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Virtual Reality Treatment of Posttraumatic Stress Disorder Due to Motor Vehicle Accident

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Abstract

Posttraumatic stress disorder (PTSD) is a complex, multifaceted disorder encompassing behavioral, emotional, cognitive, and physiological factors. Although PTSD was only codified in 1980, there has been an increasing interest in this area of research. Unfortunately, relatively little attention has been given to the psychological treatment of motor vehicle accident survivors, which is remarkable because vehicular collisions are deemed the number one cause of PTSD. As the emotional consequences of vehicular collisions prevail, so does the need for more effective treatments. Randomized controlled clinical trials have identified exposure-based therapies as being the most efficacious for extinguishing fears. One type of exposure-based treatment, called virtual reality exposure therapy (VRET), provides a safe, controlled, and effective therapeutic alternative that is not dependent on real-life props, situations, or even a person's imagination capabilities. This modality, while relatively new, has been implemented successfully in the treatment of a variety of anxiety disorders and may offer a particularly beneficial and intermediary step for the treatment of collision-related PTSD. In particular, VRET combined with physiological monitoring and feedback provides a unique opportunity for individuals to objectively recognize both anxiety and relaxation; learn how to manage their anxiety during difficult, albeit simulated, driving conditions; and then transfer these skills onto real-life roadways.

Introduction

The psychological consequences of motor vehicle collisions have swept through this population with such intensity that vehicular collisions have now been identified as the leading cause of posttraumatic stress disorder (PTSD) since the Vietnam War.[1–5] PTSD is a complex, multifaceted disorder which was only codified in 1980.[6–8] PTSD is characterized by the development of posttraumatic anxiety following exposure to a significant stressor, such as war, assault, natural or manmade disasters, or motor vehicle collisions.[9,10] The American Psychiatric Association[9] provides the most commonly accepted definition of the disorder in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV). According to the DSM-IV, in order for an individual to be diagnosed with PTSD, he or she must experience an intense emotional response as a result of a traumatic event and the symptoms must last for at least 1 month after the stressor occurred.

Each year, there are an estimated 6 million motor vehicle collisions in the United States, resulting in approximately 2.5 million injuries and over 30,000 fatalities.[3] While study percentages show varying statistics, what remains consistent is that a high percentage of these survivors may go on to develop collision-related PTSD within 1 year after the incident.[1] Although there may be a delayed onset of symptoms following a trauma, most symptoms of PTSD occur within 3 months of the trauma, and patients often first receive a diagnosis of acute stress disorder. Rates of collision-related PTSD range from 8% to over 46% in the general population.[4,11–13] PTSD from varying causes is estimated to have a lifetime prevalence of 1% to 14%, depending on the population sampled. Individuals who have a higher risk of developing PTSD generally have a history of serious injuries as a result of the incident, a fear of dying, prior trauma, major depression, panic disorder, drug dependence, and/or were involved in court litigation.[5,14,15]

According to a study done by Norris,[5] 23.4% of Americans will be involved in a motor vehicle accident (MVA) at some point in their lifetime. Of the individuals in Norris's study who had been in an MVA, 11.5% developed PTSD. In a more recent National Institute of Mental Health (NIMH)-funded study, 39.2% of the MVA survivors assessed met the criteria for PTSD and 28.5% met the criteria for subsyndromal PTSD. During follow-up, 11% of those with subsyndromal PTSD later developed full PTSD. Their diagnosis was measured

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through the Clinician-Administered PTSD Scale (CAPS). The sample showed that 43.5% of those who developed PTSD also developed major depression, compared to only 2% of those who did not develop PTSD. Comorbid panic disorder occurred in 4.8% of the PTSD survivors compared to 0% for those without PTSD. The PTSD group also showed a rate for specific phobias at 21%, although the study does not break down the exact type of phobias. It does state, however, that 15.3% developed a driving phobia, and as a result, 93.2% began avoiding certain driving situations. The long-term follow-up showed that of the 55% of the PTSD individuals who responded, only 24% still met the full criteria at their 2-year postaccident follow-up.

Individuals with collision-related PTSD frequently experience a driving avoidance or driving reluctance, such as avoidance of certain traffic, road conditions, or driving for pleasure, even as a passenger.[16] Since transportation is often necessary in assuring access to employment, health care, and social or recreational activities, individuals with driving phobias often experience impairments in role-functioning and have a tendency to become housebound, which leads to a reduction in overall quality of life.[17,18] Psychological distress is common among the survivors of both severe and minor motor vehicle collisions, and these collisions are often associated with psychiatric morbidity.[18,19]

Posttraumatic individuals may experience intense psychological distress, fearful emotions, flashback memories, nightmares, hypervigilance, and heightened physiological reactivity resulting in painstaking efforts to avoid all cues reminiscent of the trauma. Recurrent intrusive thoughts are also characteristic symptoms for individuals with collision-related PTSD. Mayou et al.,[20] for instance, found that 23% of automobile collision survivors report distressing intrusive cognitions even 1 year posttrauma. Early identification of these individuals is critical to prevent even greater impairment and restriction of daily activities.[4]

Individuals with PTSD also show high levels of sympathetic arousal when exposed to cues of the previous trauma. In an experiment that included psychophysiological assessment of MVA survivors, measurement of both heart rate and skin resistance correctly identified two thirds of the MVA survivors with PTSD by means of high levels of sympathetic arousal. At 1-year follow-up, those still meeting criteria for PTSD continued to show physiological arousal when exposed to the cues, whereas those no longer meeting criteria for PTSD showed no arousal. Those who still had PTSD in fact showed a higher rate of arousal than when first assessed 1 to 4 months after their accidents, as compared to those who no longer had PTSD.[1]

Treatment

There is a paucity in the literature specifically regarding the treatment of MVA survivors.[1,8,21,22] According to Solomon et al.,[23] behavioral techniques generate the strongest evidence for treatment efficacy for PTSD from all causes, particularly when combined with cognitive therapy. Behavioral techniques aim to weaken the anxiety response through repeated or prolonged reliving of the trauma either through in vivo (i.e., exposure to actual situations), imaginal (i.e., exposure through visualization), and most recently VR (i.e., exposure using computer simulations representative of the trauma) therapies.[6,24]

In beginning treatment for those with PTSD from an MVA, it is important to carefully assess whether the person is suffering from "accident phobia," which is a specific phobia, or from PTSD. Reports of treating accident phobias can be found as far back as 1962[25] and have traditionally included some sort of exposure therapy during treatment.

Studies show that exposure therapy is an effective way to treat PTSD.[10] Emotional processing theory suggests that in order to decrease anxiety, anxiety must first be elicited. However, many individuals are unable to imagine a vivid enough scenario to elicit an anxiety response. Therefore, many clinicians have taken their clients into the real world, also known as in vivo, to assist them in overcoming their fear. Unfortunately, this can put the clinician and patient in an unpredictable, uncontrolled, and possibly unsafe situation. Exposing clients to traffic on unfamiliar roads may result in panic attacks or overwhelming anxiety if they have not first been given a skill set or some practice sessions.

Since it is not realistic to expose someone to the trauma stimuli involved in the accident in vivo, VR holds great promise in this area. A person can first learn skill set (e.g., diaphragmatic breathing and cognitive restructuring) and can then practice these skills during exposure to virtual trauma situations. They can thereby consolidate fragmented memories and work through the emotional processing to overcome the trauma in an individualized manner. In the late 1990s, a system was developed at Hanyang University in Seoul, Korea, for treating MVA-related PTSD with VR exposure. The system was tested at the Virtual Reality Medical Center, San Diego, in the United States; at University College, Cork, Ireland; and at Hanyang University, and it is now a part of their accepted clinical protocols.

Virtual Reality

Virtual reality, first coined by Jaron Lanier in 1989, consists of auditory, visual, and tactile cues within an interactive computer-generated environment.[47] Although VR technologies have been used by the military, the National Aeronautics and Space Administration, and the entertainment industry for the past 30 years, VR did not emerge in the mental health sector until 1993, largely due to its overall expense.[26–28] VR therapies have proven successful as psychotherapeutic tools in the treatment of anxiety disorders and body image disturbances, as distraction during painful medical disorders, conditions, and procedures; and for neuropsychological assessments.[28–30]

Cognitive behavioral therapy has been successful in the treatment of driving-related PTSD.[23,31] Effective treatments include relaxation training, in vivo exposure therapy, and imaginal exposure therapy. However, given that in vivo exposure may be impractical and imaginal exposure is often not immersive enough for many individuals, the use of VR exposure therapy (VRET) for car accident victims may be the most effective method for decreasing the length of treatment and increasing treatment efficacy. VRET offers a number of advantages over traditional therapeutic approaches:[32]

Patient confidentiality. Since VR exposure is conducted in the therapist's office, it allows for patient confidentiality and guards against subjecting people to feelings of public embarrassment or humiliation.[33]

Safety. Safety may be compromised with in vivo exposure. Real-life exposures, such as in vivo flying or driving, do not afford opportunities to test conditions that may be too dangerous to evaluate in real-life situations.[6] VRET and simulation technologies eliminate these risks. Clients remain secure in the therapist's office while learning to confront their fears in a safe and controlled manner. In the event that a client becomes exceedingly anxious, he or she may opt to end the VR program. With the aid of physiological monitoring, therapists may further gauge the individual's degree of anxiety to determine when to advance or retreat to another level in the hierarchy.[33]

Cause-and-effect. Simulation technologies allow participants to examine, discuss, and rehearse cause-and-effect behaviors. Real-time rendering may also allow for the generation of consequences from errors of omission. Cause-and-effect behaviors based on probabilities offer additional realism to the participant, particularly since it is quite difficult to simulate near misses or minor collisions.[34]

Cost-effectiveness. VRET is becoming more cost-effective than in vivo therapy as computer systems are becoming more affordable. While traditional exposure therapies may be as effective as VR exposure, the latter evidences an overall decrease in the number of sessions necessary to achieve the same therapeutic effect, thereby saving time and money. The elimination of the need for in vivo props would further reduce the cost of therapy for both therapist and patient.[33]

Willingness to undergo therapy. Exposure in reality is sometimes too threatening for many individuals.[35,36] VR offers an alternative that many individuals are willing to experience, finding comfort in the safety of the office rather than in the presence of the objects or situations that they fear most.[33] In 1993, North et al.[32] conducted the first controlled study assessing the effectiveness of VRET in the treatment of 60 individuals with agoraphobia. The authors concluded that those in the treatment group showed less anxiety and more favorable attitudes toward agoraphobic situations and treatment. A positive therapeutic attitude coupled with treatment effectiveness further ensures less economic and personal costs.[32,33]

Control of the environment. Virtual driving simulations are highly responsive to participant inputs. Participants control the virtual environment through the use of various feedback devices. By becoming an active participant, the client learns how to abate physiological and emotional reactions to the feared stimuli while concomitantly being able to escape the environment if he or she so chooses. This sense of mastery and control may then generalize to real-life situations. Simulations additionally allow for complete control over environmental factors, such as producing various weather patterns including rain or snow with the touch of a button.[1]

Less dependent on a person's imagination abilities. People often experience difficulties with prolonged imagination.[37] VRET provides participants with visual and auditory cues that better enable them to visualize and experience their feared situations.[32] VRET is hence more realistic and more immersive than exposure in imagination.[38]

Rehearsal and practice. Driving participants may endlessly rehearse and problem-solve difficult scenarios, such as various weather conditions and driving on bridges or highways. Such virtual training could optimistically result in improved driving skills in real-life conditions.[34]

Flexibility. With simulation technology, therapists have the flexibility to choose when to present a participant with more conditions. Weather patterns, time of day, amount of traffic, and number of pedestrians may be chosen depending on the needs of the patient.[1,33,38]

Telemedicine. With the integration of remote physiological monitoring, in vivo driving participants can relay crucial information to doctors, who can monitor and assess severity and progress.[38] Clinicians can then make informed decisions regarding the duration of exposure and can better know when to advance to the next stage of the exposure hierarchy—for example, when to move from roadways to freeway driving. Such technology also buys time for the initiation of onsite medical care with the aid of a remote doctor if warranted.

VR allows treatment to occur in the privacy of the therapist's office, which provides a safe and confidential setting for clients. The individual can begin exposure to the fearful situation and learn to control his or her anxiety. In this way, driving exposure is achieved systematically and safely for both the patient and therapist.[39] Many behavioral treatments are designed to reduce posttraumatic symptomatology by reducing avoidance behaviors and extinguishing trauma-related anxiety states. The process of extinction and habituation occurs with controlled re-exposure to feared stimuli. In other words, when an individual is repeatedly exposed to feared stimuli in the absence of aversive consequences, anxiety tends to dissipate.[40,41] Exposure can take place systematically and be objectively measured while the client is in the VR environment with physiological monitors providing real-time data.

Physiological feedback adds the additional benefit of providing individuals with a sense of mastery and control. By being aware of their physiological reactions during stress or anxiety and during relaxation, individuals can become proficient in self-monitoring and can begin to use coping skills when signs of distress occur. The ability to positively modify his or her own physiological responses can instill a sense of self-efficacy and provide the client with firsthand evidence of his or her coping capabilities.[19,24]

VR and Physiology

In 1999, Wiederhold and Wiederhold[42] completed a study comparing the success rate of three treatment conditions for specific flying phobia: (a) VRET with physiological feedback, (b) VRET without physiological feedback, and (c) imaginal exposure therapy. The results showed respective success rates of 100%, 80%, and 20% as defined by the person's ability to engage in air travel without the use of medications or alcohol. Three-year follow-up data showed respective success rates of 100%, 60%, and 10%, demonstrating that the supplemental use of physiological feedback adds to overall treatment effectiveness with long-term and sustained benefits as compared to VR without physiological feedback, which may show relapse.[24]

Kuch et al.[16] further confirm that the initial presence of physiological arousal upon exposure to anxiety-eliciting cues was one of the best predictors of treatment outcome. This supports the rationale for the efficacy of exposure therapies, since fear activation is a necessary component of emotional processing, and also emphasized the importance of objective measures of physiology to provide the evidence that arousal has been elicited.[43] Blanchard et al.[1,44,45] report that measures of heart rate, electrodermal activity, and systolic blood pressure yield the most reliable evidence of physiological arousal in response to collision-related cues. These findings appear to contrast with other anxiety disorders, wherein heart rate has not been shown to be a particularly sensitive measure.[46] Preliminary studies by Wiederhold and Wiederhold suggest that measures of heart rate variability may be a more viable indicator of detecting arousal and verification of habituation than is heart rate alone.[46,47]

VR Driving Studies

Research on the clinical applications of VRET for the treatment of all driving-related disorders shows promise. Schare et al.,[48] for instance, conducted a controlled study to understand a driving simulation's (DriVR™, Imago Systems Inc.) utility for fear of driving and rehabilitative treatment applications. This study compared eight participants with a fear of driving to nine nonphobic controls, examining levels of immersion, comfort, affective response, subjective units of distress, and physiological arousal to a virtual driving environment. By design, the virtual environment was effective at eliciting anxiety in those directly studied, and compared to the nonphobic counterparts, the phobic individuals experienced significantly higher levels of anxiety and reported emotion. While VR exposure caused all participants to experience some increase in self-reported anxiety, the VR imagery was substantially effective for increasing the anxiety of people with driving phobia, thereby approximating what would happen in a real-life driving situation.[48] While this study shows that the DriVR simulation program can elicit arousal in individuals with driving phobia, additional studies concerning treatment efficacy of this driving program are warranted before treatment can progress to the clinical sector.

Choi et al.[32] created a virtual driving simulation with a tunnel "entrapment" scene.[32] This simulation, used by the Virtual Reality Medical Center, was designed to treat driving-related fears secondary to agoraphobia. In a preliminary study, Jang et al.[49] found that their VR driving simulation was sufficient in eliciting sympathetic arousal; participants with driving fears evidenced sweating and palpitation shortly after exposure to the virtual driving situation. However, as treatment progressed, high levels of distraction prevented the participants from getting immersed and physiologically aroused in response to the VR stimuli. The data failed to objectively evaluate the potential treatment effectiveness of this VR program, though was able to highlight factors that could have contributed to a limited treatment response. In other words, the study was useful in understanding how a poorly designed therapeutic environment could damage the beneficial effects of VRET. Facilitating presence and immersion in the virtual world is just as important as facilitating presence in the therapeutic environment. To minimize the effects of distraction in the external environment, Jang et al.[49] outlined a number of suggestions for future research:

1. Keeping the room dark so that participants are not inclined to look outside of the head-mounted display.
2. Situating the therapist away from the participant so that the participant is less aware of the therapist's immediate presence.
3. Providing a comfortable environment for the participant during both the VR exposure and the acquisition of physiological data.
4. Using verbal cues and guidance to help facilitate a sense of immersion and presence.

A study conducted by Walshe et al.[50] explored the use of computer-generated environments for the treatment of driving-related phobias resulting from vehicular collisions. Computer games have recently been successfully adapted to generate environments and treat specific phobias, relying on their potential to generate 3D VR environments. An earlier presentation of the first participants from this study highlighted that, for some phobic drivers, computer game reality (GR) induced a strong sense of presence, sometimes to the point of inducing panic. The researchers sought to investigate in an open study the effectiveness of the combined use of computer-generated environments involving driving games GR and a VR driving environment in the treatment of driving phobia following MVA, through an exposure program. Fourteen participants, who met the criteria for specific driving phobia, accident phobia, and/or driving-related posttraumatic stress, were exposed to a 1-hour driving environment. Seven of the 14 who showed physiological arousal and subjective distress, defined as an increase in distress ratings of 3 or more points and/or an increase of heart rate greater than 15 beats per minute, completed 12 VR exposure sessions. Posttreatment scores for the treatment group ($n = 7$) showed significant reductions ($p = 0.008$) in measures of subjective distress, driving anxiety, behavioral avoidance, and depression ratings with repeat exposure. Since half of the participants did not show significant increases in physiological arousal or subjective reports of anxiety, further investigation is needed to learn how to facilitate immersion in nonresponsive individuals. The authors offered suggestions, such as addressing participant willingness to "let go" to allow immersion to take place prior to treatment, improving virtual environments by eliminating aspects that distract from the immersion process, and considering the possible benefits of replacing head-mounted displays with large-screen projections. The findings of this study suggest that VR and GR may have a useful role in the treatment of postaccident driving phobia even when comorbid conditions such as PTSD and depression coexist, though findings suggest that further refinement of programs could result in a higher "hit rate," that is, inducing presence/immersion in a greater percentage of participants and in turn increasing the viability of VR/GR as an exposure treatment for driving anxiety. This study shows promise for the treatment of collision-related PTSD.

Another study examined the effectiveness of the combined use of computer-generated environments involving driving games or GR and a VR driving environment in exposure therapy for the treatment of MVA-related driving phobia.[50] The experiment consisted of 14 participants who were exposed to a virtual driving environment (Hanyang University Driving Phobia Environment) and computer driving games, such as London Racer/Midtown Madness/Rally Championship. Results showed that 50% of participants who were exposed to a combination of VR driving simulation and GR driving tasks became immersed in the driving environments. Among those participants, significant posttreatment reductions were found on all measures, including subjective distress (Subjective Units of Distress Scale), driving anxiety (FDI), posttraumatic stress disorder (CAPS), heart rate rise (HR), and depression (Hamilton Rating Scale for Depression) ratings. Subscale analysis of the fear of driving inventory (FDI) showed significant reductions on all three subscales, including travel distress, travel avoidance and maladaptive driving strategies.[51] These results suggest that VR and GR may play a useful role in the treatment of postaccident driving phobia even when comorbid conditions such as PTSD and depression are present.

Another study investigated whether a clinically acceptable immersion/presence rate of 80% or greater could be achieved for driving phobia participants in computer-generated environments by modifying external factors in the driving environment.[51] Eleven patients who met the DSM-IV criteria for specific driving phobia, seven of whom had an overlapping diagnosis of PTSD, were exposed to a computer-generated driving environment using computer-driving games. After undertaking a trial session involving driving through computer environments with graded risk of an accident, 10 of 11, or 91%, participants met the criteria for immersion or presence in the driving environment, enabling progression to VRET.[51] These findings suggest that the paradigm adopted in this study might be an effective and relatively inexpensive means of developing driving environments realistic enough to make VRET a viable treatment option for driving phobia following an MVA.[39]

Finally a VR treatment study done by Beck et al.[52] reported effect sizes ranging from 0.79 to 1.49. This indicates clinically significant changes for clients with PTSD due to MVA accidents who underwent VR therapy.

The successful use of VR to treat PTSD in MVA survivors can further be expressed in a case example. The individual was self-referred after having been involved in an MVA and unable to drive for the subsequent 5 years. Successful treatment had been stalled by an inability to successfully elicit anxiety during imaginal visualization and a refusal to participate in real-life exposure because of a feeling of lack of control and safety. After teaching the client anxiety management techniques, VR therapy began. The client began stabilizing physiologically in the virtual driving tasks and had begun initial exposure in the real world, sitting in her car and turning on the ignition. During the fifth session, however, a left turn was initiated in the VR world. This simple act caused the patient to flashback to the traumatic traffic accident that had occurred 5 years earlier when the taxi she was riding in had veered head-on into oncoming traffic. The client asked to exit the VR world, and the remainder of the treatment session was spent processing the emotions and memories that had resurfaced. The VR world had triggered the memories and successfully allowed the client and therapist to work through and fully process the trauma. Following this, the client's nightmares about the accident dissipated. Three more VR sessions were completed, and the client was able to once more attempt in vivo driving. At 1-year follow-up, she was still able to drive with little or no anxiety.[42]

At VRMC, VRET remains a part of the treatment regimen for driving fears, whether they are from a specific phobia, PTSD, or panic disorder with agoraphobia. Continuous monitoring of the client's physiological levels allows the therapist to engage the individual actively while remaining aware of habituation and arousal levels.[50] The success rate overall after 14 years is 88% as measured by an individual's ability to successfully complete driving tasks previously avoided.

The end goal of treatment is, of course, in vivo or real-world driving. To decrease avoidance behaviors and increase self-confidence in driving abilities, hands-free cellular phone technology was recommended in the past to provide clients with a "security net" should the need for communication arise. This sense of security is cognitively meaningful for clients, but recent state legislations on the use of cell phones while driving may preclude this assistive technology in some locales.[38,46,53]

Conclusion

With increasing numbers of motor vehicle collisions occurring each year, the incidence of collision-related PTSD also increases, resulting in greater numbers of individuals needing therapeutic treatment. Overall, preliminary data from treatment studies with clients suffering from driving-related anxiety suggest VR exposure to be beneficial in reducing symptomatology. Knowledge about the physiological measurements during VR therapy still remains less available, but what has been published shows enormous potential.[54]

The potential to promote VR's move into the clinical mainstream by providing an affordable treatment alternative for clinicians and clients alike is now a reality. With the availability of more cost-effective VR systems, there is the opportunity to increase effective treatment availability for posttrauma individuals. The finding that MVAs are now the number one cause of PTSD since the Vietnam War should provoke interest among clinicians and further investigation among researchers.

Disclosure Statement

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