels of presence and immersion are often perceived as less compelling and vivid (Bekrater-Bodmann et al., 2014; Ismail & Shimada, 2016; Shimada et al., 2009). While immersive VR does not have a monopoly on presence, immersion,

and embodiment, these characteristics are crucial to the medium's success in producing impactful experiences (Bailenson, 2018; Karafotias et al., 2017).

Of critical importance to the focus on this volume, presence, immersion, and embodiment relate to emotion in two complementary ways. Presence and immersion can enhance the *emotional intensity* of an experience. People who feel like they are a part of the virtual world tend to connect more deeply to it. Experiencing virtual technology with high degrees of fidelity often can have enhanced psychological effects (Baños et al., 2004; Riva et al., 2007). Embodiment can also make people feel *a range of different emotions* that they might fail to experience outside of an embodied virtual experience. For example, embodying animals can make people feel more emotionally connected to nature (Ahn et al., 2016). Embodiment can facilitate perspective-taking that encourages people to feel closer to objects or experiences that are typically foreign. Taken together, the constructs of presence, immersion, and embodiment can intensify psychological effects of emotion and/or make people experience different emotions that might be difficult to evoke in the physical world. Before we delve more deeply into the research linking VR technology and emotion, it is helpful to briefly review our perspective on emotion research from cognitive and social psychology.

Perspectives on Emotion: Classical and Constructed Views

In her canonical work of emotion, psychologist Lisa Feldman Barrett describes theories on how emotions are created. Barrett (2017) argues that the *classical view* describes how emotions are fixed in the brain and automatically revealed when a stimulus or event invokes them. According to this perspective, emotions are a "brute reflex" to what happens in the world and measurable cues (e.g., smiling, verbal expressions of affect, facial movements) are traces of emotions at work (Barrett, 2017, p. xi). On the other hand, as the more contemporary *theory of*

constructed emotions suggests, emotions may be socially constructed and expressed as a reflection of prior experience, adaptivity, and contextual factors (Barrett et al., 2019) (see Chapter 1 of this volume for more detail on each).

The classical theory of emotions — primarily expressed by the face — conceptualizes the emotion process in a linear manner: built-in emotions are triggered by some activity or experience, which is then then reflected by observable traces of behavior (e.g., facial movements, verbal output). The constructed view suggests emotions belong to categories (e.g., the category of *fear* might contain many emotional expressions and traces of behavior compared to the category of *happiness*). Categories can change over time, are context-dependent, and vary in terms of their behavioral output (e.g., fear might be expressed in the face but not body movements). The current chapter acknowledges the long and influential history of the classical view (Ekman, 2001, 2016; Ekman & Oster, 1979), while arguing that the constructed view of emotions most appropriately captures how emotions are reflected in experiences that are mediated and involve immersive technology. That is, we do not believe that a one-size-fits-all view of immersive media should apply to emotion, nor should a one-size-fits-all view of emotion apply to experiences with immersive media.

The State of Immersive VR and Emotion Research

The remainder of this chapter covers studies that address the connection between VR and emotion. We began by systematically reviewing studies available to the University of Oregon library system in search of trends that could offer insights about how researchers study these topics together. Our inclusion criteria for this systematic review were: (1) articles must contain the phrase “virtual reality” as a subject and both of the terms “emotion” and “emotions” in any part of the article (e.g., title, abstract, main text), (2) articles must be empirical (not review

papers) and experimental in nature, (3) articles must have at least 10 participants in the study, and (4) articles must use VR systems with hand or head tracking in which the rendered scene updates based on those movements. The latter criterion allowed the inclusion of most studies with head or hand tracking systems, including Head Mounted Displays, the Kinect, and Cave Automatic Virtual Environment (CAVE), but excluded mobile games, desktop VR without hand or head tracking, non-interactive movies rendered in stereo, and other custom hardware systems.

We limited results to articles published in the past 5 years (2015-2019) to evaluate recent, not historical trends. The median update time for systematic reviews is five years or more (shorter than meta-analyses), suggesting that a five-year window is reasonable for our research aim (Bashir et al., 2018). We also selected articles from the past 5 years to ensure that VR hardware was relatively consistent across studies (e.g., HTC Vive, Oculus Rift). Using a broader scope might introduce noise into the analysis that does not reflect the relationship between VR and emotion, but instead, evidence that reflects available technology at the time. Note, while Table 1 covers research studies from 2015-2019 indexed by the University of Oregon library system, additional studies are presented in the text. We included studies outside of the 5-year review timeframe to demonstrate the history of VR and emotion research, and encourage future efforts toward an empirical meta-analysis that controls for available hardware, research group, and time-dependent covariates.

From an initial collection of 172 papers, we retained 65 papers (72 individual studies), which cumulatively contained 6,362 participants. It is critical to note that while this is a representative sample of VR and emotion research, it is far from exhaustive. We did not email authors, reverse citation counts on each paper, and use other strategies that one might perform in a formal meta-analysis. Instead, we offer a rough approximation of the current work in the field.

We collected several datapoints on each paper, including the number of participants per study, how emotion or emotions were measured, and whether presence was measured or not (Table 1). We did not code for levels of immersion or if embodiment was a key part of the study. The number of participants (Ps) per study were not normally distributed but positively skewed (*M* = 88.36 Ps, *SD* = 78.03 Ps; Q1 = 40.00 Ps, *Mdn* = 59.00 Ps, Q3 = 112.75 Ps, skewness = 2.11, kurtosis = 5.28). Less than half of the studies measured presence (32/72; 44.4%).

We decided to organize our review based on the dominant themes that emerged from our collection articles. Specifically, our review considered if studies attended to dynamics of emotion regulation (e.g., mood induction, clinical applications such as treating phobias), if the studies used immersive VR to understand emotions as a mechanism for other social or psychological processes (e.g., measuring distress while they study's main research interest was to evaluate VR for empathy), or if studies focused on a deeper understanding of emotion theory and used immersive VR for this purpose. We review each theme below.

Emotion Regulation

Approximately one-fifth of the studies in our review connected VR to dynamics of emotion regulation (16/72; 22.22%). Specifically, immersive VR was often applied in mood induction studies and in the evaluation of developmental or emotion issues (e.g., anxiety disorders, phobias). We classify mood induction studies under emotion regulation since they often use immersive VR to change participant mood states, ultimately suggesting the medium has potential to modify how people think or feel about an experience. For example, Felnhofer and colleagues (2015) state, "Given the difficulty of some individuals to imagine specific situations – a problem commonly encountered in imagery exposure psychotherapy (c.f., Vincelli, 1999) – using an immersive VE would undoubtedly help users to imagine themselves in the

given situation" (p. 55). Mood induction studies in VR are indeed different from studies that evaluate clinical populations or clinical diagnoses in virtual worlds, but both are presented here for completeness.

Mood induction. Mood induction research facilitates positive, negative, or neutral experiences for people based on a variety of experimental techniques (Westermann et al., 1996). For example, in some cases, people are told to imagine a time when they felt positive, negative, or neutral, watch films that induce different emotions, listen to music that might facilitate different moods, or interact with confederates who are trained to act in a positive, negative, or neutral manner. Mood induction procedures are typically effective, producing medium to large effect sizes in facilitating a desired emotional state (Westermann et al., 1996).

Mood induction procedures have been tested in virtual environments with similar rates of success. The most common mood induction method in VR involves the creation of a virtual park, where people move and experience a variety of environments that evoke different emotions. For example, work by Felnhofer and colleagues (2015) had participants walk around one of five virtual parks created to induce different emotions. Participants randomly assigned to walk the "joy" park were presented with a sunny, daytime scene to induce calmness; "anger" contained sounds of drilling and construction projects to induce annoyance; "boredom" displayed a barren park with few objects in the visual scene; "anxiety" displayed a gloomy park with an owl that attempted to induce eerie feelings; "sadness" contained a dark and gray sky with rain that could be seen and heard. All mood inductions were successful, except for sadness, by measuring self-reported emotions after walking around the virtual park. Research by Baños and colleagues found similar effects using the park or environment manipulation with students (Baños et al., 2006) and adult samples as well (Baños et al., 2012).

Not all studies that use virtual parks as stimuli rely on self-report data, however. Rodríguez, Rey, Clemente, Wrzesien, and Alcañiz (2015) had participants walk through a "sadness" park but assigned them to construe their experience in one of three ways: (1) cognitive reappraisal, where participants had to reflect on their experience but reconfigure it without emotions; (2) emotional regulation, where participants were told to suppress their emotions during the experience; and (3) naturally, without instructions (see Gross, 1998, for similar manipulations with film). Participants without instructions had greater brain activation in regions related to sadness relative to those who reappraised or suppressed emotions. Together, the self-report and neuroimaging findings reveal that immersive VR can be used to test emotion processes. Note, studies that have not used a virtual park for mood induction (e.g., having people inhabit a virtual house called the "House of Relaxation") have resulted in mixed effects in trying to induce discrete emotions of interest (Serrano et al., 2016, 2013). Adequate sample sizes are crucial for statistical power in social science research, especially VR (Lanier et al., 2019), and mixed effects might occur if a study is underpowered.

Clinical applications. Researchers who focus on the clinical side of emotion regulation also use VR to study how people with developmental or emotion issues interact with virtual objects (Lorenzo et al., 2016). For example, Kim and colleagues (2014) compared the performance of children with autism to those of neurotypical development in an interpersonal distance task. Participants indicated if a particular emotion was expressed by an avatar in VR (e.g., anger, disgust, fear, happiness, sadness, surprise) and then moved a joystick toward or away from the avatar (Kim et al., 2015). Those with clinically diagnosed autism approached the "happy" avatar less than those with neurotypical development, a trend consistent with other clinical research (S. Parsons et al., 2004). Researchers have also used immersive VR for

cognitive therapy to overcome phobias (Breuninger et al., 2017; Côté & Bouchard, 2005), such as public speaking (Klinger et al., 2005) and spiders (Garcia-Palacios et al., 2002). In fact, meta-analytic evidence suggests that VR therapy can indeed reduce anxiety symptoms when making pre- to post-test comparisons of exposure therapy (T. D. Parsons & Rizzo, 2008). The effect sizes are quite large (Cohen's $d = 0.95$) across six types of phobias: PTSD, social phobias, arachnophobia (fear of spiders), acrophobia (fear of heights), panic disorders, and aviophobia (fear of flying). The magnitude of such effects are relatively consistent with other psychological treatments (e.g., *in vivo* exposure) toward a phobic target (Cohen's $d = 1.03$), though such *in vivo* treatments outperformed VR treatments (Wolitzky-Taylor et al., 2008). Note, one reason the *in vivo* treatments might have outperformed VR treatments in this early meta-analysis is due to the relatively cumbersome VR hardware and poor visual representation of VR objects at the time.

Finally, a study by academics and medical professionals tested how adolescent burn victims reported pain while removing their wound bandages and having media distractions during this experience (Jeffs et al., 2014). Adolescents either received standard care without mediated distractions, watched a movie during bandage removal, or engaged with a VR experience called SnowWorld. Crucially, those who experienced SnowWorld reported less pain during wound care than those in the video and standard care conditions. Immersive experiences can therefore provide psychological assistance relative to less immersive experiences, "mitigating the severe pain and emotional trauma" associated with such procedures (Jeffs et al., 2014, p. 406). Similar effects have been observed in other studies (Hoffman et al., 2019), demonstrating the many benefits of immersive experiences relative to non-immersive experience for pediatric pain (for a review, see Won et al., 2017).

Together, the prior evidence suggests studies connecting emotion regulation and immersive VR often attempt to induce various moods, suppress fears, and treat trauma. People treat VR experiences as real and can benefit from virtual experiences, such as the examples offered in exposure therapy. More work, however, is needed to evaluate how VR might compare to other media for similar tasks. The most common comparison in empirical studies is immersive VR to desktop (computer-based) VR, but comparing immersive VR to *in vivo* exposure, text narratives, video-based, and different media forms is an underdeveloped area of study.

Emotions as a Mechanism for Psychological Phenomena

The majority of studies in our systematic review used emotions as a mechanism to explain broader social and psychological phenomena (50/72; 69.44%). One area of research that has received substantial attention from VR communities is empathy (Shin & Biocca, 2018). Milk (2015) called VR the "ultimate empathy machine" because the technology can facilitate new perspectives and encourage people to adopt the experience of another race, gender, or personal background. Empathy research largely originates from fields within psychology (see Zaki, 2019, for a review) and is considered a psychosocial experience where people can proxy "the thoughts, feelings, experiences, sensitivities, or perspectives of another entity" (Foxman et al., 2021). Traditional experimental evaluations of empathy encourage people to take the perspective of another by reading about their experience and trying to feel what it is like to adopt their worldview. In immersive VR, however, three main affordances — presence, immersion, and embodiment — can make certain perspective taking possible when experiences in the physical world (e.g., taking the perspective of different ethnical or racial groups) are impossible.

Empathy and perspective taking. Recent evidence suggests that an immersive VR experience can change how people feel towards vulnerable populations (for a review, see

Bailenson, 2018; Stavroulia, 2019). A notable example by Herrera and colleagues (2018) had people take part in an imagine-self perspective-taking task where they read a story about becoming homeless or experienced homelessness in immersive VR. Those who read about becoming homeless internalized information about owing rent, potential eviction if rent was not paid on time, and then eventually losing one's house. The narrative was consistent for those who experienced homelessness in VR, though people could move their head, arms, and engage with the virtual surroundings to feel what it was like being homeless. The results suggest people who experienced homelessness in immersive VR reported more empathy toward the homeless and felt more personal distress than those who read the homelessness narrative. These effects emerged directly after manipulation but dissipated longitudinally. When people were asked about attitudes toward the homeless, however, the effects were longitudinally significant but not immediate. That is, people who became homeless in immersive VR had more positive attitudes toward the homeless — up to two months after the experience — compared to those who read the narrative (though the effect was not significant in the short term).

It is crucial to note that empathy is not an emotion per se, but the result of connecting with another person's or group's emotions (see Foxman et al., 2021). Those who empathize with another often feel and consider others' emotions (e.g., anxiety, sadness) and this form of perspective-taking facilitates strong interpersonal connections. Further, to the degree that VR can enhance, encourage, or develop empathy interpersonally, it can influence the types of emotions people feel, how strongly people feel them, and the impact of such emotions on behavior.

Emotional intensity. Beyond academia and experimental studies, the relationship between VR and emotion has transformed traditional media industries such as news (de la Peña et al., 2010). In 2015, the New York Times (NYT) sent nearly one-million Google Cardboard

headsets (e.g., a virtual reality viewer that works by placing one's smartphone in a cardboard device with lenses) to their subscribers to change how their readership consumed stories, improve storytelling, and to put people inside the news. The Times initially offered three VR news stories of children who were driven from their homes because of war, with the goal of providing the "uncanny feeling of connection with people whose lives are far from our own" (The New York Times Magazine, 2015). The program was repeated the following year after evidence of its success based on the number of people who used the associated NYT VR app and how long they used it (Perez, 2016). Bringing news and emotional content closer to readers has the potential to make people care more intensely about the information they consume. de la Peña and colleagues (2010) suggest that immersive journalism can help to "reinstitute the audience's emotional involvement in current events" and facilitate experiences while engaging with news content (p. 298). Getting people to care and trust news in a digital age is challenging (Thier et al., 2019) and presence and immersion can aid in this effort by amplifying the emotional intensity of an experience. As a result of an immersive VR experience, having people feel like they were a part of a war-torn area might increase their emotional connection to characters in a story and increase the likelihood that they take action to fight against global atrocities.

Emotion Theory

Fewer than 10% of the studies focused on advancing our understanding of emotions through immersive technology (6/72; 8.33%). While these studies differed in their exact empirical aims, they tended to focus on the study of how emotions are made or represented. For example, studies evaluated a profile of emotions to assess how they might appear or be prominent in immersive settings (Chirico & Gaggioli, 2019; Meuleman & Rudrauf, 2018), a database of VR videos that contain arousal ratings, which could be used for future empirical

investigations (Li et al., 2017), and the evaluation of how emotion can be revealed through color (Siamionava et al., 2018). Therefore, while the aims of these studies are different, they are generally concerned with using immersive VR as a lens to achieve a broader understanding of emotions and emotion processes. This is in contrast to many of the earlier studies referenced in our review, which were less concerned with how emotions are generated, developed, or operate, but focus on how immersive VR might transmit emotion or induce a particular mood state, or if immersive VR changes how people feel across unique settings.

Conceptual and Methodological Challenges

Thus far, we reviewed evidence that suggests how researchers study the connection between immersive VR and emotion. As such, it is important to acknowledge constraints in this process and the difficulties of conducting such research. One of the primary challenges associated with any form of emotion research is conceptually defining what emotion means for a particular area of study. In immersive VR, this issue is particularly pronounced. In some studies, emotion is conflated with presence. In other studies, emotion is considered part of the VR experience (e.g., mood induction studies) that should lead to downstream psychological effects. Therefore, conceptual clarity is paramount when related ideas are measured in the same study, without the assumption that one might lead to the other. For example, it is unclear if emotion leads to greater ratings of presence or presence leads to greater emotion responses.

A second constraint is methodological: as others suggest (Lanier et al., 2019), immersive VR research often contains small samples sizes due to the nontrivial hardware and resource requirements for empirical studies. Now that hardware is more available, recent work on VR and emotion is examining large sample sizes. For example, Jun and colleagues examined arousal and valence in a representative sample of over 500 participants (Jun et al., 2020). Therefore,

empirical investigations using immersive VR in emotion research often anticipate medium to large effect size estimates and might be underpowered to detect small effects.

The Future of VR and Emotion Research

In our systematic review of 72 studies, most empirical research is concerned with how emotions are connected to specific (non-universal) social and psychological experiences facilitated by immersive VR, with less of a focus on the theory of each emotion. There are several takeaways from this work and the other reviewed material for future research.

First, immersive experiences are often created without considering if a phenomenon *should* be tested in VR. Consistent with the prescriptions outlined by Bailenson (2018), immersive VR should be used when experiences are impossible (e.g., flying), dangerous (e.g., rescuing people from a burning building in VR), expensive (e.g., traveling across the world), or counterproductive (e.g., cutting down a tree to demonstrate the effects of deforestation). For example, testing anxiety responses during a musical performance does not require immersive VR, but testing anxiety responses during an immersive musical performance at Madison Square Garden in front of screaming fans might provide an indicator of stage fright. It would be nearly impossible to experience and measure the emotional effects of such a high-energy event in the physical world, but immersive VR can bring this reality one step closer to the individual.

Second, considering the broad and ever-changing media landscape, it is unclear how immersive VR compares to other media in its ability to reveal emotions or change how people feel. Building an experience in immersive VR requires considerable technical knowledge and resources, and hardware is still expensive relative to more mainstream technology. Therefore, the upfront costs are nontrivial, suggesting it is important to evaluate how immersive VR compares to other media types (e.g., desktop VR, mobile media, narratives) to understand emotion and

emotion processes. Research comparing immersive VR to other media might be scarce because: (1) immersive VR content is challenging to build and requires much computational overhead, (2) the technology is still relatively new and expensive compared to other communication media, or (3) use cases for immersive VR tend to focus on solving a particular problem with the technology (e.g., reducing racism, increasing empathy), rather than identifying the technology that might be best for solving the problem.

When comparing immersive VR to other media, if emotional responses across media are relatively equal compared to those that are non-mediated, one could argue that the simplest and least computationally intensive medium should be used. We call this the principle of *least technological effort*, drawing from the psycholinguistics phenomenon of least collaborative effort (Clark, 1996), which suggests that ideal communication patterns are brief, but meaningful. Immersive technology should be used for short periods of time but benefit users in ways that other media cannot (see Ahn et al., 2016; Markowitz et al., 2018). Studies testing the principle of least technological effort are worthwhile; to understand when immersive VR should be used for emotion studies and other psychological processes.

Finally, an important area of future work might consider how emotional arousal and persuasion processes are reflected in immersive VR. We are unaware of much research that connects these ideas, but testing how principles of influence (Cialdini, 2006) map onto immersive VR and connect with arousal is likely a fruitful line of research. Take, for example, the COVID-19 pandemic, which highlights the need for new thinking about message delivery and communicating healthy countermeasures (e.g., mask wearing, social distancing). Immersive VR might offer important avenue for training people to understand how far the virus can spread from a sneeze or cough, how to practice talking to those who do not comply with health

guidelines, or how to encourage people to get the vaccine. VR technology could be a tool that helps enhance the effects we want to see in the world (e.g., taking better care of others and our environment), though we recognize the technology should be considered alongside other media types for the most effective and efficient message delivery.

We also encourage meta-analyses on the topic of immersive VR and emotion. Most studies suggest a virtual experience heightens arousal or can induce an emotional state, though the degree to which VR is superior to other media should be explored. It is also unclear how immersive VR induces some emotions better than others. We advocate for interdisciplinary and international research that addresses how immersive VR and emotions interact.

Conclusions

This chapter reviewed the state of immersive VR and emotion research across 72 studies and three categories of investigation (e.g., emotion regulation, emotions as mechanisms for psychological phenomena, studies focused on emotion theory). Future work will benefit from considering ideas from communication, psychology, and other fields to properly conceptualize how emotion and emotion processes operate when immersive media are involved. Using VR to understand the development and boundaries of discrete emotions, in addition to emotion processes such as arousal, is an important avenue for future research. A nuanced and socially constructed view of emotions has advantages of identifying the contextual constraints that might facilitate or apprehend the ability to respond to particular stimuli. If people do not find a story or experience self-relevant, it is unlikely that they will be affected by it psychologically regardless of modality. Therefore, emotion research should be aware of constraints that may alter how people respond to stimuli, which may include the medium of communication.

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Table 1

Results from the Systematic Review of VR and Emotion Papers (2015-2019)

Authors	Journal	*N*	Presence	Interest Type	Emotion(s) measured
Ammann et al. (2019)	Food Quality and Preference	100	Y	Mechanism	Disgust
Bailey et al. (2019)	Journal of Applied Developmental Psychology	52	N	Mechanism	Distress
Benoit et al. (2015)	Neuropsychiatric Disease and Treatment	18	Y	Emotion regulation	Anxiety
Breuninger et al. (2017)	Cognitive Theory Research	48	N	Emotion regulation	Anxiety, arousal
Cameira et al. (2016)	Journal of NeuroEngineering and Rehabilitation	10	N	Emotion regulation	High arousal
Cebeci et al. (2019)	Computer Animation & Virtual Worlds	20	N	Emotion theory	Arousal, happiness, sadness, comfort, anxiety
Chamilothori et al. (2019)	Building and Environment	72	N	Mechanism	Arousal, pleasantness, excitement, interest
Chirico & Gaggioli (2019)	Cyberpsychology, Behavior, and Social Networking	50	Y	Emotion theory	Joy, awe, general positive affect, anger, disgust, fear, sadness, general negative affect
Chirico et al. (2017)	Scientific Reports	42	Y	Mechanism	Awe
Chirico et al. (2018)	Frontiers in Psychology	36	Y	Mechanism	Awe, general affect (PANAS),
Chittaro et al. (2017)	International Journal of Human–Computer Studies	105	N	Mechanism	Arousal, general affect (PANAS)
Deppermann et al. (2016)	Behavioural Brain Research	83	Y	Emotion regulation	Fear
Diemer et al. (2016)	Frontiers in Psychology	48	Y	Emotion regulation	Fear, anxiety, arousal
Ding et al. (2018)	Telematics and Informatics	40	N	Mechanism	General affect (PANAS), arousal
Du Sert et al. (2018)	Schizophrenia Research	19	Y	Emotion regulation	General affect (PANAS)
Elsey et al. (2019)	Computers in Human Behavior	95	Y	Mechanism	Arousal
Felnhofer et al. (2015)	International Journal of Human–Computer Studies	120	Y	Mechanism	Joy, anger, boredom, anxiety, sadness
Fromberger et al. (2015)	PLOS ONE	45	Y	Mechanism	Arousal
Hagerman et al. (2019)	Health Psychology	190	N	Mechanism	Guilt
Hasson et al. (2019): Study 1	PLOS ONE	112	N	Mechanism	Fear
Hasson et al. (2019): Study 2	PLOS ONE	55	N	Mechanism	Fear
Herrera et al. (2018): Study 1	PLOS ONE	117	Y	Mechanism	Distress (uneasy, troubled, distressed, disturbed)
Herrera et al. (2018): Study 2	PLOS ONE	439	Y	Mechanism	Distress (uneasy, troubled, distressed, disturbed)
Hildebrandt et al. (2016)	Psychophysiology	274	N	Mechanism	Arousal
Hoffman et al. (2019)	Frontiers in Human Neuroscience	48	Y	Emotion regulation	Pain, fun
Hortensius et al. (2018)	PLOS ONE	29	Y	Mechanism	Distress
Ip et al. (2018)	Computers & Education	94	N	Emotion regulation	Emotional expression, regulation, and reciprocity
Kandaurova & Lee (2019): Study 3	Journal of Business Research	121	N	Mechanism	Guilt
Kirshner et al. (2016)	Research in Developmental Disabilities	34	N	Emotion regulation	Arousal (IAPS), anxiety
Kothgassner et al. (2016)	Computers in Human Behavior	66	N	Mechanism	Fear, arousal, anxiety
Kwok et al. (2019): Study 1	Computers & Industrial Engineering	30	N	Mechanism	Anxiety
Kwok et al. (2019): Study 2	Computers & Industrial Engineering	30	N	Mechanism	Anxiety
Li et al. (2017)	Frontiers in Psychology	95	N	Emotion theory	Arousal, valence
Lin (2017)	Computers in Human Behavior	145	N	Mechanism	Fear
Lin et al. (2018)	New Media & Society	102	N	Mechanism	Fear, horror, enjoyment, arousal

Lin et al. (2019)	Advanced Engineering Informatics	48	N	Mechanism	General affect (PANAS), anxiety
Liu et al. (2019): Study 1	Cyberpsychology, Behavior, and Social Networking	58	Y	Mechanism	General affect (PANAS)
Liu et al. (2019): Study 2	Cyberpsychology, Behavior, and Social Networking	60	Y	Mechanism	General affect (PANAS)
Lorenzo et al. (2016)	Computers & Education	40	N	Emotion regulation	Happy, angry, sad, surprised
Ma et al. (2019)	Frontiers in Psychology	95	N	Mechanism	Anxiety
Marin-Morales et al. (2019)	PLOS ONE	60	Y	Mechanism	Arousal (IAPS)
Martínez-Navarro et al. (2019): Phase 1	Journal of Business Research	178	Y	Mechanism	Pleasure, arousal, dominance
Martínez-Navarro et al. (2019): Phase 2	Journal of Business Research	58	Y	Mechanism	Pleasure, arousal, dominance
McCall et al. (2015)	Consciousness and Cognition	306	N	Mechanism	Arousal
McCall et al. (2016)	Computers in Human Behavior	310	N	Emotion theory	Arousal, valence
Mertens et al. (2019)	Computers in Human Behavior	48	N	Emotion regulation	Fear, arousal
Meuleman & Rudrauf (2018)	IEEE Transactions on Affective Computing	53	N	Emotion theory	Interest, wonder, awe, amusement, joy, fear, disgust, anxiety
Mouratidis & Hassan (2019)	Cities	28	N	Mechanism	Pleasant, exciting, relaxing, safe, interesting, active
Navarro-Haro et al. (2017)	PLOS ONE	44	Y	Emotion regulation	Happiness, sadness, anger, surprise, anxiety, relax/calm vigor/energy
Navarro-Haro et al. (2019)	Frontiers in Psychology	39	Y	Emotion regulation	Anxiety, depression
Nelson-Coffey et al. (2019): Study 1	PLOS ONE	94	N	Mechanism	Modified differential emotions scale
Nelson-Coffey et al. (2019): Study 2	PLOS ONE	172	N	Mechanism	Awe, gratitude, love, compassion, optimism; Affective Adjective Scale
Neumann & Moffitt (2018)	Sports	40	Y	Mechanism	Arousal, valence
Pallavicini et al. (2019)	Simulation & Gaming	24	Y	Mechanism	Anxiety, happiness, surprise, arousal
Quesnel & Riecke (2018)	Frontiers in Psychology	16	N	Mechanism	Awe, wonder, curiosity, humility
Reger et al. (2019)	Journal of Anxiety Disorders	96	N	Emotion regulation	Anxiety
Riem et al. (2019)	Psychoneuroendocrinology	180	N	Emotion regulation	Anger, fear, sadness, happiness, disgust, anxiety
Roettl & Terlutter (2018)	PLOS ONE	234	Y	Mechanism	Appealing, pleasant, dynamic, attractive, enjoyable, refreshing, arousal
Romano et al. (2019)	Information and Software Technology	42	N	Mechanism	General affect (PANAS)
Sajjadi et al. (2019)	Entertainment Computing	41	Y	Mechanism	General affect (PANAS)
Serrano et al. (2016)	Computers in Human Behavior	136	Y	Mechanism	Anxiety, joy, sadness
Siamionava et al. (2018)	International Journal of Hospitality Management	139	Y	Emotion theory	Pleasure, arousal, dominance
Simon & Greitemeyer (2019)	Computers in Human Behavior	60	Y	Mechanism	Arousal
Song et al. (2019): Study 3	Cognition and Emotion	115	Y	Mechanism	Positive and negative emotion
Tcha-Tokey et al. (2018)	Hindawi Advances in Human-Computer Interaction	152	Y	Mechanism	Achievement Emotions Questionnaire
Thimmesch-Gill et al. (2017): Study 1	Computers in Human Behavior	30	N	Mechanism	Stress, arousal, valence
Thimmesch-Gill et al. (2017): Study 2	Computers in Human Behavior	94	N	Mechanism	Stress, arousal, valence
Truschzinski et al. (2018)	Applied Ergonomics	25	N	Mechanism	Multidimensional Mood State Questionnaire
van Gelder et al. (2019)	Journal of Research in Crime and Delinquency	145	Y	Mechanism	Anger, shame, guilt
Wang et al. (2019)	Journal of Clinical Medicine	60	N	Emotion regulation	Arousal
Yin et al. (2018)	Building and Environment	28	N	Mechanism	Stress, frustration, engagement, excitement
Yu et al. (2018)	Urban Forestry & Urban Greening	30	N	Mechanism	Profile of Mood States, anger

Note. In the presence column: Y = yes, presence (or presence-like characteristics) was measured; N = no. Articles are organized alphabetically by last name.