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Virtual Reality and Communication

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LAST MODIFIED: 27 FEBRUARY 2019
DOI: 10.1093/OBO/9780199756841-0222

Introduction

Virtual Reality (VR) is a communication medium that makes virtual experiences feel real and appear unmediated. Since the 1960s, VR has been used by the military and medicine for training and simulations, but VR has also become fertile ground to evaluate social and psychological dynamics in academic settings. For example, journalists use VR to situate their readers within stories, educators use virtual technologies for experiential learning, and psychiatrists leverage VR to mitigate the negative effects of psychological traumas. What can an experience in VR reveal about people and communication processes? This article provides a multidimensional view of VR by dissecting its historical, technical, and psychological underpinnings that reveal unique characteristics about human behavior. We close with a commentary on the future of VR as tensions between academia and industry emerge.

Historicizing VR

The vision for modern-day VR largely grew out of 1980s science fiction, particularly during the cyberpunk movement. Bailenson, et al. 2007 details how titles such as Gibson 1986 and Vinge 1981 developed themes of (1) blurring mediated and unmediated spaces, (2) corporate takeover of media enterprises, and (3) digital information serving as the currency of society—all prescient ideas that have played a role in shaping how VR is created, popularized, and consumed today. By historicizing VR, and further positioning its origins within the fields of computer science, psychology, and human-computer interaction (especially after reflecting on Sutherland 1965, whose ideas about the opportunities and constraints of virtual systems are still relevant concerns today), one can appreciate how the fantastical nature of VR was born and continues to inspire its development. Most people already have some experience using VR. Popular games such as Second Life and World of Warcraft allow users to form real-time collaborations that only require a basic computer apparatus (see Bente, et al. 2008, which evaluated participant satisfaction associated with an interaction that occurred over different media-types), and Vasquez, et al. 2015 describes how education has been transformed by providing VR to populations with learning needs. Desktop VR systems are fundamentally different from *immersive* VR systems, however, which typically include hardware such as a head-mounted display (e.g., a headset that people wear to orient space and sight in the virtual world) and sensory feedback (e.g., auditory, haptic responses) to provide a surrounding experience for the user. Some sophisticated laboratory setups of immersive VR can include Cave Automatic Virtual Environments (CAVEs; see Cruz-Neira, et al. 1992 for one of the first introductions to the CAVE, and The CAVE, which is a more modern view of the system), which cover the floor, ceiling, and walls of a room with displays to project the virtual world. In an immersive VR experience, the virtual world does not appear synthetic, while those using desktop VR are typically aware that their experience is mediated. As seen in Immersion and Presence, the combination of highly immersive technology and the belief that people are psychological attuned to the virtual world are two crucial ingredients for a successful VR experience.

Bailenson, J. N., N. Yee, A. Kim, and J. Tecarro. 2007. Sciencepunk: The influence of informed science fiction on virtual reality research. In *SciFi in the mind's eye: Reading science through science fiction*. Edited by Margret Grebowicz, 147–164. Chicago: Open Court.

Save Citation » Export Citation » E-mail Citation »

This piece positions VR within its roots of cyberpunk literature, culture, and themes that characterize this movement (e.g., superhuman powers, immortality, among others).

[+] Find this resource:

Bente, G., S. Rüggenberg, N. C. Krämer, and F. Eschenburg. 2008. Avatar-mediated networking: Increasing social presence and interpersonal trust in net-based collaborations. *Human Communication Research* 34:287–318.

DOI: 10.1111/j.1468-2958.2008.00322.x Save Citation » Export Citation » E-mail Citation »

An early study that compares how people rate the satisfaction of an interaction, if the interaction occurred via text, video, audio, or when people were assigned to communicate as avatars. People in the avatar condition showed an indistinguishable amount of satisfaction compared with people in the video condition, suggesting that information is not lost when people have to complete a decision making task as a virtual human online. This early account shows that communication processes are capable of maintaining their fluidity and fidelity in VR.

[+] Find this resource:

The CAVE: A Virtual Reality Theater.

Save Citation » Export Citation » E-mail Citation »

This link provides a more in-depth overview of the CAVE.

[+] Find this resource:

Cruz-Neira, C., D. J. Sandin, T. A. DeFanti, R. V. Kenyon, and J. C. Hart. 1992. The CAVE: Audio visual experience automatic virtual environment. *Communications of the ACM* 35:64–72.

DOI: 10.1145/129888.129892 Save Citation » Export Citation » E-mail Citation »

This paper provides a technical and conceptual overview of the CAVE experience. It outlines how immersive VR hardware is arranged within the virtual world, and how systems are implemented.

[+] Find this resource:

Gibson, W. 1986. *Neuromancer*. New York: Ace.

Save Citation » Export Citation » E-mail Citation »

The cyberpunk novel that motivated much of the intrigue around immersive technology affecting humans and society.

[+] Find this resource:

Sutherland, I. 1965. The ultimate display. In *Proceedings of the IFIP Congress*. Edited by W. A. Kalenich, 506–508. London: Macmillan.

Save Citation » Export Citation » E-mail Citation »

Sutherland's seminal paper describes how one of the draws of VR is its ability to provide visual representations that may be unlike real world representations. We can "gain familiarity with concepts not realizable in the physical world."

[+] Find this resource:

Vasquez, E., III, A. Nagendran, G. F. Welch, et al. 2015. Virtual learning environments for students with disabilities: A review and analysis of the empirical literature and two case studies. *Rural Special Education Quarterly* 34:26–32.

DOI: 10.1177/875687051503400306 Save Citation » Export Citation » E-mail Citation »

A review of virtual and immersive technologies that facilitate learning for students with disabilities in

social skills. The small number of studies in this review (N = 19) suggests that there is an opportunity to develop new empirical and theoretical perspectives on how VR can be used in education domains.

[+] **Find this resource:**

Vinge, V. 1981. *True names and the opening of the cyberspace frontier*. New York: Dell Books.

Save Citation » Export Citation » E-mail Citation »

Another novel that inspired thinking and interest around VR.

[+] **Find this resource:**

Immersion and Presence

Early work in the form of Pausch, et al. 1997 and Loomis, et al. 1999 opined that to be taken seriously by the mind and body, VR systems need to closely approximate reality. As a result, the fidelity of immersive VR is often determined by two phenomena: immersion and presence. *Immersion* considers how well the technology estimates characteristics and movements in the virtual space. For example, a highly immersive virtual underwater experience may require sound that reflects snorkeling, visual representations of fish that look like underwater marine life, and swimming motions by the user that map onto typical swimming motions in water. Comparatively, a non-immersive or desktop VR experience requires less hardware and fewer technical resources because people can use simpler tools (e.g., a mouse or keypad) to navigate in a virtual environment. For desktop and immersive VR, any lag, breaks, or irregular virtual representations on the technical side can negatively impact the authenticity of a virtual experience. VR must also be perceived as real, psychologically. Lombard and Ditton 1997 and Slater and Wilbur 1997 argue that *presence*, or the subjective feeling of "being there," is also crucial, because people need to believe that their actions, perceived others in the virtual space (Lee 2004), or plausible actions that occur in VR (Slater 2009) are close or equal to actions in an unmediated space. The meta-analysis Cummings and Bailenson 2016 found that immersion and presence are tightly linked (e.g., a more immersive environment leads to a greater sense of feeling a part of the virtual space). Therefore, presence is a measurable construct (often assessed via self-report) that can be directly related to the strength of one's subjective and technical experience in immersive VR. Presence is also attainable in desktop VR, as suggested by Tamborini and Bowman 2010.

Cummings, J. J., and J. N. Bailenson. 2016. How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology* 19:272–309.

DOI: 10.1080/15213269.2015.1015740 Save Citation » Export Citation » E-mail Citation »

Over eighty studies were evaluated in this meta-analysis in an attempt to understand the effect of immersion on presence. The data suggest that greater immersion facilitates greater psychological presence.

[+] **Find this resource:**

Lee, K. M. 2004. Presence, explicated. *Communication Theory* 14:27–50.

DOI: 10.1111/j.1468-2885.2004.tb00302.x Save Citation » Export Citation » E-mail Citation »

This piece coherently identifies varying levels of presence, such as *social-*, *physical-*, and *self-*presence, which can affect how people perceive virtual worlds and behave in them.

[+] **Find this resource:**

Lombard, M., and T. Ditton. 1997. At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication* 3.2.

DOI: 10.1111/j.1083-6101.1997.tb00072.x Save Citation » Export Citation » E-mail Citation »

Another seminal paper that outlines how presence plays a crucial role in the experience of a VR user. This work outlines how presence relates to other concepts explicated in the social sciences: social richness, realism, transportation, immersion, social actor within medium, and medium as social actor.

[+] **Find this resource:**

Loomis, J. M., J. J. Blascovich, and A. C. Beall. 1999. Immersive virtual environment technology as a basic research tool in psychology. *Behavior Research Methods, Instruments, and Computers* 31:557–564.

An early paper that outlines the validity of using immersive VR as a lens to evaluate social and psychological phenomena. This measured piece identifies the pros and cons of VR for social science research.

Pausch, R., D. Proffitt, and G. Williams. 1997. Quantifying immersion in virtual reality. Paper presented at SIGGRAPH '97, the 24th Annual Conference on Computer Graphics and Interactive Techniques, Los Angeles, August 1997.

An early paper by a foundational figure in VR (Randy Pausch) that compares immersive VR and desktop VR in a virtual search task.

Slater, M. 2009. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364:3549–3557.

For people to act and respond naturally in a virtual environment, they must believe in the world that they are experiencing. Slater identifies how the *plausibility illusion*, in combination with presence and a highly immersive experience, can create a virtual experience that feels real.

Slater, M., and S. Wilbur. 1997. A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and Virtual Environments* 6:603–616.

Slater and Wilbur provide one of the major pieces to document the importance and robustness of psychological presence.

Tamborini, R., and N. D. Bowman. 2010. Presence in video games. In *Immersed in media: Telepresence in everyday life*. Edited by C. C. Bracken and P. Skalski, 87–109. New York: Routledge.

Presence is not exclusive to immersive VR. Presence can occur in desktop video games as well. This review identifies the social and psychological processes associated with presence in video games.

Creating a Good VR Experience: Tracking, Rendering, and Display

Blascovich, et al. 2002 suggests that movements in the virtual space can help to understand social and psychological processes, though the technical side of this endeavor is challenging. Elements in the physical space need to be picked up by the technology to estimate where people and objects are located. This process, called tracking, uses sensors to follow where people or objects travel virtually, to then be rendered (digitally collected and then displayed) based on the person's field of view. Social interactions are difficult in VR, as outlined in Gratch, et al. 2002, though some techniques can help to form collaborative virtual environments that relieve constraints of typical face-to-face interactions (e.g., gaze), as described in Bailenson, et al. 2004. Traditional desktop VR systems use

joysticks or remotes to track where people move their avatars, which then affects the scene that is rendered for the user to view. Current immersive VR systems (see Comparison of Virtual Reality Headsets) track movements with sensors that can attach to physical limbs of users (e.g., wrists, feet) or through head-mounted displays. An immersive VR system with low latency (e.g., delay between stimulus and visual response, typically measured in milliseconds) and fast update rate (e.g., the number of times per second that a display updates, typically measured in hertz or frames per second) is required to produce visual content with great realism and to reduce the potential for simulator sickness or strain, qualities that can be measured by self-report (for an example of a simulator sickness scale, see Kennedy, et al. 1993). Immersive VR systems measure the position and orientation of objects across six degrees of freedom in a three-dimensional space. VR headsets track movements in X, Y, and Z space, called pitch, yaw, and roll, respectively. Note that these three axes have both positive and negative values, such that moving forward is positive on the Z-axis (roll) and looking left is negative on the Y-axis (yaw).

Bailenson, J. N., A. C. Beall, J. Loomis, J. Blascovich, and M. Turk. 2004. Transformed social interaction: Decoupling representation from behavior and form in collaborative virtual environments. *Presence: Teleoperators and Virtual Environments* 13:428–441.

DOI: 10.1162/1054746041944803 Save Citation » Export Citation » E-mail Citation »

Bailenson and colleagues discuss opportunities associated with social interactions that occur in virtual spaces (e.g., nonverbal and gestural mimicry for simultaneous one-on-one interactions). If the technology can appropriately map gestures, nonverbals, and verbal content at scale, virtual environments can enhance collaboration among distributed partners.

[+] Find this resource:

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

DOI: 10.1207/S15327965PLI1302_01 Save Citation » Export Citation » E-mail Citation »

This paper outlines the objectives of tracking and rendering in immersive virtual environments.

[+] Find this resource:

Comparison of Virtual Reality Headsets. 2018. In *Wikipedia*.

Save Citation » Export Citation » E-mail Citation »

This catalogue provides a running list of VR headsets and their specifications. We use Wikipedia as the source, as this database will continually update when the technology improves and new head-mounted displays are introduced.

[+] Find this resource:

Gratch, J., J. Rickel, E. André, N. Badler, J. Cassell, and E. Petajan. 2002. Creating interactive virtual humans: Some assembly required. *IEEE Intelligent Systems* 17:54–63.

DOI: 10.1109/MIS.2002.1024753 Save Citation » Export Citation » E-mail Citation »

Gratch and colleagues outline the challenges associated with creating virtual humans that communicate. A host of challenges, including voice recognition, natural language processing, facial recognition, and mapping are mentioned as a call to bring researchers from other fields to potentially resolve such issues in virtual spaces.

[+] Find this resource:

Kennedy, R. S., N. E. Lane, K. S. Berbaum, and M. G. Lilienthal. 1993. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology* 3:203–220.

DOI: 10.1207/s15327108ijap0303_3 Save Citation » Export Citation » E-mail Citation »

The degree to which people feel nauseated or ill from an experience in VR can be measured. This paper provides a well-validated questionnaire to explore simulator sickness.

[+] Find this resource:

Embodiment

One of the major draws of VR is the ability to create a different version of the self in games such Second Life (see McLeod and Leshed 2011 for a review of the literature on avatars and communication processes such as maintaining anonymity online). When people embody a virtual object and control it themselves, they take on an *avatar*, which is a human-controlled representation of a person or entity (e.g., an underwater piece of coral). People can adjust physical aspects of their avatar and these attributes can alter how people act, perceive the self, and respond to others in a virtual world. When people treat the physical characteristics of an avatar as their own, this phenomenon is often called *body transfer* (e.g., pain to a virtual limb induces pain to a person's physical limb), a well-documented illusion in VR research with ideas that have been informed by Biocca 1997, Botvinick and Cohen 1998, and Clark 1997. Although humans can embody and control avatars, computers can also control virtual actors as well. *Agents* are digital representations of another person or being, controlled by an algorithm. A mainstream example of an agent is the iPhone's digital assistant, Siri, which responds to human input based on programmed rules and decisions. Agents have become popular because they offer convenience (e.g., Siri can set an alarm and fetch information from the Internet) and scale (e.g., the same version of Siri is available on all iPhones). The acceptance of avatars in everyday life seems to be increasing as well, with intelligent personal assistants (e.g., Alexa by Amazon) and chatbots providing value in many aspects of society (e.g., troubleshooting, recommender systems, social support; see Bisset 2017 for an article that describes how social media companies are using digital agents to support issues around psychological well-being). *Embodiment* allows people to experience the world as a different person or object, which has led to an interest in measuring the effect of modifying identity (e.g., race) or physical characteristics on attitudinal and behavioral outcomes (see Lanier 2006 and Yee and Bailenson 2007, which comment on and empirically demonstrate one of the draws of VR: the ability to lift physical world constraints and change human features). For example, in social psychology, the Implicit Association Test (IAT; see Banaji and Greenwald 2017, which provides measures and insights about stereotypes, preferences, and identity) relies on the idea that faster cognitive associations correspond to positive judgements of a stimulus relative to slower associations. That is, if people classify the word *black* with the adjective *beautiful* faster than the word *white* with *beautiful*, the data indicate a more favorable association with African Americans than Caucasians. Experiences in VR can both amplify and attenuate racist stereotypes. In Groom, et al. 2009, embodying black or white avatars can lead to a priming effect where stereotypes are reinforced. Peck, et al. 2013, meanwhile, observed that embodying a minority race leads to less bias. These mixed findings suggest that more work is required to understand the relationship between VR, body transfer, and identity as represented in virtual worlds.

Banaji, M. R., and A. G. Greenwald. 2017. The IAT. Blindspot.

Save Citation » Export Citation » E-mail Citation »

This site outlines typical IAT measures and how the procedure works in greater detail.

[+] **Find this resource:**

Biocca, F. 1997. The cyborg's dilemma: Progressive embodiment in virtual environments. *Journal of Computer-Mediated Communication* 3.2.

DOI: 10.1111/j.1083-6101.1997.tb00070.x Save Citation » Export Citation » E-mail Citation »

Biocca's classic paper outlines how people can be psychologically influenced by changes to the virtual body. This early account suggests that we adopt and respond to avatars in social ways.

[+] **Find this resource:**

Bisset, J. 2017. Facebook is using AI to scan your posts for suicidal thoughts. CNET, 28 November.

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Agents are slowly playing a role in everyday life outside of commerce and convenience. Social networking sites are using natural language processing and machine learning techniques to evaluate mental health.

[+] **Find this resource:**

Botvinick, M., and J. Cohen. 1998. Rubber hands "feel" touch that eyes see. *Nature* 391:756.

DOI: 10.1038/35784 Save Citation » Export Citation » E-mail Citation »

A famous body transfer illusion study, where participants who had their rubber hand visually brush-stroked with tactile stimulation felt like the virtual arm was a part of them and their rubber hand experienced touch.

[+] Find this resource:

Clark, A. 1997. *Being there: Putting brain, body, and world together again*. Cambridge, MA: MIT Press.

Save Citation » Export Citation » E-mail Citation »

This book is highly influential in the field of embodied cognition. It outlines how our body and psychology are linked.

[+] Find this resource:

Groom, V., J. N. Bailenson, and C. Nass. 2009. The influence of racial embodiment on racial bias in immersive virtual environments. *Social Influence* 4:231–248.

DOI: 10.1080/15534510802643750 Save Citation » Export Citation » E-mail Citation »

Embodying someone in a minority race in VR can prime stereotypes that lead to more bias.

[+] Find this resource:

Lanier, J. 2006. Homuncular flexibility. Edge.com. Edge Foundation, Inc.

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One of the foundational figures in VR discusses the term *homuncular flexibility*, defined as the ability to control movements and abnormal degrees of freedom (in VR) relative to one's physical body. For example, people can learn how to operate a third arm in VR despite never having one in real life.

[+] Find this resource:

McLeod, P. L., and G. Leshed. 2011. As long as they don't know where I live: Information disclosure strategies for managing identity in Second Life. In *Reinventing ourselves: Contemporary concepts of identity in virtual worlds*. Edited by A. Peachy and M. Childs, 191–211. London: Springer.

Save Citation » Export Citation » E-mail Citation »

This chapter is an early overview of the experiences that people have in Second Life, focusing on what a virtual world means for the self and for relationships.

[+] Find this resource:

Peck, T. C., S. Seinfeld, S. M. Aglioti, and M. Slater. 2013. Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and Cognition* 22:779–787.

DOI: 10.1016/j.concog.2013.04.016 Save Citation » Export Citation » E-mail Citation »

Embodying someone of a minority race in VR can reduce racial bias.

[+] Find this resource:

Yee, N., and J. Bailenson. 2007. The Proteus Effect: The effect of transformed self-representation on behavior. *Human Communication Research* 33:271–290.

DOI: 10.1111/j.1468-2958.2007.00299.x Save Citation » Export Citation » E-mail Citation »

This two-study paper demonstrates that people conform to social and evolutionary dynamics in virtual spaces as they would outside of the virtual world. When people embodied a more attractive avatar relative to a less attractive avatar, they responded more intimately (e.g., gave more self-disclosures) to another person in the virtual environment. People who embodied taller avatars (than a confederate) were more confident in a negotiation task than people who embodied shorter avatars.

[+] Find this resource:

Communication and Psychological Processes Reflected Inside and Outside VR

In many cases, VR is a perfect medium to replicate and extend empirical findings, because research demonstrates that people respond in VR as they would outside of VR. For example, Pertaub, et al. 2002, a study on virtual public speaking, had people with high anxiety about public speaking give a speech to a negative audience in VR. As expected, people became anxious when they were given negative virtual feedback, suggesting that social responses are internalized in VR despite the characters being nonhuman. Another example, Bailenson and Yee 2005, demonstrated the *chameleon effect* in VR, a phenomenon where people form more positive associations with others if they experience gestural mimicry relative to those who do not. That is, people who were mimicked in VR also liked the agent more and viewed it as more persuasive than those who were not mimicked. The fact that people treat virtual experiences and characters as real does not suggest that the outcomes with such stimuli are always positive, however. Early research in human-robot interaction showed that the appearance of a humanoid robot can become too real and affect the emotional response of an observer. Called the *uncanny valley* problem by Mori 1970, this phenomenon has been documented in more recent VR research as well; Seyama and Nagayama 2007, for example, demonstrated the effect when people judge face-blended avatars. Do social and psychological processes that occur in VR bleed into the physical world as well? Prior evidence suggests that behavior in VR can affect behavior outside of VR in several domains. For example, prior work suggests altruistic people are more likely to be empathetic toward others, and people who are cooperative (versus competitive) often form stronger bonds with team members. Gillath, et al. 2008 outlined a series of experiments demonstrating that people can have prosocial and sometimes empathic reactions to needy others in immersive spaces. More recently, Rosenberg, et al. 2013 demonstrated that people behave prosocially after embodying a superhero in immersive VR, and Ahn, et al. 2014 showed that people are more environmentally conscious after cutting down a virtual tree versus simply reading about deforestation. Together, these examples provide evidence that VR can not only reflect a person's psychological experience while in the virtual world, but also modify attitudes and behaviors in the physical world as well. The range of studies using VR as a lens into humans, social interactions, and psychological processes is broad and continues to expand. For the latest overviews of peer-reviewed research from these academic domains, consult Bailenson 2018a (cited under Future of VR), Blascovich and Bailenson 2012, Jerald 2015, and Lanier 2017.

Ahn, S. J., J. N. Bailenson, and D. Park. 2014. Short- and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. *Computers in Human Behavior* 39:235–245.

DOI: 10.1016/j.chb.2014.07.025 Save Citation » Export Citation » E-mail Citation »

Two studies demonstrate how actions in the virtual world can affect behavior in the physical world. Here, people demonstrate more pro-environmental behavior after experiencing deforestation by cutting down a virtual tree, relative to those who read about the phenomenon.

[+] Find this resource:

Blascovich, J., and J. N. Bailenson. 2012. *Infinite reality: The hidden blueprint of our virtual lives*. New York: William Morrow.

Save Citation » Export Citation » E-mail Citation »

One of the early books to synthesize decades of academic research using VR as a lens into social and psychological processes.

[+] Find this resource:

Bailenson, J. N., and N. Yee. 2005. Digital chameleons: Automatic assimilation of nonverbal gestures in immersive virtual environments. *Psychological Science* 16:814–819.

DOI: 10.1111/j.1467-9280.2005.01619.x Save Citation » Export Citation » E-mail Citation »

The study that demonstrates the chameleon effect in VR. Participants were either mimicked or not mimicked by a virtual agent and then asked about their perceptions of the agent.

[+] Find this resource:

Gillath, O., C. McCall, P. R. Shaver, and J. Blascovich. 2008. What can virtual reality teach us about prosocial tendencies in real and virtual environments? *Media Psychology* 11:259–282.

The authors provide an overview and two tests of how virtual environments have the capacity to surface prosociality.

Jerald, J. 2015. *The VR book: Human-centered design for virtual reality*. San Rafael, CA: Morgan & Claypool.

A thorough overview text that provides information on the technical, academic, and industry sides of VR.

Lanier, J. 2017. *Dawn of the new everything: Encounters with reality and virtual reality*. New York: Henry Holt.

This text provides a thoughtful overview of VR from cyberpunk and social science perspectives, written by one of the foundational figures in VR.

Mori, M. 1970. The uncanny valley. *Energy* 7:33–35.

This original documentation of the uncanny valley phenomenon outlines the process when the familiarly of a robot and its human likeness are too uncomfortable for observers to handle.

Pertaub, D. P., M. Slater, and C. Barker. 2002. An experiment on public speaking anxiety in response to three different types of virtual audience. *Presence: Teleoperators and Virtual Environments* 11:68–78.

This study demonstrates the effect that people respond to virtual world feedback in as consistent a manner as they do to physical world feedback.

Rosenberg, R. S., S. L. Baughman, and J. N. Bailenson. 2013. Virtual superheroes: Using superpowers in virtual reality to encourage prosocial behavior. *PLoS ONE* 8:e55003.

This paper outlines the results of a study that found people are more likely to help another person in the physical world if they act prosocially in the virtual world.

Seyama, J. I., and R. S. Nagayama. 2007. The uncanny valley: Effect of realism on the impression of artificial human faces. *Presence: Teleoperators and Virtual Environments* 16:337–351.

The uncanny valley phenomenon also applies to VR. This paper provides empirical evidence that it occurs with avatars.

The Future of VR

As Dede 2009 suggests, we are beginning to see many positive applications of VR in fields such as

education, even with children (see Bailey and Bailenson 2017 for a review of work on VR and children). Difede, et al. 2007 describes positive use cases of VR for therapy and rehabilitation. STRIVR is a company using VR for athletic training and journalism—as outlined by Perez 2016, *Wired* 2017, and McPhate 2017—that places people inside stories and experiences for more firsthand accounts. The power of a virtual experience, however, may also be associated with negative consequences. For example, Tran 2010 reports that a South Korean family played a computer game for hours and neglected to feed their child outside of VR, resulting in her death. Without monitored VR exposure and breaks, VR can become overly engrossing. Therefore, Bailenson 2018a suggests VR is best used under four conditions: when experiences are impossible, dangerous, expensive, or counterproductive. It is typically *impossible* for an average human to explore the inside of a cell, but Minogue, et al. 2006 demonstrates how virtual worlds can imitate a cell's structure and be used for education. Simulating an escape from a burning building or an earthquake is *dangerous*, but developing a virtual model of natural disaster escape routes can lead to improved safety responses without risking lives. It is *expensive* to take a large number of students on a flight to Italy to see art, though experiencing the Sistine Chapel in VR is cheap, because a field trip can be projected into multiple headsets at once without flight and environmental costs. Finally, it would be *counterproductive* to chop down trees in the physical world to demonstrate the effects of deforestation, but doing so in VR leaves nearly zero impact on the physical world. Despite the prior suggestions, industry's arms race to get VR in the home may hurdle these recommendations and lead to mixed effects. On the one hand, VR content is likely to explode, because companies may compete to own the most stunning VR experiences. On the other hand, the line between content that *can* be developed for VR versus content that *should* be developed for VR is unclear. Bailenson 2018b gives an example of this regarding first-person shooting games. Decades of research suggest that there are social and psychological consequences to media violence, but the systems under investigation are clearly mediated (e.g., watching a TV show or playing a desktop game that involves death). In immersive VR, these effects may become amplified because the experience is psychologically closer and realized, yielding unexpected consequences on social and psychological well-being despite the experience being entertaining. Negotiating this tension, between producing high-quality VR content and understanding the social and psychological effects of the VR experience, is where industry and academia should work together to develop policies that make VR better for people and with limited downstream repercussions.

Bailey, J. O., and J. N. Bailenson. 2017. Immersive virtual reality and the developing child. In *Cognitive development in digital contexts*. Edited by F. Blumberg and P. Brooks, 181–200. San Diego, CA: Elsevier.

DOI: 10.1016/B978-0-12-809481-5.00009-2 Save Citation » Export Citation » E-mail Citation »

There is very little research investigating the effects of immersive VR on children. This chapter overviews current research in the area.

[+] Find this resource:

Bailenson, J. N. 2018a. *Experience on demand: What virtual reality is, how it works, and what it can do*. New York: W. W. Norton.

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Bailenson's review of VR traces how to do VR well from a technical and psychological perspective. For example, he identifies the opportunities and constraints of conducting VR research with varying populations, such as children, people with physical limitations, and people with psychological disorders.

[+] Find this resource:

Bailenson, J. N. 2018b. If a possible mass shooter wants to hone his craft, don't hand him a virtual boot camp. CNN, 5 March.

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Should first-person shooter games be allowed in VR? This opinion piece addresses what can be done to make a virtual experience less real for individuals who may be inclined to treat virtual shooting games as practice.

[+] Find this resource:

Dede, C. 2009. Immersive interfaces for engagement and learning. *Science* 323:66–69.

DOI: 10.1126/science.1167311 Save Citation » Export Citation » E-mail Citation »

Chris Dede, a leader in VR for education research, suggests why and how VR can be used to enhance learning across multiple education domains. Dede is the creator of River City, a program to teach scientific inquiry.

[+] Find this resource:

Difede, J., J. Cukor, N. Jayasinghe, et al. 2007. Virtual reality exposure therapy for the treatment of posttraumatic stress disorder following September 11, 2001. *Journal of Clinical Psychiatry* 68:1639–1647.

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VR has been a powerful medium to relieve symptoms of PTSD. This paper demonstrates such effects relative to controls, with VR subjects show reduced PTSD symptoms over time.

[+] Find this resource:

McPhate, M. 2017. California today: In virtual reality, investigating the Trayvon Martin case. *New York Times*, 24 February.

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This piece highlights one of Nonny de la Peña's creations; specifically, what is was like to be a bystander near the scene of the Trayvon Martin case.

[+] Find this resource:

Minogue, J., M. G. Jones, B. Broadwell, and T. Oppewall. 2006. The impact of haptic augmentation on middle school students' conceptions of the animal cell. *Virtual Reality* 10:293–305.

DOI: 10.1007/s10055-006-0052-4 Save Citation » Export Citation » E-mail Citation »

This paper outlines research suggesting that people can learn about cellular science by experiencing the objects and phenomena in VR.

[+] Find this resource:

Perez, S. 2016. The NYT is giving out 300,000 more Google Cardboard viewers. TechCrunch, 28 April.

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The 2015 launch of over a million Google Cardboards to *New York Times* subscribers was so successful that the major news outlet initiated a similar program nearly one year later.

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STRIVR.

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STRIVR is a company that uses immersive technology to assist with training and learning in a variety of domains. For example, STRIVR has helped athletes with play recognition and reaction time on the field.

[+] Find this resource:

Tran, M. 2010. Girl starved to death while parents raised virtual child in online game.*Guardian*, 5 March.

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This story highlights some of the potential consequences of neglecting the physical world while in VR.

[+] Find this resource:

***Wired*. 2017. How a virtual reality journalist takes viewers inside stories. *Wired*, 28 November.**

One of the key figures in immersive journalism is Nonny de la Peña. She uses VR to bring people closer to stories and feel their emotional impact. This video outlines how she does her work, using VR to complement and enhance journalism.