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LETTER FROM THE EDITORS

We are proud to present the fifth volume of the Simon Fraser University Undergradatue Journal of Psychology. This journal provides a opportunity for undergraduate students to publish and showcase their hard work in an academic platform. We are honoured to give students the opportunity to pursue their scientific interests, and further their research.

This journal would not be possible without all the hard work of our undergraduate and graduate student editors. All of our editors volunteered numerous hours to read, review, and give feedback to the students who submitted work to this year's edition. We are also grateful to the Psychology Department for their support and for funding the journal. Without the support of our department, this journal, and the opportunity it provides to students, would not be possible.

And a big thank you to the author's of this yea'rs journal. Without their hard work and dedication, this journal would not be able to publish. We are exceptionally excited to present these submissions, which were the strongest of a large pool of outstanding work. This year's students presented an incredible selection of psychological research, and we are so grateful for all the submissions received.

We also want to extend our appreciation to the readers of this journal. We hope that the research presented here by those early in their academic careers inspires you all the way we have been inspired.

Lastly, thank you to everyone who submitted to this journal. We want to encourage all of you to keep writing, and to continue to push the bounds of research.

- The Managing Editorial Staff
Bridget Beggs, Madison Edge, & Henri Lu

Treatment of Brain Disorders using Closed-Loop Brain-Computer Interfaces

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Existing treatments for brain disorders are time and resource-intensive, requiring patients to continually attend therapy sessions or purchase medicine. Closed-loop brain-computer interfaces (BCIs) allow an implanted computer to monitor brain activity, recognize illness-associated patterns and impact brain activity through deep brain stimulation (DBS). This technology could improve existing treatments by replacing a lifetime of therapy or pharmaceuticals with a one-time surgery and a short calibration period. This paper discusses how BCIs could be paired with DBS to increase its responsiveness to assist patients with major depressive disorder or post-traumatic stress disorder,and how a BCI could calibrate the stimulation pattern to improve function in patients with Parkinson's disease, obsessive-compulsive disorder, and neuropathic pain. BCIs are currently limited by a lack of flexibility and the foreign-body response, but organic electronic biomimetic neurons are being developed that could overcome these issues. BCIs may also cause concerns about patient autonomy, but open-source coding and electromagnetic shielding could be used to alleviate their fears. By giving patients control over certain aspects of their treatment and requiring less clinical intervention for DBS calibration, BCIs could increase patient autonomy and improve treatment outcomes.

Keywords: Brain-computer interface, MDD, PTSD, Parkinson's, OCD, neuropathic pain

Over one in three Canadians will suffer from some form of mental or substance use disorder in their lifetime (Pearson, Janz & Ali, 2013), rivaling coronary heart disease (Lloyd-Jones, Larson, Beiser & Levy, 1999) and diabetes (Venkat Narayan, Boyle, Thompson, Sorensen, & Williamson, 2003) in incidence rates. Brain disorders have primarily been treated using medicine and psychiatric therapy, and while these methods are effective they also have major drawbacks. Although these techniques are noninvasive, they often involve lengthy regimens of expensive medication or visits to the therapist. Medicines also often come with various side-effects, while therapy sessions take time from the patient's daily life that they may wish to use elsewhere (as compared to a one-time recovery from surgery). Deep brain stimulation (DBS) has also been used to treat disorders; however only a specialist can adjust the stimulation (Volkmann, Herzog, Kopper & Deuschl, 2002). This means that it is not very responsive to changing brain states, as the patient must wait for an appointment with their specialist to adjust the stimulation.

However, brain-computer interfaces (BCI) show potential for providing treatment without extracranial side effects, constant cost or frequent appointments (Shih, Krusienski, & Wolpaw, 2012). BCIs provide communication pathways between the human brain and computer algorithms, allowing the brain and the computer to directly affect each other. Currently, there are two main types of open-loop BCIs, where information flows in only one direction between the brain and the computer. One type ('Computer to Brain') utilizes computer sensors to collect external information, which is then directed towards the relevant brain region(s) to circumvent faulty sensory organs (e.g., camera sending signals to the visual cortex to bypass a damaged retina). The other type ('Brain to Computer') observes the motor cortices of the brain, watching for motor commands that can be passed on to prosthetic or paralyzed limbs. These allow their users to mitigate disabilities such as blindness (Kotler, 2002), locked-in syndrome (Kelland, 2017) and quadriplegia (Gettler, 2012). Closed-loop BCIs differ from these open-loop BCIs in that they can both monitor and affect brain activity, allowing them to identify pathological activity and work to normalize it. While they have only been tested in mice (Widge, Dougherty & Moritz, 2014) and sheep (Afshar et al., 2013), in humans, closed-loop BCIs could allow for highly responsive brain disorder treatment without requiring long-term medication or therapeutic regimens. These closed-loop BCIs would work by analyzing brain activity using electrocorticography (ECoG), then modulating DBS activity to treat the disorder. Therefore, closed-loop BCIs can be used to increase the effectiveness and efficiency of DBS in treating brain disorders (such as mood and sensorimotor disorders) by using brain activity to regulate treatment.

Brain Disorders

Major Depressive Disorder

Extreme cases of major depressive disorder (MDD) could be alleviated using DBS, with usage of closed-loop BCIs improving DBS responsiveness and efficiency. MDD is a mental illness characterized by persistent negative mood, impacting a person's emotional and social quality of life (American Psychiatric Association, 2013). This disorder is primarily treated using individualized regimens of antidepressants or psychotherapy, but these come with the risks of side effects, dependency and continued financial cost. These treatment methods are usually successful, but at least 30% of people with MDD are resistant to more than one antidepressant (Little, 2009), complicating and extending the treatment plan.

However, DBS inhibition of the subgenual cingulate region (SCR) has been found to help alleviate symptoms in over half of treatment-resistant MDD cases (Mayberg et al., 2005), with less than half of these patients lapsing back over the 3 years following DBS implantation (Kennedy et al., 2011). The issue with this is that DBS activity must be adjusted every few months for best results, and on its own this can only be done by visiting a specialist (Shukla, Zeilman, Fernandez, Bajwa & Mehanna, 2017). By using a DBS contact with a built-in microelectrode (University of Pittsburgh Neurological Surgery Department, n.d.), an attached BCI could continually monitor activity of the SCR and adjust DBS inhibition to keep SCR activity at an optimal level (Khan & Deng, 2017). This increased responsiveness would in turn lead to greater effectiveness, as the SCR would not become desensitized to constant DBS, but instead would only receive stimulation when it was needed. It would also lead to higher efficiency; as intermittent stimulation would deplete the battery slower than constant stimulation.

Post-Traumatic Stress Disorder

BCI-mediated amygdala DBS could be used to alleviate post-traumatic stress disorder (PTSD) symptoms. PTSD is a mental illness where after experiencing a traumatic situation, a person develops symptoms such as flashbacks of the traumatic event, a sensitivity to elements that remind them of the event, and mood problems (National Institute of Mental Health, 2016b). Depending on the nature of the event, the duration of these symptoms and their effect on daily functioning can range from slightly inconveniencing (e.g., unable to sky-dive for a month) to crippling (e.g., unable to be near cars ever again). Like MDD, PTSD is mainly treated using individualized treatment plans of antidepressants and psychotherapy (U.S. Department of Veterans Affairs, 2017), with similar downsides (side effects, dependency, continual cost, personal effort required for treatment).

DBS treatment of the basolateral amygdala for PTSD symptoms recently underwent its first human trial, where there was a decrease in the severity of a veteran's PTSD symptomatology as measured by a 37.8% decrease in score on the Clinician-Administered PTSD Scale (Blake et al., 1995) from baseline (Langevin et al., 2016). This and other successes in the rodent model point to DBS as being a possible major treatment method for PTSD. However, like MDD, without the controlling influence of a BCI, DBS calibration is slow and inefficient. In the case of PTSD, an additional complication to BCI usage is that current technology (which relies solely on the amygdala to identify pathological activity) may confuse PTSD-related activity with normal fear-triggering activity (e.g., watching a scary movie or going bungee-jumping). To distinguish between the two, the user could use a phone or computer to communicate with the BCI and tell it to deactivate for a certain length of time. This would temporarily diminish or turn off the DBS, allowing the user to fully experience normal fear-triggering activities. In this way, the BCI would still allow for normal amygdala functioning, while preventing pathological activity.

Obsessive-Compulsive Disorder

Obsessive-compulsive disorder (OCD) could also be treated using DBS controlled by closed-loop BCIs. OCD is a mental illness characterized by reoccurring urges, known as obsessions, which cause anxiety unless the patient performs specific behaviors, referred to as compulsions (National Institute of Mental Health, 2016a). These rituals regularly interrupt the patient's daily life, forcing them to stop whatever they are doing and deal with the nagging compulsion. Currently, this disorder is treated using medication and cognitive-behavioural therapy (Abramowitz, Taylor, & McKay, 2009). However, as mentioned previously, these methods involve extensive pharmaceutical regimens and frequent trips to a psychiatrist for treatment.

DBS has been used on patients who prove resistant to these methods, where it was found to be able to reduce symptoms by around 30% for several years (Greenberg et al., 2006). OCD can be treated using DBS in several different brain regions, including the nucleus accumbens, the anterior limb of the internal capsule, the ventral striatum, the subthalamic nucleus, and the bed nucleus of the stria terminalis (Jancin, 2016). For patients with co-morbid mood disorders, DBS of the ventral striatum has been effective in reducing OCD symptoms as well as improving mood (Holtzheimer & Mayberg, 2011). This variety of possible DBS locations implies that OCD involves multiple brain structures, meaning that individual cases may have different areas receptive to treatment. In patients with multiple DBS electrodes, the BCI could monitor brain activity and use patient feedback to learn what OCD-related brain activity looks like in each specific patient through machine learning. For instance, the patient could answer a prompt on their phone every few hours asking how active their OCD has been, and by comparing stored activity from high-OCD times and low-OCD times the device could identify the pathological signals. The DBS-BCI could then experiment with different stimulation patterns to determine which stimulation pattern is most effective for the patient (i.e., minimizes high-OCD times). If that pattern later becomes ineffective, the BCI could either start experimenting after a certain threshold of OCD activity has been reached or the user could signal the BCI to start finding a new pattern. By monitoring brain activity and allowing for easy recalibration of the stimulation pattern, a closed-loop BCI can make DBS treatment of OCD much more responsive, bringing with it the efficiency and efficacy benefits discussed in prior sections.

Parkinson's Disease

Closed-loop BCIs could be used to improve DBS functioning in patients with Parkinson's. Parkinson's is a gradual motor system disorder that causes trembling and impairs balance, movement speed, and flexibility, making many everyday tasks impossible as the symptoms worsen (National Institute of Neurological Disorders and Stroke, 2019). Current treatments of Parkinson's include medication and DBS of the subthalamic nucleus (STN) (Davie, 2008). Medication suffers from the same faults as in prior disorders, but usage of DBS in Parkinson's cases can cause side-effects as well. Although DBS does have a positive effect on motor symptoms, it can also cause or worsen commonly comorbid disorders like impulse control disorder by stimulating nearby brain reward pathways (Broen, Duits, Visse-Vandewalle, Temel & Winogrodzka, 2011), limiting its overall usefulness. However, a closed-loop BCI could monitor brain activity levels in the putamen, which is inhibited in Parkinson's (National Institutes of Health, 2016), as well as the nucleus accumbens, which is a focal point of the reward pathway (Malenka, Nestler & Hyman, 2009). By controlling multiple microelectrodes in the STN, the BCI could then find the firing pattern that maximizes putamen activity, while minimizing reward pathway stimulation. In this way, the BCI could increase DBS flexibility, efficiency and responsiveness without addictive side-effects.

Neuropathic Pain

Neuropathic pain could be treated without costly pharmaceutical regimens by using DBS paired with closed-loop BCI modulation. Neuropathic pain is the product of damage or dysfunction in the somatosensory cortex, stimulating neurons responsible for pain sensation and causing illusory pain elsewhere in the body (Treede et al., 2008). One form of this is phantom limb syndrome, where somatosensory neurons associated with an amputated limb misfire and cause perception of activity or pain in the absent limb (Elbert, 2012). Neuropathic pain is primarily treated using a variety of pain medication (Finnerup, Sindrup, & Jensen, 2010), all of which have side effects and have to be taken for the rest of the patient's life.

Alternatively, DBS has been found to be effective in treating certain kinds of neuropathic pain such as peripheral neuropathic pain (Rasche, Rinaldi, Young & Tronnier, 2006) and long-term treatment of phantom limb pain (Abreu et al., 2017). As with any of the other usages of DBS to treat brain disorders, combining it with a closed-loop BCI could make the system more reactive and more efficient. After the BCI is installed, the user could use an outside device to signal the BCI when they feel illusory pain. The BCI could then examine brain activity recorded before and during the pain. Over many occurrences, the BCI could be trained to recognize brain signals associated with the neuropathic pain, at which point it could use DBS stimulation to shut down the pathological brain activity. Increasing the responsiveness of DBS makes constant stimulation unnecessary, preserving battery life and preventing desensitization of the target tissue.

Limitations and Solutions

Physiological

While closed-loop BCIs have the potential to improve treatment plans for the aforementioned brain disorders, their current effectiveness is hampered by the lack of long-term stability or flexibility in intracranial BCI components. ECoG electrodes have been shown to last for many months with no signal loss or degradation (Chao, Nagasaka & Fujii, 2010). However intracortical electrodes such as those used in DBS are connected to the skull, occasionally leading to motion relative to the brain and separation of stimulation from the target neurons (Adewole et al., 2016). This lack of flexibility also excludes children and adolescents from treatment due to their still-growing brains, which may cause the target neurons to move away from the DBS location over time. In addition, these fixed electrodes trigger the brain's foreign-body response, isolating the electrode within scar tissue and degrading signal stability (Tresco & Winslow, 2011).

However, the foreign-body response can be minimized if an implant is as flexible as neural tissue (University of Cambridge, 2014), and a flexible implant is also more likely to stay in place among the brain's existing structures. Simon et al. (2015) have developed organic electronic biomimetic neurons (OEBNs) that are made of flexible organic polymers, allowing them to avoid the foreign-body response if they were used instead of intracortical electrodes. OEBNs work by using enzyme-based biosensors and organic electronic ion pumps to translate chemical signals to electrical signals and back again, mimicking neuronal activity and successfully using acetylcholine to communicate with human cells (Simon et al., 2015). They could also act as a translator between chemical signals within the brain and electrical signals within a computer (Cronberg, 2015), making them ideal for usage in BCIs. Compared to standard electrodes, OEBNs carry the additional benefit of stimulating neurons through chemical means rather than just electrical. This lessens the risk of neuronal damage from repeated electrical stimulation and expands the possible usage of this technique through usage of different neurotransmitters. OEBNs controlled by closed-loop BCIs could be used to treat disorders caused by the death of specific neurons, such as orexin in narcolepsy (Mahlios, De la Herrán-Arita, & Mignot, 2013) or dopamine in Parkinson's (Bernheimer, Birkmayer, Hornykiewicz, Jellinger, & Seitelberger, 1973). Unfortunately, OEBNs are currently too large to be implanted into the brain, but researchers at the Karolinska Institutet in Sweden are working on miniaturizing them (Cronberg, 2015).

Psychological

In addition to the physical limitations of BCI, patients may be concerned that by using BCIs they are opening themselves to being controlled or deceived by other people. Such lines of thought have existed for decades, being crystallized in movies like the Matrix, and have only intensified since the 9/11 attacks in the USA (Harrington, 1996; Shrira, 2008). However, there are two main ways BCIs can overcome this potential negative reaction. First, to overcome fear of the companies producing this technology, the design and coding of the BCIs could be made open-source. This would allow the global community of patients, computer programmers and neurologists to pick it apart, multiplying the number of possible opportunities for a mind-control attempt to be exposed. By being open-source about everything involved with the device, the BCI producer would also display themselves as having nothing to hide, helping users trust them even if they themselves cannot understand the code. While having an open-source design could lead to copycat devices being developed, quality would be ensured by the stringent clinical testing process required for distribution.

Second, to avoid outside manipulation of the BCI signal, bio-friendly electromagnetic shielding could encase the main circuitry of the device (e.g., a very thin layer of titanium). For devices that interact with an outside device (such as the PTSD deactivation app discussed earlier), it may be possible to use miniaturized quantum key distribution (QKD) to ensure the connection is not tampered with. QKD uses quantum mechanics to ensure a signal sent by one device cannot be manipulated before it reaches the target device (Powell, 2016), which would allow for very high security despite open-source design. It is possible that despite efforts to secure the wireless connection between two devices that hacking will still remain a concern. However, with advancements in cryptographic methods, the risk of manipulation of the signal or devices will hopefully be minimized to a point that patients can safely use the technology.

By using these two methods, BCI development companies can help counter the dual accusations of trying to control people or letting others control people. In cases where the patient can give external commands to the BCI (e.g., patients with PTSD turning off amygdala inhibition when they want to be scared), having this ability would greatly increase the patient's participation in and feeling of control over their treatment. Increased patient participation is associated with improved treatment results over a variety of physiological and psychological diseases (Vahdat, Hamzehgardeshi, Hessam & Hamzehgardeshi, 2014), while increased feelings of control have been correlated with diminished post-operative issues, earlier discharge from hospital, decreased anxiety and overall health improvements (Auerbach, 2000). Meanwhile, patient misuse of the device could be avoided by only allowing user input to electrodes far from the reward pathways, preventing an addiction cycle. Overall, by taking steps to mitigate patient concerns regarding autonomy and by emphasizing the increased patient control BCI technology can offer, patients can be made more comfortable with the technology, resulting in better treatment outcomes and decreased patient stress.

Conclusion

Overall, closed-loop BCIs can improve treatment of multiple brain disorders across different disorder families through DBS modulation. DBS treatments can be enhanced via closed-loop BCIs, which can coordinate DBS activation with relevant brain activity to improve system responsiveness and power efficiency. If the DBS target is close to sensitive nuclei, usage of a closed-loop BCI can help maximize treatment efficacy while minimizing side effects by monitoring relevant brain regions. In cases where multiple target locations can be stimulated for the effect, BCIs can simplify the process of trying different firing patterns between the areas to determine what is most effective for the user. The BCI could additionally be attached to a smartphone or regular computer via a quantum or otherwise-encrypted wireless signal, allowing the user to give feedback to the BCI and improving patient agency. While usage of closed-loop BCIs would require an invasive surgery and recovery from the surgery, this would be a one-time cost compared to the potentially long and expensive regimen of medication or therapy. Additionally, BCIs could handle treatment of multiple comorbid disorders through their ability to quickly adjust DBS firing patterns in response to brain activity. These potential advantages over traditional methods suggest that once the technology involved in BCIs develops to a certain point (e.g., OEBN and QKD development), there may be a sudden surge in BCI usage for treating brain disorders. This increased demand would lead to faster development of BCI technology, making them cheaper, more reliable, and easier to install and maintain. This would then lead to greater acceptance of BCIs in the public eye, which may eventually lead to them being as integrated into society as regular computers are now. By gaining an understanding of computer programming and the basic principles behind BCIs, the average person can prepare themselves for the arrival of BCIs in the doctor's office, in everyday life, and perhaps someday into their own body.

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Virtual Reality In Legal Psychology Research: Advancing Jury Similation Research Methodology

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Jury simulation research methodology is often criticized for lacking sufficient generalizability to impact legal proceedings. The implementation of Virtual Reality (VR) technology would benefit the domain of jury simulation research by addressing some of the persistent areas of concern by courts, such as limited ecological validity and generalizability, and by providing insight into the cognition of simulation participants. Other issues include the lack of decisional consequence experienced by simulation participants, and the contrast between the written transcripts often used as experimental stimuli and what is experienced in a real courtroom. If implemented, VR technology would address these issues by providing more realistic stimuli, conveying consequences for the choices made within-simulation by participants, and using dependent measures such as eye tracking and pupillometry. Furthermore, by developing a software application that facilitates the efficient production of virtual environments by researchers with limited technical knowledge, the costs of integrating VR for jury simulation research can be greatly reduced. Overall, when implemented in conjunction with core methodological advancements in the field of jury simulation research, such as drawing participants from jury pool samples, the use of VR as a tool for jury simulation research would allow for a higher level of ecological validity and generalizability than previously achieved.

Keywords: virtual reality, jury simulation, generalizability, technology

Despite decades of simulation research on jury behaviour, criticism from scholars and those within the legal community remains persistent. Investigators and critics alike have noted that the primary shortcomings of jury simulation research are perpetual methodological practices that decrease the ability to generalize experimental findings to real-word courtrooms (Bornstein, 1999; Diamond, 1997; Krauss & Lieberman, 2017; Vidmar, 2008). Methodology has come under scrutiny regarding this domain of investigation because the intent of jury simulation research is usually applied. While some simulation research is done with the intent of illuminating basic psychological processes, it is evident that much of the research is done with the underlying goal of applying findings from simulations to improve the legal system (Bornstein, 1999). Put differently, jury simulation research tends to pragmatically imply that the way participants behave in a study is the way that real-life jury members will behave in a trial. It is this underlying goal that leaves jury simulation research rightfully open to questions about whether the implemented methods result in adequate generalizability (Bornstein, 1999; Christensen, Johnson, & Turner, 2014). For example, in Lockhart v. McCree (1986), 15 jury studies which alluded to an effect between death-qualified jurors and conviction-proneness were rejected by the U.S Supreme Court on the grounds of the research lacking ecological validity (Krauss & Lieberman, 2017).

It is here that a distinction must be made between two related constructs: ecological validity and generalizability. Generalizability, in this context, is the ability to generalize research findings across case types, legal contexts, jurisdictions, and legal actors, whereas ecological validity is narrower in scope, referring to how closely the research mirrors real-world courtroom practice (Krauss & Lieberman, 2017; Vidmar, 2008). Consequently, when highlighting the need for research to generalize to real-world trials, this discussion is alluding to ecological validity, a validity concern that is a prerequisite to generalizability in the broader sense (Bornstein, 1999).

To allow greater generalizability to jury venires and courtroom settings, current jury research needs to address three key components which past methodologies have had difficulty actualizing: (1) implementing more realistic trial simulations, (2) conveying the weight of consequence to participants' decisions, and (3) using reliable dependent measures. As discussed by

Bornstein (1999) and Diamond (1997), the inability of past jury research methodology to address these issues has played a role in an extensive body of simulation research being criticized by those in the legal community. Considering the current issues with past jury simulation research methodology, virtual reality (VR) technology may be a valuable asset when integrated with jury simulation research because it can increase ecological validity through the presentation of more realistic trial simulations. Additionally, VR can implement more reliable and valid dependent measures such as eye tracking, and it may present a notion of consequence for the choices made by participants.

Overview of Virtual Reality

VR systems are technological tools that are becoming increasingly accessible to researchers. According to Harrison, Haruvy, and Rutström (2011), VR technology refers to "computer-generated 3D real-time environments where users interact with the simulated environment" (p. 87). The virtual environment in turn implements visual and auditory stimulation and invokes a sense of spatial presence which facilitates interactions between people and computer-generated characters in real-time (Harrison et al., 2011).

Virtual reality has been used in flight simulators in commercial and military aviation training for decades and is now being utilized in a wide range of research scenarios, from traffic research to attentional research. This increased accessibility of VR technology stems from a rapidly growing consumer interest in VR, and a corresponding increase in commercial production of VR hardware and software. Although still costly to implement in a research scenario, these developments have drastically lowered the cost of such products and increased their availability, making a previously inaccessible technology a viable option for research purposes. For example, early VR systems were marketed at a cost of over $10,000.00 CAD per system (Virtual Reality Society, n.d.). Currently, high-end VR systems are available at a starting point of $1,700.00 CAD for both a headset and computer, although development of software programs currently constitutes the largest expense and is discussed below in more detail (Buzzi, 2018; Greenwald, 2018). While the high accessibility of an experimental material answers some questions regarding its ease of implementation, an in-depth look at the advantages provided by a tool is necessary to answer why it should be chosen over other materials.

Virtual Reality in Jury Simulation Research

Realism

The lack of realistic trial simulations has led to persistent concerns regarding the ecological validity of jury simulation research. In a recent review of the past research, Krauss & Lieberman (2017) con-cluded that among other amendments - such as drawing more realistic participant samples - implementing more realistic stimuli is a key part of increasing the ecological validity and generalizability of jury simulation research. This thought is reflective of the concerns highlighted by Bornstein (1999) who discussed how research settings dissimilar to the courtroom and trial stimuli lacking realism are among the major validity concerns for jury simulation research. The finding that such concerns are still relevant at this point in time reveals that these issues have persisted for several decades. Indeed, the most popular simulation medium, the written transcript, has its greatest limitation in that it has low generalizability to real-world trials (Krauss & Lieberman, 2017). For example, in Free v. Peters (1993), research on jury comprehension that used written stimuli was evaluated as lacking ecological validity by Judge Posner due to it being analogous to a written examination setting, and thus far removed from a trial setting.

Additionally, critics and researchers alike have drawn attention to a feature of written transcripts that further reduces their ecological validity: that they provide participants the opportunity to reread sections of the trial (Pezdek, Avila-Mora, & Sperry, 2010; Rose & Ogloff, 2001). Significantly, this may lead to differences in the comprehension of various trial details between real jurors and mock jurors, further reducing simulation generalizability. In fact, differences have been observed with different trial presentation (e.g., Bornstein et al., 2017; Pezdek et al., 2010). However, it is important to consider that the dependent measures employed have been inconsistent between studies and that the effects of the presentation medium may be different for different dependent measures (Pezdek et al., 2010). Moreover, illuminating the effect of experimental medium on two groups of mock jurors is not equivalent to understanding the effect on comprehension between those exposed to experimental stimuli and those in a real trial. Thus, the issue of low ecological validity for the most commonly used trial stimuli remains unresolved, although the utilization of VR environments may allow for progress in this domain.

By transporting participant jurors to a virtual courtroom where they can see and hear events unfold in real time, VR has the capacity to achieve a level of realism previously unattainable by trial simulations. For example, in a review of several virtual reality experiments on decision making, a unique feature of VR is described by Harrison et al. (2011) as the ability to present naturalistic cues that allow the participant to become immersed in the task at hand, eliciting the same decision heuristics that would arise in the real-world analog of the virtual environment presented. These naturalistic cues arise from setting up a virtual environment that is familiar or recognizable to participants in the real world, and it is this unique feature of VR that distinguishes it from the laboratory setting (Harrison et al., 2011). This finding may reflect the core strength of utilizing VR for jury simulation research: by immersing participants in a virtual courtroom and eliciting the same psychological processes that are evoked in the analogous real-world environment, the decisions made by mock jurors may be more reflective of those made by a real jury. Furthermore, by bringing a virtual courtroom into the laboratory, realism is gained without having to sacrifice experimental control, since experimenters dictate what stimuli is presented to participants. By contrast, past alternatives to laboratory research, such as field research on jury behaviour, have allowed for increased realism at the cost of experimental control (Bray & Kerr, 1979). In short, VR experiments can facilitate increased ecological validity while retaining the experimental control of the laboratory setting.

Consequences of Decisions

Even with more realistic trial stimuli, one of the most potent criticisms of current simulation re-search on jury cognition and behaviour remains: participants have knowledge that their decision will not affect the fate of the person(s) involved (Bornstein, 1999; Diamond, 1997). This represents a key issue because no previous methodology has been able to portray case scenarios in a way where participants feel any sort of consequential weight for the decisions they make as simulated jurors. This has been the basis for court skepticism toward even the most elaborate simulation research, as a court will always point to the fact that participant jurors are aware that the trial is not real, and that they know their decision will not have fateful consequences for the involved parties (Bornstein, 1999; Diamond, 1997). Although empirical evidence is yet to be seen for a relationship between VR immersion and increased perception of responsibility, there are several features of VR that may allow future simulation research to begin bridging this gap. VR blurs the line between what is reality and what is virtual, and immerses participants in a simulated environment where their choices will affect the fate of virtual people. Furthermore, as this technology continues to rapidly advance, the images and audio presented by VR systems may more closely reflect what is experienced in real life.

Regarding VR's capacity to increase participant's sense of importance for decisions affecting a simulated defendant, an area of concern is that the simulated parties - being 3D models of people and not real humans - will not evoke the level of empathy needed to alter participants' perception of the gravity of their choices. However, empirical evidence by Shin (2018) suggests that the real-time interactions of VR promote perception that the narrative is happening in the present, drawing participants into emotional engagement and stimulating empathetic reactions. In addition, the first-person view of VR elicits a much higher engrossment for users than the third-person view utilized by videotaped trial methods, and such engrossment is further instilled by the sense of spatial presence provided by VR (Skulmowski, Bunge, Kaspar, & Pipa, 2014). Significantly, the sense of spatial proximity to a simulated person is enough to evoke an emotional response from research participants, as indicated by moral dilemma studies where participants who perceived closer spatial proximity to virtual people experienced stronger emotional responses (Skulmowski et al., 2014). Therefore, the temporal realism, spatial proximity, and emotional engagement experienced in VR may work to increase participants' perception of decisional consequence, which is an experience unrealized through past experimental materials. Still, experimental jury simulation research that examines the effect of these features on participant's perception of consequence is needed to determine how effective VR environments are in this regard.

Dependent Measures

One final way that VR surmounts past experimental media is its capacity to employ reliable and valid dependent measures. Questionnaire-based dependent measures have faced criticism from members of the judiciary on the grounds of being akin to a written examination (Diamond, 1997). The significance of this lies in the finding that participants who are adequately capable of performing on a real jury may not fully understand the written questions utilized as dependent measures (Diamond, 1997).

Although this issue may be especially pronounced when drawing samples from jury venires where English is an additional language for a large proportion of the population, it can also arise in native English speakers, since reading ability often lags behind verbal comprehension ability (Carrell, 1991). Consequently, questionnaire-based dependent measures may not always be sufficiently reliable or valid. Contrastingly, VR technology can provide dependent measures that are consistent across populations, while giving insight into automatic processes as they happen. One such measure is eye tracking, a method commonly used in a range of research fields such as linguistics, cognitive psychology, and neuroscience. Eye tracking is considered a highly reliable dependent measure because eye movement programming is critically influenced by subcortical structures, resulting in eye movements that precede conscious, deliberate thought about the stimuli present at the location (Goldberg & Wertz, 1972). Thus, eye tracking measures behaviour that is largely automatic, allowing for reliable measurements across diverse populations and samples, and giving researchers insight to where, what, and when participants are directing their attention. Such dependent measures may provide researchers with deeper understanding of participants' responses to the manipulation of independent variables. Moreover, unlike typical infrared eye tracking devices which have eye tracking as their sole function, VR headsets allow for the collection of data while simultaneously projecting the visual component of a simulation to participants.

Another measurement technique that allows for data collection during a VR simulation is pupillometry, which uses the pre-existing hardware in a VR headset to measure pupil dilation or diameter. As demonstrated in research by Skulmowski et al. (2014), the physiological measure of pupil diameter corresponds to participants' affective arousal or cognitive load. Interestingly, measures of pupil diameter provided indicators of affective responses to experimental stimuli when self-reports purported there were none, demonstrating the utility of this technology to capture data that would not be revealed by means of self-reports (Skulmowski et al., 2014). Thus, with pupillometry capabilities, VR presents yet another dependent measure that is reliable and valid across experimental conditions and participants. Indeed, when used in the context of jury simulation research, measurements that provide data on participants' affective arousal in response to factors such as testimony or prior criminal records will provide a rich psychological tapestry untapped by past methods.

Considerations of Virtual Reality in Research

Ethical

Concerns have been raised regarding the ethical implications of collapsing real and virtual worlds in a research scenario. Madary and Metzinger (2016) described several ethical concerns for the use of VR technology in research, including avoiding harm to participants and describing any risks associated with VR experiences. Therefore, it is the responsibility of researchers to ensure that their stimuli adhere to the principle of non-maleficence and that ongoing, informed consent is obtained from participants. Other such concerns involve the potential mental health risks that have been linked with extensive VR use (Spiegel, 2017). For instance, Aardema, O'Connor, Cote, and Taillon (2010) suggests that with prolonged use, some vulnerable individuals may experience effects that are similar to the symptoms of depersonalization and derealization dissociative disorders (DP/DR), where a sense of detachment to one's thoughts, sensations, actions, and environment are reported. As researchers of psychology, it is imperative that the mental health of participants be protected and prioritized. Therefore, more research is needed to determine the appropriate amount of VR exposure to employ, thereby avoiding prolonged exposure and reducing this risk for individuals who are more susceptible to DP/DR. It is worth noting that it would be a mistake to remove higher-risk individuals from simulations as this would create unequal opportunities to participate in research. Additionally, this practice would bias samples and subsequently reduce generalizability to real juries. Instead, eliminating the risk itself should be a priority for researchers using VR.

Practical

While concerns such as participant behaviour can be addressed during a study's design phase, there remains a logistical concern that must be addressed well before the design phase begins. If researchers desire to create the virtual environments themselves, they will be required to have a knowledge of game engine logic and scripting, 3D modeling and texturing, and possibly animation (Vasser et al., 2017). Learning these skills is an intensive and time-consuming affair, and obtaining proficiency in them often takes several years. The most popular alternative is to hire a professional company to produce the virtual environments necessary for the experiment, which incurs a significant cost. Regarding this, research by Conrad et al. (2015) demonstrated that a lower production quality of dialogue and animation leads to decreased engagement within the virtual environment. Therefore, attempts to decrease the costs associated with production of the environment, characters, and avatars would be detrimental to the immersivity of the experimental paradigm.

However, the cost associated with creating virtual environments can be greatly reduced if an initial investment is made to develop a user-friendly software application that enables researchers with limited technical knowledge to develop and customize their own virtual environments. This initial investment would involve collaboration with those in the field of computer science, game designers, 3D modelers, and animators. The result would be a software toolkit for jury simulation research in VR, similar to that developed by Vasser et al. (2017) for cognitive psychology paradigms. Such an application would include various 3D models that can be manipulated to create unique environments, such as room layouts, the furnishings found in typical courtrooms, and a selection of modelled characters. As opposed to having a company produce the environment from scratch, this type of application would allow for the streamlined production of virtual environments by researchers with limited technical knowledge, thereby greatly reducing the financial expediture associated with the production of environments for VR.

Experimental

Despite technological advances that give VR the capability to present visual stimuli that are increasingly similar to what is seen in real life, participants are still able to discern that the virtual environment is in fact virtual and not reality. This raises the question of whether a participant will behave uncharacteristically due to the perception that they are in a simulated world, resulting in decisions dissimilar to what jurors would make in real-life. Accordingly, research by Yee and Bailenson (2007) indicates that behaviour in a virtual environment which deviates from participant's typical real-life behaviour does indeed occur. Yee and Bailenson (2007) established that atypical behaviour is due to deindividuation of the participant, which is when a participant takes on the visible characteristics of a digital self-avatar, and the corresponding stereotypes associated with those characteristics.

Nevertheless, since this issue stems from a mismatch of self-representation due to the self-avatar possessing different visible identities than the participant, the solution is rather straightforward: reducing or eliminating this mismatch. One method is to create self-avatars that accurately match the visible identities of participants, such as ethnicity and gender. Another more pragmatically appealing method is to completely eliminate the presence of a self-avatar, thus removing the possibility for participants to observe mismatching cues of self-representation. Yet, research shows that the presence of a visible body which represents the participant in the virtual environment leads to greater immersion in the simulation, thus revealing a considerable downside to this solution (Steed et al., 2016). Ultimately, either of these solutions would prevent participants from unknowingly altering their behaviour to fulfill stereotype expectations of the self-avatar, thus allowing for behaviour and choices that are more congruent with those of real life, and crucially, increasing the generalizability of research findings.

Conclusion

Although VR technology can improve the generalizability of research claims, by itself, it is not enough for jury simulation research to have high external validity. To achieve the highest level of generalizability, researchers must continue to apply and expand on the key progressions that have been made in the domain of jury simulation research, as explained by Diamond (1997) and Krauss and Lieberman (2017). That is, they must continue to draw participants from jury pool samples, implement jury deliberation, use dichotomous dependent measures as response items such as guilty-not-guilty verdicts, and test for consistent results across a variety of simulated cases. These are critical practices because student samples have been shown to differ compared to those taken from jury venires in ways that can affect research results. Similarly, a lack of simulated jury deliberation can introduce questionable results, since research reveals that deliberations can influence outcome. Likewise, a failure to test for similar results across case types raises inevitable questions about generalizability. Hence, maintaining these practices is essential for the generalizability of VR-based research.

In conclusion, for the domain of jury simulation research to benefit from the methodological improvements that advances in technology can bring, VR technology should be implemented as an experimental medium. Due to the capacity of VR to facilitate naturalistic cueing, spatial proximity with simulated people, and immersive experiences through real-time interactions, VR can provide more realistic trial simulations and may be able to invoke the weight of decisional consequence for participants. Additionally, owing to its eye tracking and pupillometry capabilities, VR is an advantageous way to incorporate reliable, valid, and psychologically insightful dependent measures. Utilizing VR in research methodology would allow for the acquisition of more generalizable results while peering into untapped areas of investigation.

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