Special Issue: Virtual Reality Applications in Neuropsychology
Guest Editors' Introduction

Welcome to this special theme issue of *Presence*, "Virtual Reality Applications in Neuropsychology." As this is the first time that *Presence* has devoted an entire issue solely to this topic, we wanted to briefly put the relevance of virtual reality's intersection with neuropsychology into context for those who are not familiar with the background in this area. It is our view that this is a turning point for information and telecommunication technology applications in psychology generally and that, with presently available assets, compelling and well-thought-out VR scenarios will have a substantial impact on neuropsychology in the very near future.

Virtual reality (VR) technology has already emerged as a viable tool that is well matched to the needs of a variety of psychological and mental health applications. Continuing advances in underlying enabling technologies have supported the development of more usable, useful, and accessible VR systems that can uniquely target a wide range of physical, emotional, social, cognitive, and psychological human issues and research questions. This is in sharp contrast to the early to mid-1990s when VR languished in what the Gartner Group (Gartner Web page, 2000) termed the "trough of disillusionment" within the technology "Hype Cycle." According to the Gartner Group, the trough of disillusionment for any new technology usually follows a period of inflated expectations where the technology becomes "unfashionable," as the press and the general public perceive it to have not lived up to overinflated expectations. During these early years, VR's "expectation-to-delivery" ratio was somewhat imbalanced, as most users trying systems during that time will attest. However, in the last five years, advances in computing power, graphics and image capture, display technology, immersive audio, haptics, wireless tracking, voice recognition, intelligent agents, and authoring software, have supported the delivery of more usable and compelling VR scenarios. These developments have also resulted in more accessible, low-cost, PC-driven VR systems with greater sophistication and responsiveness. Such advances in both technology and access is allowing for more widespread application of VR technology in clinical areas and will support the independent replication of research findings needed for scientific progress in the psychological sciences.

Neuropsychology is one branch of the psychological sciences in which VR stands to have significant impact. This discipline focuses on the study of brain/behavior relationships (Lezak, 1995) for experimental purposes in the study of cognitive and functional processes and for clinical purposes in the assessment and rehabilitation of populations with impairments due to central nervous system (CNS) dysfunction (such as learning disabilities, brain injury, and neurological disorders). What makes VR application development in the area of neuropsychology (and in the psychological sciences generally) so distinctively important is that it represents more than a simple linear extension of existing computer technology for human use. VR offers the potential to deliver systematic human testing, training, and treatment environments that allow for the precise control of complex, dynamic 3-D stimulus presentations, within which sophisticated behavioral recording is possible. When combining these assets within the context of functionally relevant, ecologically valid virtual environments (VEs), a fundamental advancement emerges in how human cognitive and functional behavior can be studied, assessed, and rehabilitated. In this regard, much like an aircraft simulator serves to test and train piloting ability, VEs can be developed to present simulations that assess and rehabilitate human cognitive and behavioral processes.

The potential for VR's significance in this area was suggested early on by Myron Krueger (1993) in a visionary article published in the second volume of *Presence* ("The Experience Society"). In a prophetic statement, in the context of a discussion of VR's overall societal impact, Krueger proclaimed that virtual reality "arrives at a moment when computer technology in general is moving from automating the paradigms of the past, to creating new ones for the future" (p. 163). In this comment, Krueger encapsulated what had also been so limited in psychology's approach to using computer and information technology at that time, and opened a conceptual door to VR's potential to advance a field that had long been mired in the methods of the past. Indeed, psychology's use of technology up to that time could be characterized as mainly translating existing traditional paper and pencil tools directly into computer-delivered formats. As well, a dearth of conceptual growth in the field of psychometric testing methods was conjectured in a 1997 *American Psychologist* article by the respected intelligence theorist, Robert Sternberg in which he compared currently used intelligence and ability tests to black-and-white TV, rotary-dial phones, and the UNIVAC computer. His argument started by observing that the first edition of the most widely used intelligence test, the Wechsler Adult Intelligence Scale appeared in 1939, well before the UNIVAC. However, although computer and other information technology and telecommunication tools (that is, TV, telephones, and sound recording) had undergone a revolution since then, tests of cognitive ability—with the exception of essentially cosmetic changes—have remained essentially unchanged. Sternberg posited that "dynamic" interactive testing would be needed to provide a new option that could supplement traditional "static" tests. The "dynamic" assessment approach requires the provision of guided performance feedback as a component in tests that measure learning. This method appears well suited to the assets available with VR technology. In fact, VEs might be the most efficient vehicle for conducting dynamic testing in an "ecologically valid" manner while still maintaining the acceptable level of experimental control needed for good science.

In its defense, the general field of psychology has had occasional and valuable forays into technological domains, most notably in the areas of psychophysiological recording and measurement that also later served as the basis for biofeedback treatment approaches. As well, neuropsychology has been increasingly integrating advanced neural imaging technology tools (such as fMRI, SPECT, QUEEG, and CT) in its quest for a better accounting of the structure and process underlying brain/behavior relationships. However, although these advances in response measurement have led to new findings and conceptualizations, the stimulus delivery end of the equation has been somewhat limited. Stimulus presentation in traditional neuropsychological applications can be characterized as mainly coming in two forms: analog tasks and naturalistic tasks. Analog tasks involve standardized delivery of sound, text, symbols, and still/moving image stimuli, responses to which are readily quantifiable but limited in ecological validity. Naturalistic tasks in "real-world" scenarios (usually requiring behavioral rating judgments) are difficult or impractical to administer while still maintaining a systematic level of experimental control. Again, VR stands poised to fundamentally advance this area with innovative applications that leverage the immersive, involving and interactive assets available in VEs to deliver quantifiable analog-like stimulus protocols within the context of functionally relevant (and controllable) environments. Until now, these features have not been pragmatically available with existing methods in neuropsychology, and thus it is our view that VR has plenty to offer in this vital and challenging area of the psychological sciences.

The papers in the current issue focus on the design, development, implementation, and evaluation of VR systems for use with persons having CNS dysfunction. As well, some applications are presented that address relevant neuropsychological variables in unimpaired and elderly populations that will ultimately be applied with clinical groups. We have attempted to bring together papers from some of the leading labs that are conducting research in this area. These papers address a range of component cognitive processes (such as attention, memory, and executive functions), as well as more functional behavior applications (such as driving, instrumental activities of daily living skills, and motor rehabilitation). The authors were also asked to provide enough background information and supporting rationales in their articles such that key concepts would be understood by a wide range of professionals, some of whom may not have domain-specific knowledge in neuropsychology or with clinical CNS populations. In this regard, it is felt that a basic awareness of the underlying neuropsychological principles, issues, and approaches employed when addressing impaired performance, could serve to inform VR strategies applied in general testing and training with nonclinical groups.

The issue begins with Rose, Attree, Brooks, and Andrews providing an excellent review of their evolved series of applications for memory assessment and rehabilitation with a variety of populations having brain dysfunction. Their article provides a clear discussion of the clinical and neurological rationale for applications in this area. Rizzo et al. then review their lab's research on molecular components of visuospatial ability with a projection-based VR system and on more ecological HMD environments for attention assessment in children with Attention Deficit Hyperactivity Disorder and adults with acquired brain dysfunction. McGeorge et al. presents a study comparing a traditional method for assessing executive functions with a flat-screen VR scenario in which early results suggest that the VE was more effective for discriminating brain-injured patients on these types of planning deficits. Pugnetti, Meehan, and Mendozzi review work in their lab that focuses on recording psychophysiological variables in VEs that could have implications for better mapping of brain/behavior relationships, providing options for hands-off assistive control in VEs for persons with motor impairments, and training of attention performance via biofeedback methods in VR. Brown, Standen, Proctor, and Sterland discuss their longstanding use of flat-screen VEs in populations with severe learning disabilities and present work on extracting key characteristics of successful real-life tutors to incorporate into the VE as embedded-agent tutors. Excellent application of user-centered design methods, which is so important generally in VR application development, is also highlighted in this work. Deutsch, Latonio, Burdea, and Boian then present a case study of a systematic rehabilitation program for ankle physical therapy with a stroke patient that suggests how the involving characteristics of VEs can motivate performance to levels needed to produce measurable and meaningful outcomes. Schultheis and Mourant outline the rationale and development of a novel approach to VR driving assessment that will compare the driving skills of brain-injured patients in a VE with performance on a real-world "behind the wheel" standard route that the VR system was modeled after. In this type of "head-to-head" comparison of assessment formats, driving performance under challenging circumstances in the VE that are not possible to test for on the "real" route (such as rain, fog, and other emergency conditions) can be compared with traditional subjective assessments that do not allow for such "testing of the limits" opportunities. Bertella, Marchi, and Riva then present the rationale and progress on development of a system for targeting topographical disorientation. This is a fairly common impairment in wayfinding that is seen across a variety of clinical conditions and has significant impact on consequent functional independence. Finally, Optale et al. present an initial case study with suggestive results on a novel approach to integrating music into a virtual environment to enhance memory and functional abilities in a woman with Alzheimer's disease. In view of the chronic progressive dysfunction that occurs with this neurological disease, methods that can at least slow the decline in performance could have positive impact for maintaining/extending functional independence and quality of life.

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