

Review Article: The Current State of Virtual Reality on Behavior Change

Background: Virtual Reality (VR) is a standard and even necessary tool for advancing the science across a wide variety of disciplines including the military, healthcare, engineering and education¹. This article will review the VR literature on influence research and examine VR's impact on the field of behavior change with a focus on the common findings and limitations.

Objective: In line with the first objective of the ICRC's Operational Strategy (2019-2022), influencing behavior to prevent violations of IHL, the Innovation Unit is specifically exploring the efficacy of virtual reality for influence and behavior change. This study aims to consolidate evidence, lessons learned and commonly accepted results specific to the impact of VR in behavior change.

Method: An article review of studies investigating behavior change potential using VR was conducted between April and June 2019. Keyword searches were performed using database searches of PubMed, Science Direct, ST Technologies Published Works, ResearchGate, Semantics Scholar, Frontiers in Psychology and psycINFO. The search parameter algorithm included all possible combinations of (1) "virtual reality" or "augmented reality" or "extended reality" (2) "influence," or "behavior change," or "psychology" and (3) "virtual environment or simulation" or "video game"² or "gamification."

Results: The search yielded 579 studies with the inclusion criteria of VR behavior change techniques. The abstracts and titles of all were reviewed, with the full text of 136 papers reviewed; 79 papers from 25 countries met the inclusion criteria. Two types of articles were defined – a) those that studied specific behavior changes as a result of VR use and b) those that studied the efficacy of VR as a behavior change research tool. Of the 79 papers, 25 were published between 2001 and 2011 while the other 54 are between 2012-2019; 15 of the papers are systematic reviews and/or meta-analyses which collected data from multiple studies³, thus bringing the total body of referenced studies to 919 papers.

Summary

Virtual Reality is a reliable tool to affect behavior change and to advance the study, assessment, and treatment of certain psychological conditions. There is sufficient evidence of VR's capacity for enabling behavior, empathy building, experiencing consequences, projection of the future, feedback and emotional self-regulation. Like video games, it is equally associated with addiction although there is insufficient research regarding long-term immersion. VR is most suited to training **cognitive** skills related to memory and understanding spatial and visual information and knowledge; psychomotor⁴ skills; and **affective** skills related to controlling emotional responses to stressful or difficult situations. Research examined in this review suggests commonalities specific to VR training: it is more **memorable** than simple video content, easily **repeatable**, infinitely **scalable** and can **isolate users** from distraction. Due to its immersive properties, VR is uniquely suited to provide accessible exposure therapy. Studies find that behavior change research may be reliably conducted because VR effectively simulates reality, which is particularly useful when real life prevents the experimental control needed for scientific validation; this is most notable when replicating an experiment in real life would be too dangerous, introducing ethical concerns/challenges, or when practicality and/or cost prevents real life replication.

¹ For more details, please read the Innovation Unit's November 2018 publication, "Extended Reality: Determining Needs, Expectations and the Future of XR for the ICRC"

² Virtual reality video games played with both head-mounted devices and on desktop computers.

³ Duplicate studies were consolidated in references.

⁴ Psychomotor learning is demonstrated by physical skills such as movement, coordination, manipulation, dexterity, or actions which demonstrate the fine or gross motor skills, such as use of precision instruments or tools.

Start at the Beginning

VR is an experiential tool that not only provides multiple opportunities for observation and education but also a disruptive mechanism for behavior research and treatment in controlled environments. A familiarity with certain terminology will aid the reader.

Virtual environments (VE) are interactive image displays enhanced by special processing and by nonvisual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space. **Presence**⁵ is the extent to which an individual consciously experiences the VE. **Immersion**⁶ is a quality of the system's technology, an objective measure of the extent to which the system presents a vivid VE while shutting out physical reality. An **immersant** is the VR user, the one inhabiting the VE.

Embodiment⁷ is a phenomenon where the immersant believes that they physically inhabit their virtual body, or avatar. Embodiment is also sometimes referred to as the Body Transfer, *homoncular flexibility*, or the Proteus Effect⁸. **Agency**⁹ is the power to take meaningful action and see the results of our decisions and choices. In VR, higher agency is related to higher presence. Awareness of agency limitations can remind the immersant that they are in a simulation.

Non-immersive VR refers to the use of 3D images to create a navigable VE but this technique only uses 2D visual interfaces, such as computer screens or projectors. **Immersive VR** refers to 3D environments with immersive visual interfaces such as head-mounted devices or isolated rooms.

Cognitive Psychology is the scientific study of mental processes such as attention, language use, memory, perception, problem solving, creativity and thinking; learning is an example of cognition. VR is a relevant tool for studying complex cognitive functions, such as prospective memory. **Psychophysiology** is a branch of psychology concerned with the physiological basis of psychological processes; how a person's mental and physiological responses interact.

Neuroplasticity is the change in neural pathways and synapses that occurs due to certain factors, like behavior, environment, or neural processes. During such changes, the brain engages in axonal sprouting leading to increased neural connections in the brain, as well as synaptic pruning, deleting the neural connections that are no longer necessary or useful, and strengthening the necessary ones.

On the larger subject of influence and behavior change, the sheer amount of research literature has garnered descriptions from simply "enormous¹⁰" to "bordering on the unmanageable¹¹", which is unsurprising, as it covers the entirety of human existence. Recently however, some scholars have introduced a distinction¹²: whereas **models of behavior** are more diagnostic and geared towards understanding the psychological factors that explain or predict a specific behavior, **theories of change** are more process-oriented, aimed at changing a given behavior. Thus, from this perspective, understanding and changing behavior are two separate but complementary lines of scientific investigation.

⁵ Wallach, H., Safir, M.P., et al. How Can Presence in Psychotherapy Employing VR be Increased? *Virtual Reality*. Mar 2012.

⁶ Wilson, C., et al. The Use of VR in Psychology: Perception. *Methods in Medicine*. 2015(1-2):151702. Sept2015. DOI: 10.1155/2015/151702

⁷ Kilteni, K., Groten, R., Slater, M. Sense of Embodiment in VR. *Presence Teleoperators* 21(4). Nov 2012. DOI: 10.1162/PRES_a_00124

⁸ Yee and Bailenson. The Proteus Effect: The Effect of transformed self-representation on behavior. 2007. doi:10.1111/j.1468-2958.2007.00299.x; Kilteni, K. Drumming in immersive virtual reality: the body shapes the way we play. *PubMed Apr2013*. DOI 10.1109/TVCG.2013.29.

⁹ Kong, G., He, K., Wei, K. Sensorimotor experience in VR enhances sense of agency associated with an avatar. *Consciousness & Cognition*. 52:115-124. July 2017. DOI: 10.1016/j.concog.2017.04.018

¹⁰ Maio, G. et al. Social Psychological Factors in Lifestyle Change and Their Relevance to Policy. *Social Issues and Policy Review*, Vol 1, No 1, 2007, pp 99-137. DOI: 10.1111/j.1751-2409.2007.00005.x

¹¹ Jackson, T. *Motivating Sustainable Consumption: A Review Of Evidence On Consumer Behaviour And Behavioural Change*. A report to the Sustainable Development Research Network. London: SDRN. 2005

¹² Van de Lindon, S. "A Response to Dolan" Princeton University. Oliver, A. (Ed). 2013.

Evidence of Behavior Change in Virtual Reality

VR is an amazing and significant piece of technology, but the experience inside an immersive virtual environment is entirely subjective. To be effective, immersants must trust the experience on a visceral level – and trust in technology is not universal. But for the believers, today's premium Extended Reality (XR)¹³ hardware tools are capable and comfortable, immersive and affordable, and increasingly mobile.

As an embodied technology that alters our experience of the body, time and space, VR has a considerable influence on neuroplasticity research. What we see or do in VR can affect how we behave in real life; this is demonstrated in the Proteus Effect, when subjects “conform to the behavior that they believe others would expect them to have” based on the appearance of their avatar¹⁴. For example, subjects embodied in a taller avatar tend to negotiate more aggressively than subjects in a shorter avatar¹⁵.

But while the Proteus Effect changes our virtual behavior, the Effect can also change how that behavior generalizes to the real world. Immersive VR has the ability to make us feel; it is this power to create emotionally evocative experiences that provides the illusion of presence in a VE and higher immersion is correlated with higher psychological presence¹⁶. When people experience real or perceived physical and social dangers inside VR, evidence suggests behavioral responses can be specifically influenced. A series of experiments demonstrated that:

- When people experienced racism in the form of a minority avatar, their implicit racial bias in the real world was reduced¹⁷.
- Inhabiting the avatar of an elderly person makes subjects more willing to save for their retirement¹⁸.
- Inhabiting the body of logger, chopping down an inviting glade of trees with a chainsaw, makes people behave in a more environmentally conscious manner in the form of a 20% reduction in paper use¹⁹.
- Swimming through virtual coral reefs as they bleach to death can trigger ecofriendly behavior, like turning off lights or using less water (the resulting behavior was also measured one week after the VR experience)²⁰.
- Embodying the form of a cow and experiencing the animal's suffering in the slaughterhouse can also generate empathy for another species²¹.
- Experiencing a terminal diagnosis and subsequent death can better prepare medical students to enhance empathy for patients²².

Current research also demonstrates that behavior change campaigns which concentrate largely on sending messages and information about what target audiences *should do* have surprisingly little effect on behavior²³. The way the message is communicated is as important as the content itself, and the way in which different parties

¹³ Extended Reality (XR) comprises Virtual Reality (VR), Augmented Reality (AR), Augmented Virtuality (AV) and Mixed Reality (MR).

¹⁴ Kilteni, K. Drumming in immersive virtual reality: the body shapes the way we play. PubMed Apr2013. DOI 10.1109/TVCG.2013.29

¹⁵ Yee and Bailenson. The Proteus Effect: The Effect of transformed self-representation on behavior. 2007. doi:10.1111/j.1468-2958.2007.00299.x

¹⁶ Cummings and Bailenson. How Immersive is Enough? A Meta-Analysis of the effect of immersive technology on user presence. Media Psychology, 00:1–38, 2015. DOI: 10.1080/15213269.2015.1015740

¹⁷ Hasler, B., et al. Virtual Race Transformation Reverses Racial in-group bias. PlosONE Apr2017. doi.org/10.1371/journal.pone.0174965 ; Peck, TC., et al. Putting yourself in the skin of a black avatar reduces implicit racial bias. Conscious Cogn. 2013 Sep;22(3):779-87. doi: 10.1016/j.concog.2013.04.016. Epub 2013 May 28.

¹⁸ Hershfield et al. Increasing saving behavior through age-progressed renderings of the future self. J Mark Res. 2011 Nov; 48: S23–S37. doi: 10.1509/jmkr.48.SPL.S23

¹⁹ Ahn et al. Short and long-term effects of embodied experiences in immersive VEs on environmental locus of control and behavior. Epub 2014. doi: 10.1016/j.chb.2014.07.025

²⁰ Markowitz, D.M., et al. Immersive Virtual Reality Field Trips Facilitate Learning About Climate Change. *Frontiers in Psychology*, 9, 2018. DOI=10.3389/fpsyg.2018.02364

²¹ Ahn, et al. Experiencing Nature: Embodying Animals in Immersive Virtual Environments Increases Inclusion of Nature in Self and Involvement With Nature. 2016. <https://doi.org/10.1111/jcc4.12173>

²² “End-of-Life Virtual Reality Simulation”, University of New England College of Osteopathic Medicine, March 2019

²³ Rice RE, Atkin CK, editors. Public communication campaigns. 4th. Thousand Oaks, CA: Sage; 2013. ; Harrington NG, Helme DW, Noar SM. Message design strategies for risk behavior prevention. In: Scheier LM, editor. Handbook of adolescent drug use prevention: Research, intervention strategies, and practice. Washington, DC: American Psychological Association; 2015

perceive their reality is crucial. VR360° films have been increasingly used in immersive VR, especially in journalism, but most of the content in this format limits users to a passive mode, therefore allowing presence but limiting immersion and agency²⁴.

The viability of psychological treatment in VR is based on the effectiveness of virtual environments to elicit comparable subjective and physiological reactions as in real situations²⁵. VR can trigger similar levels of real world stress and physiological reactions in VR immersants, which means the virtual world can have as lasting, or even as traumatic, an effect outside of VR²⁶.

An experiment reproducing the famous Milgram obedience experiments²⁷ in VR not only replicated the real life results but also found that subjects reacted as if the shocks they administered were real, despite understanding that they were merely virtual²⁸.

Decades of research provides evidence that VR can be used to successfully treat phobias and post-traumatic stress disorder²⁹. For example, phobic patients can be repeatedly exposed to a scalable, stressful stimulus in safe conditions, a VR version of exposure therapy. Over time, this sort of experience reduces the stress or fear response to that stimulus. Such findings provide support for the idea that emotional and physiological responses to stimuli in virtual reality are similar to what we would experience in real life situations.

The Versatility of VR: Research, Education and Treatment

Scalability (or controllability) of the stimulus presentation is a significant feature of VR because the subject can become gradually accustomed to more fear-inducing stimuli with repeated exposures. Any stressful situation can be turned from a safe VR experience to one that is more provocative—from holding a spider to dealing with an angry client. In the simulation, *SpiderWorld*, patients view a computer-generated spider in a VE while caressing a furry toy spider in real life³⁰; tactile augmentation was shown to double treatment effectiveness compared to ordinary VR. With additional senses, the level of immersion is higher, hence the correlated higher level of presence and the subsequent increased level of behavior change potential. When designing an intervention with the purpose of behavior change, the level of presence, immersion and agency must be taken into account.

Studies further demonstrate that VR is an exceptionally relevant tool in the study of complex cognitive functions. For example, the ability to assess and evaluate prospective memory (PM) - defined as the ability to remember to execute intentions at some point in the future—can be precisely measured in a VE³¹. A deficit in PM can be found as a result of traumatic brain injury, multiple sclerosis, Parkinson's disease, Alzheimer's, or similar neurological conditions. Virtual reality is a promising way to assess cognitive functions while overcoming logistical or methodological limitations by increasing experimental control in realistic settings. Attention span – or selectively concentrating on a discrete aspect of information, whether deemed subjective or objective, while ignoring other perceivable information – can also be effectively assessed inside VR. This capability can provide physicians, researchers and educators with innovative and ecologically-relevant methods to more accurately assess focus, motivation and learning capacities or to monitor progress after some form of training or treatment³².

²⁴ Hardee and McMahan. A Framework for the Immersion-Journalism Intersection (FIJI). UT Dallas. 2017. doi.org/10.3389/fict.2017.00021

²⁵ Cornwell, Johnson, Berardi, & Grillon, 2006; Opris, et al, 2012; Diemer, Mühlberger, Pauli, & Zwanzger, 2014; Mühlberger, Bülthoff, Wiedemann, & Pauli, 2007; Villani, Repetto, Cipresso, & Riva, 2012 ; Stolz, et al, 2018; Poultney, et al 2016.

²⁶ Allcoat, D., et al. Frozen with Fear: Conditioned Suppression in a VR Model of Human Anxiety. DOI: 10.1016/j.beproc.2015.06.011

²⁷ Stanley Milgram, a psychologist at Yale University, conducted a study in 1963 to determine whether Nazi soldiers were simply following orders or if they could be considered accomplices to war crimes. Based on the premise of issuing pain on another human being, Milgram's results suggest that ordinary people are likely to follow orders given by an authority figure, even to the extent of killing an innocent.

²⁸ Slater, M., et al., A Virtual Reprise of the Stanley Milgram Obedience Experiments. PLOSOne2006. doi.org/10.1371/journal.pone.0000039

²⁹ Powers and Emmelkamp, 2008; Wang & Li, 2007; Gregg and TARRIER, 2007; Rizzo et al, 2015; Ling, et al, 2014

³⁰ Hoffman, H.G., Immersive VR for Reducing Experimental Ischemic Pain. Intl Jour of Hum-Comp Interactions. 15(3), 469-486. 2003.

³¹ Gonneaud, et al. Assessing prospective memory in young healthy adults using VR. Université de Caen Basse Normandie France. 2012.

³² El Beheiry, et al., 2019; Gonneaud, et al., 2012 ; Powers & Emmelkamp, 2008

Findings suggest that VR can be used to help treat psychological disorders beyond PTSD³³ and arachnophobia to strokes³⁴, cerebral palsy³⁵, Parkinson's disease³⁶, Guillain-Barré syndrome³⁷, and multiple sclerosis³⁸, among others. Children on the autism spectrum have benefited from social behavior modeling in VR³⁹, while children with Cerebral Palsy undergoing physical rehabilitation⁴⁰ trained longer and more often through a motivational "game-based" VR simulation that distracted them from pain⁴¹.

The possibilities to better understand the mind-body connection are expansive. Psychophysicologists use VR to measure physiological responses, such as an increased heart rate (or heart rate variability), as a reaction to psychological stimuli, for example fear or anger as a result of experiencing a combat simulation. Cognitive functions, data treatment and numerical simulations – especially those mixing interactions with data, human cognition and automated algorithms – are expected to have a significant impact on the future of VR in scientific research⁴².

VR is revolutionizing learning experiences that focus on acquiring new knowledge and skills while prioritizing safety and it is pushing forward advancements diverse fields, from healthcare to machine learning. Already a disruptive tool for manufacturing and hands-on training, it is also being investigated for its applications to promote fitness and as an approach to pain management. And all of this is due to VR's unique ability to lend itself towards engrossing storytelling and the illustration of complicated visual concepts. VR training modules can be used to deliver relevant customized content in an engaging fashion that leverages narrative-based experimental learning, the educational value of which is supported by a long history of research.⁴³

The Benefits & Risks of Isolation in Virtual Reality

Isolation, whether in a real or virtual environment, can be both rewarding and punishing. In the virtual world, it is known as cognitive distraction and it can provide focus in a learning environment as well as separation from the physical body.

Isolation from distraction in VR can result in more engagement and interactivity among users, which can be a positive transformation in certain classroom environments⁴⁴. Evidence suggests that the isolating and tactile approach to learning in VR aids memory retention; subjects after a VR spatial experience tend to have better recollection of learning materials than after viewing video- or text-based tools⁴⁵. Gains in education through VR are most often seen in spatial or visual lessons⁴⁶; other objective types of educational VR simulations achieve the same

³³ Parsons, T.D., Rizzo A. A. Affective Outcomes of VR Exposure Therapy for Anxiety Disorders: A Quantitative Meta-Analysis. Institute for Creative Technologies, USC. *Journal of Behavior Therapy and Experimental Psychiatry* 39 (2008) 250–261.

³⁴ Jack, D. et al. VR-enhanced stroke rehabilitation. *IEEE Trans Neural Syst Rehabil Eng.* 2001 Sep;9(3):308-18. DOI: 10.1109/7333.948460

³⁵ Reid, DT. Benefits of a virtual rehabilitation for children with cerebral palsy. *Pediatr Rehabil.* 2002 Jul-Sep;5(3):141-8. DOI: 10.1080/1363849021000039344

³⁶ Mirelman, A., et al. VR for gait training: can it induce motor learning to enhance complex walking and reduce fall risk in patients with Parkinson's disease? *J Gerontol A Biol Sci Med Sci.* 2011 Feb;66(2):234-40. doi: 10.1093/gerona/gdq201.

³⁷ Albiol-Pérez, S. et al. A virtual rehab system for Guillain-Barré syndrome. *Met Inf Med.* 2015; 54(2):127-34. doi: 10.3414/ME14-02-0002.

³⁸ Fulk, G.D. Locomotor training & VR-based balance training for multiple sclerosis. *J Neurol Phys Ther.* 2005 Mar; 29(1):34-42.

³⁹ Schuller, B., et al. Serious Gaming for Behavior Change. *IEEE Pervasive Computing* 12(3), 48-55. 2013. DOI: 10.1109/MPRV.2013.54

⁴⁰ Rose, T., et al. Immersion of VR for Rehabilitation. *Appl Ergon.* 2018 May; 69:153-161. doi: 10.1016/j.apergo.2018.01.009. 0

⁴¹ Sveistrup, H., Motor rehabilitation using VR. *Journal of NeuroEngineering and Rehabilitation* 2004;10. doi.org/10.1186/1743-0003-1-10

⁴² El Beheiry, M., et al. Virtual Reality : Beyond Visualization. *J Mol Biol.* 2019 Mar 29; 431(7):1315-1321. doi: 10.1016/j.jmb.2019.01.033.

⁴³ Bartlett, F. C. (1932). *Remembering: An experimental and social study.* Cambridge: Cambridge University Press. Karpicke, J. D., & Grimaldi, P. J. (2012). Retrieval-based learning: A perspective for enhancing meaningful learning. *Educational Psychology Review*, 24(3), 401-418. Walsh, S. (2016). Learning from stories of mental distress in occupational therapy education. *The Journal of Mental Health Training, Education and Practice*, 11(4).

⁴⁴ Christopoulos, A., Conrad, M., Shukla, M. Increasing Student Engagement through VR Interaction: How. VR, November 2018, Vol 22, Iss 4, pp 353-369 ; Allcoat, D., Von Muhlenen, A. Learning in VR: Effects on Performance, Emotion and Engagement. *Research in Learning Technology* 26. November 2018. DOI 10.25304/rlt.v26.2140.

⁴⁵ Clark, J.M., and Paivio, A., Dual Coding Theory and Education. *Educational Psychology Review*, Vol 3, No. 3, 1991 ; Christou, C. VR in Education. *Affective, Interactive and Cognitive Methods for E-Learning Design: Creating an Optimal Education Experience*, Edition: 1, Chapter: 12. DOI: 10.4018/978-1-60566-940-3.ch012. June 2010.

⁴⁶ Christou, C. *Virtual Reality in Education.* June 2010. DOI: 10.4018/978-1-60566-940-3.ch012

results as in-person or text-based lessons⁴⁷. When subjects feel presence in VR, they experience it as if something is actually happening to them in real life rather than simply observing. The impact of VR in the classroom is not decisive but the majority of research studies analyzed for this review demonstrate improved motivation among students and more efficient communication between teachers and students⁴⁸.

This means VR learning can generate memories as an experience, as part of the extensive autobiographical associative network, instead of as a lesson, or isolated episodic event. Recollection of an autobiographical memory seems to be much stronger than the memory of an isolated episodic event⁴⁹. Moreover, the learned memory is anchored and made stronger when there is increased multi-sensory and emotional input. As presence—and emotional responsiveness—increases, memory retention also improves.

- In one study⁵⁰, participants were presented with either a 360-degree VR video or a 2D video of a motorcycle ride. This was followed 48 hours later by a spatial memory test, reconstructing the route (map) they drove. The results showed that the VR group performed twice as well as the video group in the memory recollection test.
- In another study⁵¹, one group of medical students was able to manipulate a 3D image of an anatomical system while the other group merely observed. The group that controlled the 3D manipulation scored consistently and significantly higher than the observation group.
- Repeat studies on medical students show not only VR's effectiveness in training as compared to real life but also a slight advantage in post intervention knowledge⁵².

Isolation from surroundings in VR can produce varying results ranging from personal neglect to being unaware of extreme pain or negative surroundings. In one study, people inside of VR were less likely to recognize stimuli outside of VR⁵³, for example, something touching their hands. This presents practical risks to an individual's health and safety. Real life dangers may not provoke the injury-saving reactions or protective behaviors due to a lowered distinction over what is virtual and what is real. A 2014 study by a team at the University of Hamburg⁵⁴ placed a scientist in a VE for 24 hours; he was then tasked with separating artifacts from the real and virtual world but several times during the experiment, the participant was confused about whether he was in the virtual environment or the real world.

Yet as unsettling as cognitive distraction may be, it may also have its positive uses. A number of research groups have experimented with different VE's that can help distract severe burn patients from the painful procedure of daily wound care, bandage removal, and painful physical therapy to promote successful healing of skin grafts⁵⁵. The designer's goal was to distract immersants from pain in a virtual activity while limited by their physical constraints. In many cases the immersant was completely constrained, unable to use their hands or feet, and at least partially sedated; therefore, locomotion needed to be automated for maneuvering through the VE with tasks simple enough for the patient to accomplish while also complex enough to distract them from the outside world. Overall, patients reported 60 to 75-percent less pain than before their VR sessions; for comparison, morphine averages were around 30-percent pain reduction.

⁴⁷Allcoat, D., Von Muhlenen, A. Learning in VR: Effects on Performance, Emotion & Engagement. Research in Learning Technology 26. Nov 2018. Doi: 10.25304/rlt.v26.2140

⁴⁸ Hew and Chung. Use of 3D immersive virtual worlds in K-12 and higher education settings: A review. British Journal of EduTech 41(1):33 - 55 · Jan2010. DOI: 10.1111/j.1467-8535.2008.00900.x

⁴⁹ Jebara, N., et al. Effects of enactment in episodic memory: a pilot VR study. Front. Aging Neurosci., 17 December 2014. doi.org/10.3389/fnagi.2014.00338

⁵⁰ Roettl, J., Terlutter, R. The Same Video Game in 2D, 3D, and VR – How does technology impact game evaluation and brand presence? PLOSOne 2018. doi.org/10.1371/journal.pone.0200724

⁵¹ Jang, S., et al. Direct manipulation is better than passive viewing for learning anatomy in 3D VR. DOI: 10.1016/j.compedu.2016.12.009.

⁵² Kyaw, et al. 2019; Madary & Metzinger, 2016; El Beheiry, et al., 2019

⁵³ Hoffman, H.G (2001 and 2003); Gromala et al, 2016.

⁵⁴ Steinicke, F., Bruder, G. A Self-Experimentation Report about Long-Term Use of Fully-Immersive Technology. October 2014. ACM Symposium on Spatial User Interaction (SUI). DOI: 10.1145/2659766.2659767

⁵⁵ Gromala, et al. Mobius Floe: An Immersive VR Game for Pain Distraction. 2016. ; Haik et al. The Use of Video Capture VR In Burn Rehabilitation: The Possibilities. 2006. ; Hoffmann, H.G., et al. 2001 ; Hoffmann, H.G., et al. 2003.

Distraction can also help people endure difficult physical rehabilitation⁵⁶ and/or exercise longer and harder⁵⁷, blurring perception of muscle fatigue and pain. Overall, participants who wore VR headsets had a lower heart rate, lower reported pain intensity, and lower perceived exertion compared to the non-VR group at mid-training, which thereby increased motivation to continue. The participants were also able to exercise up to three minutes longer than the control group.

Gaming and Nudge Theory in Virtual Environments

Nudge theory⁵⁸ is mainly concerned with the design of choices that will influence the decisions we make, based on how people actually think and decide (instinctively and rather irrationally), rather than how we traditionally believe people think and decide (logically and rationally). Gamification is the use of game mechanics and design techniques in non-gaming contexts to change behaviors, develop skills and drive innovation, such as competition, a sense of accomplishment, and rewarding players with appropriate and timely feedback. It aims to create engagement and help people making better decisions and achieve ideal outcomes. Research shows that the use of gaming methods in classrooms produces higher learning gains than mere simulations or virtual environments⁵⁹.

The planet spends 3 billion hours a week playing video games⁶⁰ that transport us to new environments (or let us leave our own) where we can strengthen skills like pattern recognition, develop strategies and practice making the right decisions. The essential feedback loop leads to self-reflection and learning.

Cumulative research suggests that playing video games can:

- change the brain regions responsible for attention and visuospatial skills,
- improve visual acuity⁶¹,
- and increase multi-tasking and efficiency⁶².

Video games can also be addictive, and this kind of addiction is called “gaming disorder”. Researchers have found functional and structural changes in the neural reward system in gaming addicts, in part by exposing them to gaming cues that cause cravings and monitoring their neural responses. However, these effects do not always translate to real-life changes. As video game risks are still quite new, what aspects of gaming affect which regions of the brain (and how) is still relatively unknown.

The very subjective perspectives of embodiment and agency make it difficult for researchers to clarify specific parameters for immersion, however the objective is to engender presence in a VE that will create emotional engagement at the appropriate “dose” for each individual. Advances in graphic quality, 3D audio, first-person viewpoints, interface design, and haptic feedback in video games have begun to bridge the immersion gap between isolated VR and desktop video games – thereby allowing gamers to decide their own VE dosage.

The way we play games – focused, dedicated, perhaps obsessed, even addicted sometimes – demonstrates how game techniques engage us in many unique ways and how gamification is used to change behavior. Queen’s University Belfast recently studied the role of video games in teaching ethics and problem solving specific to international humanitarian law (IHL). The study found that the gamification of IHL was “a beneficial way of accessing students’ multiple intelligences and providing additional learning entry points to bridge the gap between black letter law and real world applications”⁶³.

⁵⁶ Anderson-Hanley, C., et al. Social Facilitation in VR-Enhanced Exercise. *Clin Interv Aging*. 2011; 6: 275–280. doi: 10.2147/CIA.S25337 ;

Nunes, M. et al. Motivating People to Perform Better in Exergame VEs. 29th ACM Symp on AppComp. DOI: 10.1145/2554850.2555009

⁵⁷ Matsangidou, M., et al. VR: The effect of body consciousness on exercise sensations. *Psych of Sport/Exer*, Vol41, Mar 2019, pp218-224.

⁵⁸ *Thaler, Richard H.; Sunstein, Cass R. (2008). Nudge: Improving Decisions about Health, Wealth, and Happiness. Yale University Press. ISBN 978-0-14-311526-7. OCLC 791403664.*

⁵⁹ Merchant, Z., et al. Effectiveness of VR-based instruction on students’ learning outcomes in K-12 and higher education: a meta-analysis. *Computers and Education*. Vol 70 January 2014, pp 29-40. Doi: 10.1016/j.compedu.2013.07.033

⁶⁰ Heitner, D. Inc. Com. 2 April 2018. <https://www.inc.com/darren-heitner/watching-video-games-is-now-bigger-traditional-spectator-sporting-events.html>

⁶¹ Green CS, Bavelier D. Action-video-game experience alters the spatial resolution of vision. *Psychol Sci*. 2007;18(1):88–94.

⁶² Palaus, M., et al. Neural Basis of Video Gaming: A SysReview. *Front. Hum. Neurosci.*, 22 May 2017 doi.org/10.3389/fnhum.2017.00248

⁶³ Moffett, L., Cubie, D., & Godden, A. (2017). Bringing the battlefield into the classroom: using video games to teach and assess international humanitarian law. *The Law Teacher*. doi.org/10.1080/03069400.2017.1356659

The Known Unknowns of Virtual Reality

This review has identified research covering a 20-year timespan with evidence of psychological influence on subjects while immersed in a virtual environment. As such, VR clearly poses significant opportunities as well as risks that are novel, that go beyond the risks of traditional psychological experiments in isolated environments, and that go beyond the risks of existing media technology for the general public.

The psychological impact of long-term immersion is, quite simply, unknown. So far, most scientific research using VR has involved only brief periods of immersion, typically on the order of minutes rather than hours. Once the technology is adopted for personal use, however, there may be no time limits on immersants just as there are no limits on video game or internet use. The possibility of people retreating from society in favor of an artificial, automated world is not without basis. Apps and social media are built to demand and hold our attention⁶⁴; set inside a controlled environment with a non-pharmacological analgesic effect, chronic dependency and addiction are very real threats.

It is important to note that, for the purpose of this review, behavioral psychologists use VR to visualize causality or corrective behavior in such a way that individuals can decide (evoke agency) to change their own behavior for the greater good. The implicit requirement is consent; if individuals do not seek to alter their psychological profile in the ways intended by the VR interventions, then such interventions would be considered a violation of their autonomy.

Coercion and deception are the hallmarks of unethical persuasive technology and the plasticity of the human mind is central to VR development, particularly when this involves dangerous objectives⁶⁵. Commercial applications of VEs introduce new possibilities for targeted advertising or “neuromarketing,” thus attacking the individual’s mental autonomy. By tracking the details of one’s movements in VR, including eye movements, involuntary facial gestures, and other indicators of what researchers call low-level intentions or “motor intentions”⁶⁶, corporations will be able to acquire details about one’s interests and preferences in completely new ways⁶⁷.

*Changes in behavior while in the virtual environment are of ethical concern, since research shows such behavior can have serious implications for our non-virtual physical lives — this becomes more significant as more personal, medical and financial transactions take place in a non-physical environment*⁶⁸.

The use of big data to “nudge” users (“Big Nudging”) while in VEs could have long-lasting effects, perhaps producing changes in users’ mental mechanisms themselves. Immersants ought to be made aware that there is evidence that advertising tactics using embodiment technology such as VR can have a powerful unconscious influence on behavior. Yet virtual reality was imagined as a human simulation technology long before humans were able to tweet their every inconsequential thought out into the metaverse. Its status as a technological tool is more mature than emergent. Now, by rendering high framerate graphics using multiple, stereoscopic points, VR is matching the speed and accuracy of robotic sensors and cameras. By modeling physics, motion, and material interactions, virtual reality will train automatons - robots, drones, and diagnostic gear - before they need to perform in the real world⁶⁹. That’s one small step for robotics, but it foretells a much bigger step forward for artificial⁷⁰ and augmented⁷¹ intelligence.

⁶⁴ Turel, O., et al. Examination of neural systems sub-serving Facebook addiction. *Psychological Reports*. 115(3). December 2014. DOI: 10.2466/18.PR0.115c31z8

⁶⁵ There is a sect of virtual content known as the “dark triad” (Paulus and Williams, 2002) that refers to narcissism, machiavellianism and psychopathy, whereby individuals find it appealing to spend time in VEs designed to reward characters that exhibit traits associated with the dark triad.

⁶⁶ Riva, G., et al. Affective Interactions Using VR: Presence and Emotions. *CYBERPSY & BEH* Vol10(1), 2007. DOI: 10.1089/cpb.2006.9993

⁶⁷ Coyle, J.R., and Thorson, E. Interactivity and Vividness. *Journal of ADV* 30(3):65-77 · Oct 2001. DOI: 10.1080/00913367.2001.10673646

⁶⁸ Madary, M. Intention & virtual objects: Qiu Chengwei’s dragon sabre. *Ethics Inf. Technol.* 16,219-225. Doi:10.1007/s10676-014-9347-4

⁶⁹ Solotko, S. “Virtual Reality is the Next Training Ground for Artificial Intelligence”, *Tirias Research*, October 2017

⁷⁰ The theory and development of computer systems able to perform tasks normally requiring human intelligence.

⁷¹ Emphasizing that cognitive technology is designed to enhance human intelligence rather than replace it (as per AI).

Recent advancements point to a potentially disruptive combination of virtual reality and artificial intelligence which will unlock a future with safe and competent intelligent machines, able to learn exponentially through self-training in intelligent, realistic simulations. Faster-than-real-time automated training combined with intelligent, virtual reality simulators may be the last exponential in machine learning⁷². AI-assisted virtual simulations can now predict common problems associated to everything from climate change⁷³ to global conflict⁷⁴. And adept machine learning models will only gain more and more access to the flood of interactive VR training data needed to become expert learning systems and ultimately useful, intelligent agents with exponential and disruptive advancements⁷⁵.

ICRC's Limitless Future

A computing concept known as the 'mirrorworld' can be traced back to NASA, circa 1960, and the logic was simple: for every shuttle NASA sent into outer space, an exact duplicate was left on earth to troubleshoot a malfunctioning component. Eventually these mechanical twins evolved into computer simulations – or digital twins. Creating a digital twin soon morphed into replicating environments, entire cities and landscapes replicated virtually.

The proposed mirrorworld of the future is expected to be a virtual map that overlays reality. Accessible through any XR experience, it will be an accurate, functional computer-generated replica of life as we know it - not only reflecting what something looks like but recreating its context, meaning and function. When you wear an AR or MR device, you might turn your head to see a virtual whale swim outside your office window. If you wear a VR device, you might find yourself swimming alongside a whale in the middle of a deep sea. In the mirrorworld, you could be the whale watching an avatar of yourself sitting at your desk.

Today, modern science can give explicit details about what happens to the human mind inside VR. At a physiological level, the brain and sensory organs start to dance in a sensorimotor loop to make sense of a simulated environment with haptic and auditory cues⁷⁶. One may feel a weightlessness in the stomach as the hippocampus attempts to regulate the sudden spatial shift⁷⁷. The abstract mind becomes separated from the corporeal form as *homoncular flexibility* comes into play; quickly learning to control a new, unfamiliar virtual body even as the computer continuously changes the relationship between tracked and rendered motion⁷⁸. The neural pathways and synapses firing in the brain change patterns as spatial impairment requires the search for new pathways, triggering other senses like auditory or temporal markers to navigate a new world⁷⁹.

And just like skin exposed to the sun, science is certain that the brain in a virtual environment is extremely vulnerable. That VR is effective is not in question. Copious amounts of research demonstrate it can control, change and violate a person's autonomy yet it is also uniquely capable of evoking empathy, emotion, care, and imagination like no other technology. Understanding VR is key. This can serve the ICRC in a variety of ways, from forecasting critical responses to urban conflict scenarios or preparing disaster response options, testing AI programming in automated weapons, or simply connecting the most remote populations to state-of-the-art educational and informational facilities. Just hit enter. And repeat.

⁷² Jaderberg, M., et al. DeepMind - Capture the Flag : The Emergence of Complex Cooperative Agents. *Science*. 31 May 2019: Vol. 364, Issue 6443, pp. 859-865. DOI: 10.1126/science.aau6249.

⁷³ Schmidt, V., et al. Visualizing the Consequences of Climate Change Using Cycle-Consistent Adversarial Networks. *Computer Vision and Pattern Recognition*. May 2019. arXiv:1905.03709

⁷⁴ Olsher, D.J. New AI Tools for Deep Conflict Resolution and Humanitarian Response. *Procedia Engineering* 107 (2015) 282–292. doi: 10.1016/j.proeng.2015.06.083

⁷⁵ Culp, Steve. Virtual Reality Plus Artificial Intelligence Can Transform Risk Management. *Forbes Magazine*, April 2018.

⁷⁶ Banos, R.M., et al. Transform Exp: The Potential of AR and VR Pers & Clin Change. *Front Psych* 7: 164. Doi 10.3389/fpsy.2016.00164

⁷⁷ Banos, et al. 2016. Coyle and Thorson, 2001. Cummings and Bailenson, 2016.

⁷⁸ Yee and Bailenson. *The Proteus Effect*.

⁷⁹ El Beheiry, et al. *Virtual Reality: Beyond Visualization*.

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