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13 Communication and Experience in Clinical Psychology and Neurorehabilitation: The Use of Virtual Reality Driving Simulators

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Abstract. Virtual reality (VR) driving simulators may be used as an aid to traditional cognitive-behavioral therapy in the treatment of a variety of driving-related disorders. In recent years there has been a heightened interest among researchers and clinicians in using VR technology to address a wide range of driving-related issues. Clinical applications include specific driving phobias, driving phobias related to panic and agoraphobia, and posttraumatic stress disorder (PTSD) as a result of motor vehicle accidents. Other areas of interest include neurorehabilitation for individuals who have sustained various brain injuries, examining the impact of pharmaceuticals while driving, and assessing and predicting driving abilities among teenage and elderly populations. The VR world elicits real reactions that can be modified through therapy to help people overcome disorders and traumas such as these. As with any type of treatment, some limitations exist. However, results thus far have been promising and directions for future research are discussed.

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13.1 Introduction

Virtual driving systems have a variety of applications including (a) clinical applications in psychotherapy for the treatment of specific driving phobia, panic disorder and agoraphobia, and posttraumatic stress disorder (PTSD) for individuals recovering from motor vehicle accidents (MVA's); (b) treatment for neurorehabilitation; (c) testing of pharmaceuticals, and (d) driver training. Furthermore, there are a variety of new and exploratory applications including the assessment of vestibular disorders and examining the effects of road rage. The table below briefly outlines why VR driving assessment protocols outweigh other current assessment protocols (see Table 1).

Table 1. Current driving assessment protocols versus VR driving assessment protocols

Current Driving Assessment Protocols	Limitations	How VR Addresses Limitations
Neuropsychological Tests	▪ Assesses component cognitive skills individually ▪ Questionable ecological validity	▪ Allows assessment of "complex" behaviors, such as driving ▪ Allows assessment of driving skills in "real-life" situations
Computerized Tasks	▪ Simplified graphics ▪ Limited user interaction	▪ Interactive, detailed, "real-life" graphics ▪ Maximum user interaction
Driving Simulators	▪ Variability in level of interaction ▪ Financially inaccessible	▪ Submersive effect allows higher level of interaction ▪ Increased advances in technology allow for a financially achievable system
Behind-the-Wheel Evaluations	▪ Based on subjective measures ▪ Limited driving scenarios due to safety ▪ Non-standardized procedures	▪ Allows for objective recording of all driving measures and behaviors ▪ Easily modifiable environment allows assessment under various conditions ▪ Controlled environment allows for safe evaluation of driving in complex and challenging situations ▪ Allows for standardized assessment across evaluators

13.2 Driving-related Anxiety Disorders

13.2.1 Specific Driving Phobia

Drivers who have been in serious car accidents may develop specific driving phobias. One study found that 15% of car accident victims developed such a phobia [1]. Driving phobias may be so severe that individuals are limited to drive very short

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distances, or, in some cases they may be unable to drive at all. Patients who present with a fear of driving may be diagnosed with a specific phobia, panic disorder or agoraphobia, or, posttraumatic stress disorder (PTSD) due to a MVA. In addition, as a person avoids driving situations, some of the driving skills previously learned may begin to deteriorate [2].

Emotional processing theory suggests that in order to decrease anxiety one must first elicit the anxiety [2]. However, many patients are unable to imagine a vivid enough scenario to establish an anxiety response. Therefore, many clinicians have taken their patients into the real world (in vivo), in order to assist them in overcoming their fear. Unfortunately, this can put the clinician and patient in an unpredictable, uncontrolled, and often, unsafe situation, with the client exposed to traffic an unfamiliar roads which frequently result in a panic attack or overwhelming anxiety [2]. VR allows treatment to occur in the privacy of the therapist's office, which provides a safe and confidential place in which to begin exposure to the fear situation, with the patient visualizing the fear situation (imaginal exposure) and learning to control anxiety. In this way, driving exposure is achieved systematically and safely for both the patient and therapist. At The Virtual Reality Medical Center (VRMC) VR graded exposure therapy (VRGET) is used to treat driving phobias and is similar to its use with other specific phobias, focusing on gradual exposure and cognitive and behavioral modifications. Tasks of increasing difficulty are assigned to the patient, while the patient's reactions are observed and measured [2, 3].

Early research on VR applications for driving phobias has been promising. Matthews et al. examined individuals' vulnerability to stress during driving by assessing their performance in a driving simulator [4]. It was found that participants who disliked driving (possibly due to their anxiety) had reduced driving control skills, experienced greater mood disturbance while driving, and drove more cautiously. Furthermore, individuals who scored high on aggressive driving were also more prone to errors due to confrontational passing tactics.

Janelle [5] examined the influence of distraction and anxiety on driving abilities during a simulated driving task. Forty-eight women were randomly assigned to one of six groups, each with varying levels of peripheral distraction and anxiety instruction sets. Cognitive anxiety, visual search patterns, performance, and arousal were measured. Results showed that highly anxious participants made more driving errors and displayed a lower driving proficiency than participants in any other group. In addition, they showed a decreased level of concentration, implying a reduced ability to process peripheral information.

Schare et al. examined levels of immersion and emotional reactions to VR driving environments in 17 participants (8 phobic and 9 non-phobic drivers) [6]. Results demonstrated that phobic participants reported higher levels of immersion and higher emotional reactions to the environment. In addition, while subjective ratings of distress levels for the two groups significantly differed, both groups showed similar patterns of change with: 1) an increase in distress from pretest to the first practice course, 2) a decrease from the first practice to the second practice, and 3) an increase from the second practice to the test course. Increases were more prominent for phobic participants, and this pilot study indicated that a VR environment is capable of eliciting subjective anxiety and physiological arousal for both phobic and non-phobic individuals [6].

Additional research conducted by Wiederhold et al. examined the advantages of using wireless communication technology for treating fear of driving [7]. Three case

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studies, including patients with a fear of driving as part of panic disorder with agoraphobia, PTSD due to a MVA, and fear of driving due to a lack of driving skills all used a cellular telephone to treat patients with a fear of driving. Therapists accompanied patients for in vivo driving sessions once VR exposure (computer simulation) therapy had been performed. The therapist followed the patient in another vehicle, and the patient was allowed to contact the therapist using a cellular phone during periods of increased anxiety. Although in some cases the phones were never used, they provided a "security net" for the patient if needed. While the risks of cellular phone use must be addressed, the ability of patients to contact the therapist with a cell phone was instrumental in overcoming the fear of driving. Therefore, the benefits and cost advantages of increased mobility, reduced dependence on others, and reduced utilization of health care services for patients seem to outweigh the risks associated with cellular phone use [7].

In 2001, Wiederhold et al. examined the physiological responses of 10 patients with a fear of driving using a VR driving simulation (developed and tested at Hanyang University in Seoul, Korea) [2]. Results showed that physiological desensitization, as well as subjective desensitization occurred through the use of physiological feedback and virtual exposure [2]. In comparison, Jang et al. examined the normal physiological response of participants in two different types of virtual environments: driving and flying simulations [8]. There are few studies that have examined the normal physiological response to virtual environments, or reactions to different virtual environments. However, as VR technology continues to attract significant attention, the use of objective measurement tools, such as physiological monitoring, are even more important than ever. In the present study, 11 non-phobic participants were exposed to each virtual world for 15 minutes. Heart rate, skin resistance, and skin temperature were measured and the Presence and Simulator Sickness Questionnaire scores were obtained after each exposure. Results showed that heart rate and skin resistance can be used as objective measures in monitoring the reaction of non-phobic participants to virtual environments [8].

While earlier studies demonstrated that VR is an effective means to evaluate driving deficits among phobic patients, more recent studies show the importance of obtaining physiological measures as well. Physiological measurements significantly aid in the verification of emotional processing [9]. Furthermore, the advantages of measuring anxiety levels via physiological measures include the ability to obtain objective information about a specific patient's physiological response to the stressor, the possibility for therapeutic intervention during various levels of stress, and gauging effectiveness of psychological therapeutic interventions while driving [7].

13.2.2 Panic and Agoraphobia

Individuals who suffer from panic disorder with agoraphobia, or agoraphobia without a history of panic, may experience a fear of driving far from home or on the freeway [10]. Such fears are due to the idea of feeling trapped without the ability to escape and having no help in sight. This type of fear can be treated in VR using the same systems that are used for specific driving phobias or driving-related PTSD. At The Virtual Reality Medical Center in San Diego, CA, patients progress through increasingly difficult driving scenarios (e.g., stuck in a tunnel with cars crowding in behind them) and are taught to employ breathing techniques, thought stopping, and cognitive restructuring techniques while encountering such anxious situations in the

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virtual world. Between sessions, patients are encouraged to practice tasks as homework assignments in the real world. Eventually, they begin to realize that they can control their reactions to situations, in addition to their interpretations of those situations (i.e., dangerous or not dangerous). Practicing these skills in the virtual world allows patients to generalize their experiences to the real world and they develop a sense of mastery and self-efficacy much more quickly [10].

An additional study set out to use VR in order to treat panic and agoraphobic patients more effectively [11]. In order to accomplish this, it is necessary to determine the physiologic responses of non-phobics when placed in the virtual panic and agoraphobia environments. This study exposed non-phobic participants to virtual panic and agoraphobia worlds. Participants were exposed to four different VR environments (e.g., elevator, supermarket, town square, and beach). Physiologic responses were measured via noninvasive sensors including peripheral skin temperature, heart rate, heart rate variability, respiration, and skin conductance. This study was useful in laying the foundation for future research on treating individuals with panic and agoraphobia using virtual worlds for exposure to fearful situations. Determining how non-phobics respond to VR worlds created for panic and agoraphobia individuals can help to establish a baseline for physiological responses during clinical treatment of those with panic and agoraphobia [11].

Similar to the studies conducted for a specific driving phobia, studies on individuals who suffer from panic disorder with agoraphobia, or agoraphobia without a history of panic have also demonstrated that VR is an effective way to treat [11]. In addition, studies have shown the importance of obtaining physiological measures – not only in those with the disorder, but in individuals without a history of the disorder as well. By knowing the reaction of non-phobic individuals, it is easier to determine what levels of arousal might be realistic to expect from phobic patients. Differences in level of immersion and self-report responses are important as well [11].

13.2.3 Posttraumatic Stress Disorder

MVA's account for over 3 million injuries annually and are one of the most common traumas individuals experience. In any given year, approximately 1% of the U.S. population will be injured in a MVA [12] and approximately 45% of MVA survivors develop PTSD [1]. These individuals may have recurrent flashbacks to the accident, nightmares, avoidance behaviors, and a generalized increase in anxiety. Cognitive-behavioral therapy has been shown to be successful in the treatment of driving-related PTSD [1]. Effective treatments include relaxation training, *in vivo* and imaginal exposure therapy. However, given that in vivo exposure may be impractical and imaginal exposure is non-immersive, the use of VRGET for car accident victims may serve as the most effective method for decreasing the length of treatment and increasing treatment efficacy [3].

One study examined the effectiveness of the combined use of computer generated environments involving driving games (game reality [GR]) and a VR driving environment in exposure therapy for the treatment of driving phobia following a motor vehicle accident [13]. Fourteen participants were exposed to a Virtual Driving Environment (Hanyang University Driving Phobia Environment) and computer driving games (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.

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Among those participants, significant post-treatment reductions were found on all measures including subjective distress (SUDS), driving anxiety (FDI), posttraumatic stress disorder (CAPS), heart rate rise (HR) and depression (HAM-D) ratings. Subscale analysis of the FDI showed significant reductions on all three subscales including travel distress, travel avoidance and maladaptive driving strategies. These results suggest that VR and GR may play a useful role in the treatment of driving phobia post-accident even when co-morbid conditions such as posttraumatic stress disorder and depression are present.

A second study aimed to investigate if 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 [14]. Eleven patients who met the DSM-IV criteria for Specific Driving Phobia (seven of which 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 (91%) driving phobic participants met the criteria for immersion/presence in the driving environment enabling progression to VR exposure therapy. 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 VR exposure therapy a viable treatment option for driving phobia following a MVA [14].

13.3 Driving for neurorehabilitation

VR driving simulations can also be useful for evaluating the visual-motor skills of individuals recovering from traumatic brain injury, stroke, or other types of physical trauma in order to re-learn driving skills [3]. About 700,000 people have a stroke in the United States annually [15]. Given our modern fast-paced society, a great value is placed on an individual's ability to function independently [16]. However, individuals who sustain brain injuries are often faced with physical and cognitive impairments that hinder their ability to function independently with respect to everyday living. Even more surprising, one-third of the 500,000 people that will survive a stroke each year resume driving without any formal testing, training or counseling [15].

Wald et al. conducted a pilot study in which 28 adults (22 males, 6 females) with a brain injury participated in a standardized driving evaluation, which included VR driving simulator software (DriVR) developed by Imago Systems, Inc. [17]. The DriVR allows playback of the participant’s performance, compiles quantitative statistics of the session, and simulates a range of driving routes in a variety of weather conditions, road conditions, and times of day. The system includes head tracking with a head-mounted display (HMD) and tracker, a steering wheel, brake, gas pedal, and graphics of open road scenarios and tall buildings. The system can also be easily adapted for other driving tasks, such as systematic desensitization of those with phobias, PTSD or to teach young drivers. Results of this study showed that DriVR appeared to be a useful adjunctive screening tool for assessing driving performance in participants with brain injury. Moreover, DriVR may be used as a driving rehabilitation tool to retrain driving skill deficits, as well as treating driving fears and avoidance. Future research will need to determine whether the skills mastered from DriVR will generalize to improved driving skills or reduced driving fears in everyday

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life [17]. One group of researchers developed a VR driving simulator in order to safely evaluate and improve the driving ability of spinal injury patients [18]. Fifteen patients with thoracic or lumbar cord injuries and 10 normal patients participated. Spinal injury participants manipulated the break and accelerator pedal of the simulator by using the hand control device, whereas the normal drivers used foot controls. During the 20 minute simulation, driving data was recorded via computer and five driving skills were measured including average speed, steering stability, centerline violations, traffic signal violations, and driving time in various road conditions such as straight and curved roads. Patients then self-reported level of realism for the driving simulator and the amount that their fear of driving had been reduced. Results showed that type of manipulation method did not seem to influence the relative performance in the VR driving simulator between groups. Furthermore, participants reported an average score of 51.5% for level of realism of the driving simulator and 73% reported that their fear of driving was reduced when driving with their hands. Suggestions for future research include enhancing the realism of driving simulators and increasing the variety of training situations.

In 2003, Kim et al. aimed to identify a driving assessment that would best predict the driving ability of brain injury patients [16]. This study explored the relationship between perceptual, cognitive, and operational variables that form the basis for off-road evaluations. In addition, the authors were interested in determining whether there are basic dimensions that may underlie performance in such evaluations, and to identify the variables that might help refine the methods used for evaluating persons with cerebral injuries. A driving simulator including adaptive hand and foot controls to simulate a real-time driving experience was created. The driving simulator and off-road evaluations composed of psychometric testing that were used in this study are commonly used in rehabilitation settings to assess a person's ability to resume driving after a brain injury.

Recently, Lew et al. evaluated whether driving simulator and road test evaluations could predict long-term driving performance [19]. Eleven patients with moderate to severe traumatic brain injury and 16 healthy subjects participated in this prospective study. At the initial evaluation (Time 1), participants' driving skills were measured during a 30-minute simulator trial using an automated 12-measure Simulator Performance Index (SPI), while a trained observer also rated their performance using a Driving Performance Inventory (DPI). In addition, participants were evaluated on the road by a certified driving evaluator. Ten months later (Time 2), family members observed patients driving for at least three hours over four weeks and rated their performance using the DPI. Results showed that at Time 1, patients were significantly impaired on automated SPI measures including speed and steering control, accidents, and vigilance to a divided-attention task. At Time 2, simulator indices significantly predicted handling of automobile controls, regulation of vehicle speed and direction, higher-order judgment and self-control, as well as a trend level association with car accidents. Automated measures of SPI were more sensitive and accurate than observational measures of simulator skill (DPI) in predicting actual driving performance. Surprisingly, the road test results at Time 1 were not significantly related to driving performance at Time 2. This study showed that simulator-based assessment of patients with brain injuries can provide ecologically valid measures, which may be more sensitive than traditional road tests as predictors of long-term driving performance [19].

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Current reports show that a Driving Performance Laboratory has been established at Sharp Memorial Rehabilitation Services in San Diego, CA to evaluate and train patients with stroke and brain injury who want to resume driving [15]. Experts at the Driving Performance Laboratory agree that there are a number of advantages to the driving simulator over the road test. The first advantage is safety because assessment and training of skills and abilities of drivers in hazardous situations can be done in realistic, virtual driving environments without adverse consequences. Second, driving scenarios can be replayed for review and critical analysis by patients and therapists, and third, the simulator may act as a training device to improve driving skills of attention, speed of processing visual information, and situational awareness. Moreover, training sessions can be individually tailored to the specific needs of each patient, encouraging them to practice and make improvements in their specific areas that need improvement [15].

13.4 Testing pharmaceuticals

Driver impairment by medication or illness is an important issue in our society [20]. It is estimated that approximately 30% of all accidents are primarily or secondarily related to driver impairment due to drowsiness, drug consumption or illness [20]. However, the ability to drive is important, especially for depressed patients because it allows mobility and the ability to reestablish social networks that may have been lost. Few studies have examined the effects of antidepressants on driving ability, and those that do exist have primarily been employed in real traffic. However, one study (N = 23 participants; 10 female, 13 male) evaluated a real car-based driving simulator using a motorway test-track to investigate the impact of a single oral dose of sertraline (50 mg) on various cognitive functions related to driving tasks and objective driving performance. Results showed no evidence of drug induced impairment of drivability in the simulator. Until a standardized methodology for evaluating drivability is created, studies such as this one are important and can help to close the gap between driving simulators and driving in real life [20].

As previously mentioned, driver impairment can also be related to illness. One study examined 37 adults with Type I diabetes and their ability to drive in driving simulation tests [21]. Researchers manipulated participants' blood glucose levels by giving them an intravenous insulin solution containing various amounts of sugar (61-72 mg/dl, 50-60 mg/dl, and less than 50 mg/dl). At all three ranges of hypoglycemia, driving performance was found to be significantly impaired. Participants were more likely to swerve, brake inappropriately, and speed in comparison to when their glucose levels were within normal limits. Even more surprising, less than 1/4 of drivers realized that their driving was impaired, while only 1/3 took corrective action by drinking soda or stopping driving, and most did not do so until their glucose levels were below 50 mg/dl. The researchers recommend that Type I diabetes patients have fast-acting glucose- and carbohydrate-rich snacks on hand when they drive or measure their blood sugar before driving.

Drivability is an important and relevant performance parameter in our society [20]. It can be especially important for depressive patients as it means mobility and in many cases, a higher degree of integration with the rest of society. However, there are some limitations regarding drivability related to the unknown drug effects related to driving. Currently, there is no common and reliable method to test drivability.

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Furthermore, it is impossible to validate driving tests (on the road) or any other experimental test against the criteria of an accident in real life [20]. It is for this reason that driving simulators are so important, and why realistic virtual driving tests are essential in order to define and measure the potential hazards of drug use while driving.

13.5 Driver training

There are also a variety of non-clinical virtual driving applications, including training new drivers and assessing and retraining older drivers. This type of application could also be applied as a disciplinary treatment for drivers charged with road rage infractions.

13.5.1 Driver Training and Teens

An early study examined young novice drivers and their relationship to high-risk behaviors, traffic accident records and simulator driving performance [22]. Among 198 young male drivers (ages 16-19), this study identified five subtypes of drivers. Clusters one and five showed an increase in high risk behaviors and driving-related aggression and hostility. When placed in a driving simulation task, the drivers in Clusters one and five showed a lower level of skills than the participants in Clusters two through four. These clusters specifically related to ability to handle traffic hazards and to maintain driving ability while having to attend to simultaneous tasks. This study provided a preliminary look at ways to structure training courses for young drivers to help minimize their involvement in automobile crashes. Furthermore, as skill sets in simulated scenarios are increased, their abilities can be transferred and generalized to the real world.

Several years later, The Centers for Disease Control (CDC) funded a study to determine whether training young drivers with a driving simulator would reduce the number of traffic violations and accidents experienced by novice licensed drivers (2002). Two groups participated in this study. The control group attended standard drivers' education and training classes. The experimental group attended standard drivers' education and training classes *and* participated in training utilizing a VR driving simulator. In addition, driving records for both groups were monitored over the next two years.

In particular, one aspect of the cognitive screening protocol evaluated impulsivity, which is being correlated with the two year follow-up data, and related to numbers of fatalities, MVAs, DUIs, moving violations and any other infractions. The study protocol included two phases. Phase I included an introduction to the simulator and minimum performance on a computerized training test that tracks errors such as inappropriate lane changes (going over the white line) and "rolling stops" at stop signs. In Phase II, driving skill development was learned. Teenage participants drove in simulated situations that are often difficult and at times dangerous (e.g., a child running in front of their car – and the computer tracked the errors).

As part of the screening process to enter the study, participants were administered standard personality inventories, a computerized cognitive screening task, and self-report questionnaires concerning perceived self-efficacy. After completion of the study, participants were administered questionnaires to determine level of presence

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(or immersion) in the VR training simulators and level of simulator sickness, which might have occurred during training. VRMC is in discussions with several physician groups in San Diego to develop a driving simulator that can be used to assess the status of elderly drivers, and to test for early deficits in cognitive function. While this data is still being analyzed, researchers are hopeful that the results of this study will add to the existing literature on teens and driving.

13.5.2 Driver Training and Elderly Individuals

As people age, they often develop difficulties with the demands of driving. Moreover, decrements in cognitive processing speed may limit an individual's ability to handle complex driving situations. Visual processing decrements, including visual processing speed and impaired visual attention skills, have been blamed for the decline in driving skills in older individuals [23]. This can lead to anxiety about driving and insecurity about one's abilities. A driving simulator may allow for a more objective test of such skills in a safe, systematic manner. Interactive simulators, which can simulate various road, traffic, and weather conditions may be used to determine whether these individuals are capable of safe driving, as well as to reassure them that their abilities are still intact. By interacting in an environment that allows for safe assessment and "instant replays", the patient is able to objectively see what their true abilities are. The virtual environment appears to provide a good representation of real world driving skills, and anecdotal reports suggest that patients readily accept weaknesses that are pointed out by simulation tasks [24]. In fact, according to a study funded by the National Institute of Aging and the National Institute on Nursing Research, improvements gained from using a driving simulator and training people to improve their processing speed over ten training sessions led to the successful transfer of real-world driving skills [25]. An early study examined driving performance and simulator sickness in 256 participants as a function of age and gender [26].

Current drivers, between the ages of 60 and 90, participated in this study by using the Atari driving simulator for 20 minutes. Simulator data was collected on 11 variables, eight times per second, while simulator sickness was rated on a 5-point scale at the end of the drive. Results showed that older drivers (70-74 year) drove worse than younger old drivers (60-64 years) on a number of variables including more crossing of the midline, more swerving, more inappropriate braking, more slow driving relative to speed limit, fewer full stops at stop signs, more time to complete left hand turns, and more collisions per miles driven. However, age did not affect speeding, speed variability, maximum break pressure, hesitation at stop signs. Also, in general, gender did not relate to driving performance. Simulator sickness did not affect driving performance and was also not associated with age, although it was significantly worse for females with a history of motion sickness. In a later study, a driving simulator was used to predict future automobile accidents [27]. Data were collected for 38 older subjects who had participated in a driving simulator study three years prior. Both high- and low-risk participants reported that they were still driving. Both types of drivers were also found to have driven similar miles per week, used their seat belt equally as often, and had a similar gender distribution. However, high-risk participants reported having 47 crashes per 1,000,000 miles driven, while low-risk participants reported having 6 crashes per 1,000,000 miles driven. In addition,

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self-reported ability to drive was unrelated to either crash history or age. Results supported the predictive ability of the driving simulator [27].

13.6 Exploratory Areas

13.6.1 VR as a Diagnostic Tool

The VR driving simulation system developed at Hanyang University is one of the systems currently being used at VRMC to treat patients with driving difficulties related to panic and agoraphobia (see Figures 1 and 2). For example, one case study using this system has been reported in which a 42-year-old female patient suffered from agoraphobia for eight years [7]. When her therapy began, she was unable to drive more than one mile from her home. She also reported being unable to fly or ride in old elevators that she felt were unsafe. After learning anxiety management techniques, she was introduced to a VR world containing a beach scene and an open plaza. Since the scenes did not cause any subjective anxiety and little physiological arousal, the driving scenario was attempted. After four minutes in the environment, the patient became nauseous and the VR session was discontinued.

Figure 1. This driving simulation is used for treating driving phobia as well as driving rehabilitation. Software developed at Hanyang University, Seoul, Korea

She reported feelings similar to motion sickness but no feelings of panic. During her next attempt at VR driving she became nauseous again, this time within two minutes of initiating the VR exposure. The patient was removed from VR and a joint decision was made by both the patient and therapist to discontinue VR treatment. During subsequent sessions, driving was continued in vivo. The patient was subsequently referred to an otolaryngologist and a diagnosis of vestibular disorder was established.

In some cases, patients have been unable to complete VR therapy because of nausea, or "cybersickness" [3]. These patients are referred to an otolaryngologist and the majority of patients who experience cybersickness are diagnosed with a vestibular

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disorder. Thus, the VR system may also prove useful as a diagnostic tool. Studies have shown that 5% - 42% of patients with panic disorder may have abnormalities in their balance system, compared to up to 5% of healthy controls [3]. There also appears to be a link between subclinical balance abnormalities and the development of agoraphobia [28].

Figure 2. An additional driving simulation used for treating driving phobia as well as driving rehabilitation. Software developed at Hanyang University, Seoul Korea

13.6.2 Road Rage

In the United States, MVA's are the leading cause of accidental death and injury [29]. Moreover, American insurance industry representatives reported that approximately 50% of MVA's involved some type of aggressive driving [30]. Malta et al. compared the physiological responses of self-referred aggressive and non-aggressive drivers [29]. Heart rate, blood pressure, facial muscle activity, and skin resistance were monitored as participants listened to individual vignettes of driving and fear-provoking scenarios, and completed a standard stressor task. Results showed that aggressive drivers, in comparison to controls, exhibited significant increases in muscle tension and blood pressure during the driving vignettes. In addition, the aggressive drivers responded to the fear vignette and mental arithmetic with a lower overall heart rate and electrodermal reactivity, but increased blood pressure and muscle tension. In comparison, controls responded to the fear vignette and mental arithmetic primarily with increased heart rates and decreased skin resistance. It may be that both physiological hyper-arousal and differential responses to stressful stimuli contribute to aggressive driving.

According to research from John Hopkins University in Baltimore, women have more automobile crashes than men [31]. However, men are far more likely than women to have a fatal car crash. It appears that "road rage" behaviors – aggressive driving, speeding, and risk-taking – are concentrated in male drivers, making them three times more likely to have a fatal car crash. Females in the study did have 10%

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more collisions per one million miles on the road, but men's additional propensity for drunk driving and distracted driving made them more likely to suffer fatalities [31].
It is troubling that aggressive driving, in one form or another, is responsible for nearly half of all MVA's. Furthermore, aggressive driving behavior usually occurs as a result of heavy traffic, hectic schedules, and pressure and it is unlikely that any of these daily stressors will substantially decrease in any individual's life. That is why virtual driving applications may be a useful treatment; not only as a disciplinary means for drivers charged with aggressive and/or road rage infractions, but even for individuals who want assistance with decreasing their stress levels while on the road.

13.7 Conclusions

There is great interest among researchers and clinicians in using VR technology to address a range of driving-related issues. Clinical applications include specific driving phobias, driving phobias related to agoraphobia, and PTSD as a result of motor vehicle accidents. Other areas include neurorehabilitation, assessing driving ability in teens and elderly populations, and new exploratory areas. Although additional future work is required to standardize VR driving test applications, results thus far show much promise.

13.8 References

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