Chapter 16
Virtual Simulations and the Second Life Metaverse:
Paradigm Shift in Neuropsychological Assessment

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ABSTRACT

In neuropsychology's received paradigm, the "normal science" of assessment and treatment planning appears to be approaching a paradigm shift: first, there are the general developments in other neurosciences that inform the practice of neuropsychological assessment. Second, there is the shift in the purpose of neuropsychological assessment from differential diagnosis of brain pathology to predictions about activities of everyday functioning and treatment planning. Third, there is growing need that neuropsychologists update their outdated technology for ecologically valid assessments. The impending paradigm shift may be well served to include the utility of virtual worlds for ecologically valid neuropsychological assessments. Actualization of the potential of virtual worlds for assessment will require the following: comparisons with well-validated neuropsychological measures, data storage, improved documentation of specific computer hardware and software used in experimental methods, and enhanced methods and result reporting by the researchers publishing studies on virtual worlds.

INTRODUCTION

Neuropsychological assessment represents an integration of a systematized neurological assessment of functional cortical and subcortical systems and a precise scaling of psychometric measurement. A typical neuropsychological assessment evaluates several aspects of psychological functioning. In addition to measures of intelligence (e.g., IQ) and achievement, the neuropsychological assessment is made up of a battery of tests to examines multiple areas of functioning that also have an

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impact on performance of activities of daily living. The following represents a set of cognitive functions that is likely to be assessed: learning/memory, intelligence, language, visuoperception, and executive-functioning. The historical development of neuropsychology has resulted in a "normal science" that is informed by developments in psychology, neuroscience, neurology, psychiatry, and computer science. Each of these "informing disciplines" has gone through changes that challenge theory and praxes of neuropsychological assessment. These changes are what Kuhn (1962/1996) describes as paradigm shifts, in which new assumptions (paradigms/theories) require the reconstruction of prior assumptions and the reevaluation of prior facts. For psychology, the paradigmatic shifts are found in the move from mentalism (i.e., study of consciousness with introspection) to behaviorism (Watson, 1912), and then cognition (Miller, 2003) as now understood through connectionist frameworks (Bechtel & Abrahamsen, 1990). Neurorehabilitation has undergone a paradigm shift as a result of influences from basic and clinical research (Nadeau, 2002). For psychiatry (e.g., neuropsychopharmacology) the "paradigm shift" has been found in an understanding of psychiatric disorders and molecular biology models that account for gene/environment/development interaction (Meyer, 1996). Likewise, neuroscience has seen a shift related to the understanding of communication between nerve cells in the brain—shift from predominant emphasis upon electrical impulses to an enhanced model of chemical transmission (Carlsson, 2001). For neurology (and a number of related branches of neuroscience) a shift is found in new ways to visualize the details of brain function (Raichle, 2009). Finally, we are seeing shifts in computer science in the areas of social computing (Wang, 2007), information systems (Merali and McKelvey, 2006), and even the video game industry (Zackariasson and Wilson, 2010).

Developments in the area of neuropsychological assessment parallel several of Kuhn's observations concerning the nonlinear trend of progress in the history of science (Kuhn, 1962/1996). For example, the naive assumption that traditional neuropsychological assessment procedures would continue to maintain prominence following the advent of neuroimaging characterized an earlier status quo, a period Kuhn referred to as normal science. The untenable presumption that traditional paper-and-pencil batteries (or automated computerized versions) were generally capable of forming accurate judgments about the everyday functioning (i.e., ecological validity) of persons tested on the basis of observation was another received belief that characterized this soon to be archaic era of practice. According to Kuhn, "paradigms" are initially recognized scientific achievements that for a period provide model problems and solutions to a community of practitioners. For the most part neuropsychologists are interested in "normal science" research based upon previous neuroscientific realizations that provide the foundations for neuropsychology's further practice. From a Kuhnian perspective, the unprecedented achievements of notable neuropsychologists, for example Wernicke or Luria, have provided the context for the neuropsychological research of the next generations and their theories are adequately open ended to allow for a variety of problems to be explored. For example, the localization and connectionist theories begun by Wernicke culminated in Luria's (1973) theory of three interacting functional systems. From a Kuhnian perspective, the attainment of a paradigm is found in its potential for achievement in still unfinished examples and normal science consists in the actualization of this potential. Further, normal science is interested in answering questions and a revolution occurs in response to a "crisis" when theory and praxis cannot be integrated and neuropsychological research problems can no longer be adequately resolved. In neuropsychology, such a paradigm shift would result in a community of neuropsychologists coming to view their theory and practice quite differently.

The advent of neuroimaging caused a crisis state in the normal science of neuropsychological assessment. During a pre-neuroimaging paradigm focusing on localization, neuropsychologists received referrals from neurosurgeons to psychometrically localize brain damage. However, over the past few decades a number of developments in neuroimaging have made virtually obsolete the normal science of localization by neuropsychogists. Unfortunately, technological progress in clinical neuropsychology has not been made at the rate that is found in the other clinical neurosciences (Dodrill, 1997). As a result, the normal science of neuropsychology is increasingly being questioned as it uses outdated methods (e.g., paper-and-pencil tests). What is needed is a shift to technologically advanced and ecologically valid neuropsychological assessment that made predictions of the patient's real world functioning. A response to this need may be found in the virtual worlds that are being created for clinical neuropsychology applications. Potential virtual world use in assessment and treatment of human cognitive and affective processes is becoming recognized as technology advances. Such simulation technology appears to be distinctively suited for the development of ecologically valid virtual worlds, in which stimuli are presented in a consistent and precise manner. As a result, subjects are able to manipulate objects in a virtual world that proffers a range of potential task demands.

A further development of this emerging paradigm for clinical neuropsychologists may be found in the expanding metaverse of virtual worlds such as Second Life (SL; Linden Lab, San Francisco, Calif.) that proffer tools (i.e. scripting and graphics) and environments that facilitate the creation of virtual environments that can be made available to potentially thousands of research subjects in an economical manner (Bainbridge, 2007). The population of users in Second Life has reached more than six million virtual citizens (Boulous, 2007). Within virtual worlds, it is possible to systematically present cognitive tasks targeting neuropsychological performance beyond what are currently available using traditional methods. Reliability of neuropsychological assessment and treatment of affective and cognitive disorders can be enhanced in virtual worlds by better control of the perceptual environment, more consistent stimulus presentation, and more precise and accurate scoring. Virtual worlds may also improve the validity of neurocognitive measurements via the increased quantification of discrete behavioral responses, allowing for the identification of more specific cognitive domains. Virtual worlds could allow for cognition and affect to be assessed and treated in situations that are more ecologically valid. Participants can be evaluated in a virtual world that simulates the real world, not a contrived testing environment.

Virtual worlds offer the option to produce and distribute identical "standard" simulation environments in which performance can be measured and treated. Within such digital scenarios, normative data can be accumulated for performance comparisons needed for assessment/diagnosis and for treatment/rehabilitation purposes. In this manner, reusable archetypical virtual worlds constructed for one purpose can also be applied for applications addressing other clinical targets. This chapter will provide a review of such a retooling approach using virtual environments that were originally developed as a controlled stimulus environment in which cognitive processes could be systematically assessed in persons with various neurocognitive and affective deficits.

The organization of this chapter is as follows. In section one a brief overview will be given of the historical development of clinical neuropsychology's normal science and the crisis state that is leading to a paradigm shift. In section two, a brief discussion of current applications of computer-based neuropsychological assessment are described. In section three, there will be a discussion of the utility of virtual worlds for ecologically valid neuropsychological assessments that make use of current technological advances.

Obstacles and limitations are discussed in section four. A discussion of future directions is given in section five.

NEUROPSYCHOLOGICAL ASSESSMENT: FROM LOCALIZATION TO ACTIVITIES OF DAILY LIVING

The neuropsychological assessment has historically been characterized as both a refinement and an extension of the neurological examination (Benton, 1985). Much of what is now considered part of neuropsychological assessment originated from localizationist attempts of late nineteenth and early twentieth century physicians to improve evaluation of the cognitive capacities of persons with brain disease (e.g., Broca and Wernicke aphasics). Part of this has to do with the fact that many widely used neuropsychological tests were constructed before the advent of neuroimaging and emergence of much of the currently available information relating altered behavior to brain dysfunction. During this pre-neuroimaging era localization required clinical neuropsychology to establish standardized assessment measures for a normal science capable of identifying the neurocognitive effects of brain dysfunction. Standardized assessment in neuropsychology is largely due to its historic development from Alfred Binet's tests of intelligence and the United States's entry into the World War I in 1917 (see Anastasi and Urbina, 1997 for a review). During this time Robert Yerkes, Arthur Otis, and the American Psychological Association developed a group administered version of the Stanford-Binet (i.e., Army Alpha), and a novel group administered assessment composed of nonverbal tasks (i.e., Army Beta). A shift occurred with Yerkes (1917) move Binet's age-scale approach (i.e., tasks fluctuate with age and developmental level) to a point-scale methodology (i.e., tests selected based upon specified functions) over. Ultimately, the Army group administered measures reflecting an amalgamation of Yerkes's point-scale approach and Binet's task-specific approach to measuring cognitive performance. Further, a performance scale developed by David Wechsler was included in an Army battery, (1920) that was made up of subtests developed primarily by Binet and World War I psychologists. A major shift in testing occurred when Wechsler applied testing procedures (i.e., group and individual) developed for normal functioning persons to the construction of a clinical test battery. Following World War I, Wechsler assembled the Wechsler-Bellevue battery, which included both Verbal and Performance Scales. By the 1940s a number of specialized neurocognitive tests were available to clinicians for assessing the mental capacities of persons with brain disease. The additive effects of these tests provided the foundation for the normal science found in today's neuropsychological assessment procedures (see Lezak et al., 2004).

As mentioned above, during a period focusing on localization, the normal science of neuropsychologists involved the development and administration of measures based upon a localization paradigm that focused upon double dissociation—two neocortical areas are functionally dissociated by two behavioral measures, each measure is affected by a lesion in one neocortical area and not the other (Pribram, 1971). It is important to note, however, that with the advent of neuroimaging, the need for neuropsychologists to localize brain damage has been greatly reduced. Unfortunately, many neuropsychologists continue to rely on "localization" as the chief basis for validating neuropsychological tests. As Ronald Ruff has contended, although neuroimaging caused the role of neuropsychology to shift from localization to documentation of neuropsychological deficits for prediction of real world functioning, clinical neuropsychologists many times fail to develop ecologically oriented assessments and continue to use localizationist-developed test batteries (Ruff, 2003).

Clinical neuropsychologists are increasingly being asked to make prescriptive statements about every-day functioning (Long, 1996). This new role for neuropsychologists has resulted in increased emphasis upon the ecological validity of neuropsychological instruments. To establish ecological validity of neuropsychological measures, neuropsychologists focus on demonstrations of either (or both) verisimilitude and veridicality (Franzen and Wilhelm, 1996). By verisimilitude, ecological validity researchers are emphasizing the need for the data collection method to be similar to real life tasks in an open environment. For the neuropsychological measure to demonstrate veridicality, the test results should reflect and predict real world phenomena (Chaytor and Schmitter-Edgecombe, 2003).

In addition to the controversy related to whether or not current indices found on commonly used paper-and-pencil neuropsychological tests give us sufficient detail for prediction of the potential everyday difficulties likely to be faced by patients (Wilson, 1993), a dearth of research has addressed the degree to which neuropsychological testing is ecologically valid (Nussbaum et al., 1995). Review of the ecological validity of neuropsychological tests has provided support for the superiority of verisimilitude tests as the results from these measures tended to be more consistently related to the outcome measures than the traditional paper-and-pencil tests. However, a problem for the verisimilitude approach is that these instruments do not appear to be migrating from research laboratories into the applied settings of clinical neuropsychologists (Rabin et al., 2007). An additional problem for this approach is that although these neuropsychologists have developed instruments that more closely approximate skills required for everyday functioning, have not made use of advances in computer technology. As a result, they are in danger of continuing the negative trend that deemphasizes psychology's role as a science.

COMPUTER AUTOMATION OF PAPER-AND-PENCIL TESTS

In the 1980s there was some initial interest in computerization of various assessment measures and neuropsychologists transferred a number of paper-and-pencil measures to the personal computer platform. Initial attempts at assessing the equivalence of these measures to traditional tests were made. A few examples of computerized versions of traditional paper-and-pencil neuropsychological tests include: the Raven's Colored Progressive Matrices; the Peabody Picture Vocabulary Test; Category Test subtest of the Halstead Reitan Battery; and the Wisconsin Card Sorting Test. Further, in the past decade, a number of computerized tests of neurocognitive function have been developed: CogSport, ImPACT, ANAM, and Headminder. Computer-based neuropsychological assessments offer a number of advantages over traditional paper-and-pencil testing: increased standardization of administration; increased accuracy of timing presentation and response latencies; ease of administration and data collection; and reliable and randomized presentation of stimuli for repeat administrations (Schatz & Browndyke, 2002).

Despite these computerized versions of traditional paper-and-pencil neuropsychological tests, the vast majority of current neuropsychological assessment procedures represent a technology that has not changed since the first scales developed in the early 1900s (e.g., Binet and Simon's first scale in 1905 and Wechsler's in 1939). For the past few decades, the Wechsler scales (in various manifestations; e.g., WAIS-R, WAIS III) have been the most widely used neuropsychological tests. While automated versions were developed of the original WAIS in 1969 and again in 1980, these automations provided only rudimentary stimulus presentation and limited data recording. Since the 1980s, the automated versions are all but abandoned and now the focus is upon slight revisions of the paper-and-pencil versions with computerized

scoring. In fact, the latest revisions of the Wechsler scales (e.g., Wechsler Adult Intelligence Scale—Third Edition; Wechsler Intelligence Scale for Children—Fourth Edition) offer little more than cosmetic change and improved standardization. This lack of technological advancement of the Wechsler scales is important because according to a 2005 study surveying assessment practices and test usage patterns among 747 North American, doctorate-level clinical neuropsychologists, the Wechsler Scales were the most frequently used tests in their neuropsychological assessments (Rabin, Barr, and Burton, 2005).

Robert Sternberg (1997) pointed out over a decade ago the discrepancy between progress in cognitive assessment measures like the Wechsler scales and progress in other areas of technology. Sternberg used the example of the now obsolete black and white televisions, vinyl records, rotary-dial telephones, and the first commercial computer made in the United States, UNIVAC I to illustrate the lack of technological progress in the standardized testing industry. According to Sternberg, currently used standardized tests differ little from tests that have been used throughout this century. For example, while the first edition of the Wechsler Adult Intelligence Scale appeared some years before UNIVAC, the Wechsler scales (and similar tests) have hardly changed at all (aside from primarily cosmetic changes) compared to computers. Although one may argue that innovation in the computer industry is different from innovation in the standardized testing industry, there are still appropriate comparisons. For example, whereas millions of dollars spent on technology in the computer industry typically reflects increased processing speed and power; millions of dollars spent on innovation in the testing industry tends to reflect the move from multiple-choice items to fill-in-the-blank items. Sternberg's statements are as true now as they were over a decade ago. While neuropsychology emphasizes its role as a science, its technology is not progressing in pace with other clinical neurosciences. Sternberg also points out neurocognitive testing needs progress in ideas, not just new measures, for delivering old technologies.

The recent shifts in computer science in the areas of social computing (Wang, 2007), information systems (Merali and McKelvey, 2006), and even the video game industry (Zackariasson and Wilson, 2010) reflect a growth in telecommunication and internet-based technologies. Given these advances, it is becoming increasingly possible to conduct social and behavioral science research via the internet. Researchers have reported the development and use of a handful of internet-based neurocognitive assessment measures. An internet-based neurocognitive screening for adult head injuries has been developed (Erlanger et al., 2003); the Cognitive Stability Index (CSI). The CSI assess neurocognitive functioning in persons with known or suspected primary central nervous system illness (Erlanger et al., 2002). The CSI is made up of ten subtests that comprise four domains: attention, processing speed, response time, and memory. In addition to use with adult head injury, it has been applied as a measure of cognitive function in patients with mild to moderate traumatic brain injury (Erlanger et al., 2003; Erlanger et al., 2002), Alzheimer's disease (Lichtenberg et al., 2006), and multiple sclerosis (Younes et al., 2007). Other internet-based cognitive assessments include IntegNeuro and WebNeuro. These assessments are being used in healthy controls and clinical populations. Reliability, validity, and norms for comparison with clinical groups are being established for both the IntegNeuro (Paul et al., 2005) and the WebNeuro (Silverstein et al., 2007).

While standard neuropsychological measures have been found to have adequate predictive value, their ecological validity may diminish predictions about real-world functioning (Chaytor and Schmitter-Edgecombe, 2003). Regardless of the medium (e.g., paper-and-pencil; computer automations; or internet delivered), traditional neurocognitive measures may not replicate the diverse

environment in which persons live. Additionally, standard neurocognitive batteries tend to examine isolated components of neuropsychological ability, which may not accurately reflect distinct cognitive domains (Parsons et al., 2004a, 2005). Only a handful of neuropsychological measures have been developed with the specific intention of tapping into everyday behaviors like navigating one's community, grocery shopping, and other activities of daily living. Of those that have been developed, even fewer make use of advances in computer technology. It is important to note that the ones that have been applied to computer technology also run this risk of not offering the ecological validity needed for assessment of real world functioning.

VIRTUAL WORLDS OFFER ADVANCED ECOLOGICAL VALIDITY

Virtual worlds offer an advanced computer interface that allows humans to become immersed within a computer-generated simulation. Potential virtual world use in assessment and rehabilitation of human cognitive processes is becoming recognized as technology advances. Since virtual worlds allow for precise presentation and control of dynamic perceptual stimuli, they can provide ecologically valid assessments that combine the veridical control and rigor of laboratory measures with a verisimilitude that reflects real life situations. Additionally, the enhanced computation power allows for a range of the accurate recording of neurobehavioral responses in a perceptual environmental that systematically presents complex stimuli. Such simulation technology appears to be distinctively suited for the development of ecologically valid environments, in which stimuli are presented in a consistent and precise manner. As a result, subjects are able to manipulate three dimensional objects in a virtual world that proffers a range of potential task demands.

Virtual world applications that focus on treatment of cognitive (see Rose et al., 2005; Parsons 2009a) and affective disorders (see Powers & Emmelkamp, 2008; Parsons et al., 2008a), as well as assessment of component cognitive processes are now being developed and tested: attention (Law et al., 2006; Parsons, et al., 2007) spatial abilities (Beck et al., 2010; Parsons et al., 2004b), retrospective memory (Parsons & Rizzo, 2008b), prospective memory (Knight & Titov, 2009), spatial memory (Astur et al., 2004; Goodrich-Hunsaker and Hopkins, 2010); and executive functions (Elkind et al., 2001; Pugnetti et al., 1998; McGeorge et al., 2001). The increased ecological validity of neurocognitive batteries that include assessment using virtual scenarios may aid differential diagnosis and treatment planning. Within a virtual world, it is possible to systematically present cognitive tasks targeting neuropsychological performance beyond what are currently available using traditional methods (Rizzo et al., 2004). Reliability of neuropsychological assessment can be enhanced in virtual worlds by better control of the perceptual environment, more consistent stimulus presentation, and more precise and accurate scoring. Virtual worlds may also improve the validity of neurocognitive measurements via the increased quantification of discrete behavioral responses, allowing for the identification of more specific cognitive domains (see Gaggioli et al., 2009). Virtual environments could allow for neurocognition to be tested in situations that are more ecologically valid. Participants can be evaluated in an environment that simulates the real world, not a contrived testing environment (see Gorini et al., 2008). Further, it offers the potential to have ecologically valid computer-based neuropsychological assessments that will move beyond traditional clinic or laboratory borders.

Technological advances in computing and the World Wide Web in the last couple decades (Abbate, 1999) have allowed for internet-based virtual worlds testing with potentially more diverse samples in respect to socioeconomic status, sex,

and age than traditional samples that are often drawn from undergraduate university students (Gosling et al., 2004). Virtual worlds are made up of online communities in which persons interrelate in simulated environments. The continued progress in the development of robust technologies such as more rapid and secure internet connections has led to the ever increasing interest in social networks (Boulos & Wheeler, 2007). Virtual worlds provide users to experience social interaction as they participate in individual and group activities. The virtual world Second Life proffers multiple medical and health educational projects (Boulos, Hetherington, & Wheeler, 2007). Although these programs focus primarily on the dissemination of medical information and the training of clinicians, a handful of private islands in Second Life (e.g., Brigadoon for Asperger's syndrome; Live2give for cerebral palsy) have been created for therapeutic purposes. In a recent article by Gorini et al (2008), the authors describe such sites and the development and implementation of a form of tailored immersive e-therapy in which current technologies (e.g., virtual worlds; bio and activity sensors; and personal digital assistants) facilitate the interaction between real and 3-D virtual worlds and may increase treatment efficacy.

In a recent article in *Science*, Bainbridge (2007) discussed the robust potential of virtual worlds for research in the social and behavioral sciences. For social and behavioral science researchers, virtual worlds reflect developing cultures, each with an emerging ethos and supervenient social institutions (for a discussion of supervenience see Hare, 1984). In addition to the general social phenomena emerging from virtual world communities, virtual worlds provide novel opportunities for studying them. According to Bainbridge (2007), virtual worlds proffer environments that facilitate the creation of online laboratories that can recruit potentially thousands of research subjects in an automated and economically feasible fashion. Virtual worlds like Second Life offer scripting and graphics tools that allow even a novice computer user the means necessary for building a virtual laboratory. Perhaps even more important is the fact that social interactions in online virtual worlds (e.g., Second Life) appear to reflect social norms and interactions found in the physical world (Yee et al., 2007). Finally, there is the potential of virtual worlds to improve access to medical rehabilitation. Klinger and Weiss (2009) describe the evolution of virtual worlds along to two dimensions: 1) the number of users; and 2) the distance between the users. According to Klinger and Weiss, single user and locally used virtual worlds have developed into three additional venues: 1) multiple users located in the same setting, 2) single users remotely located, and 3) multiple users remotely located. According to Klinger and Weiss, single user, locally operated virtual worlds will continue to be important for rehabilitation within a clinical or educational setting. However, the literature, to date, has been limited to descriptions of system development and reports of small pilot studies (Brennan, Mawson, & Brownsell, 2009). It is anticipated that this trend is changing and future years will see evidence of the effectiveness of such virtual worlds for therapy.

OBSTACLES AND LIMITATIONS

For social and behavioral scientists to make good use of internet-based virtual worlds, there is need for empirical, procedural, ethical, and professional practice guidelines. A general literature review reveals that most internet-based virtual worlds' development efforts have been conducted in relative isolation with varying standards for data transmission, platform dependence, normative comparison, and clinical application. Although guidelines are emerging for internet and data storage issues among collaborative researchers who are scattered geographically (Marshall & Haley, 2000), many virtual world studies fail to provide sufficient quantitative information to allow readers to evaluate the appropriateness of the analysis and

to draw their own interpretations. For example, a Meta-analysis by Parsons and Rizzo (2008a) found that the inadequate characterization of results and design across studies made it impossible to carry out an analysis to determine the influence of moderator variables upon treatment effects. Hence, for clinical variables, such as presence, immersion, anxiety and/or phobia duration, demographics (e.g. age, gender, and ethnicity), it was not possible to calculate correlation coefficients because numerous studies did not report exact values, and, for some parameters, the number of studies was too small to meaningfully interpret the r value. While the application of virtual worlds to social and behavioral science can increase the ecological validity of these studies allowing for results to generalize beyond the controlled laboratory context (Rizzo et al., 2004), the ecological approach to such research runs the risk of being inconsequential because scientific progress necessitates greater emphasis on experimental control (Banaji and Crowder, 1989). As a result, there is a consistent tradeoff between enhanced fidelity and experimental control.

There are some relatively obvious practical and technical limitations of virtual world-based assessment that will cause clinical neuropsychology to be slow in adopting computerization on a large scale. For example, synchronization between the user's computer processor and the user's internet connection occurs with varying amounts of delay, or error, in timing. As a result, it will be difficult to standardize or control this delay with a degree of consistency. At one time this was an issue for any computerized testing. However, researchers have since developed software solutions that provide near-millisecond accuracy (Westall et al., 1989). Hence, there is a need for both the development of internet-based measures and "measure development" software. Further, there is the issue of crucial sources of error in computerized neuropsychological assessment (Cernich et al., 2007). For example, various configurations and operating systems are in use. A further example may be found in real-time versus store-and-forward Internet-based assessment. These issues emphasize the need for technology standardization in which internet-based information may be exchanged. At minimum, researchers should use the American Psychological Association's (APA) established guidelines for the development, administration, and interpretation of computerized assessments (APA, 1986, 1987). Given the many changes that have occurred in the years since these guidelines were developed, there is need for a documented standard beyond those recommendations offered by the APA. There is a need for neuropsychology to update such guidelines and maintain a professional and guiding presence. Clinical practice is increasingly being impacted by the internet's ability to disseminate rapidly vast amounts of information and facilitate the instantaneous exchange of ideas.

Another issue is that the automated nature of virtual world measures does not allow an examiner to interrupt or stop the assessment and "test the limits" or be more flexible with their evaluation. Further, virtual world assessments may not provide as much qualitative information as standard evaluations in which a clinician examines the type of errors a patient makes and the strategies a patient might use to arrive at his or her answers (Woo, 2008). Hence, any computerized assessment should not remove a clinician from the equation. Instead, virtual worlds, like automated neuropsychological assessments, should be viewed as a tool to be used by a clinician, and not a replacement of the clinician.

FUTURE RESEARCH DIRECTIONS

The "normal science" that makes up clinical neuropsycholoy's cognitive and affective assessment is informed by developments in psychology, neuroscience, neurology, psychiatry, and computer science. The paradigm shifts that have occurred in each of these "informing disciplines" may reflect an impending paradigm shift in neuropsychology.

This impending shift is also reflected in the ways in which traditional paper-and-pencil assessments of cognition and affective presentations have been replicated with general equivalence to their paper-and-pencil predecessors. Likewise, virtual world applications that focus on treatment of cognitive (see Rose et al., 2005; Parsons 2009a) and affective disorders (see Powers & Emmelkamp, 2008; Parsons et al., 2008a), as well as assessment of component cognitive processes are now being developed and tested. One example of such developments can be found in a set of projects at the University of Southern California's Institute for Creative Technologies (USC/ICT). At USC/ICT, a number of projects have been designed, developed and implemented using a Virtual Iraqi/Afghani theme. The Virtual Iraq/Afghanistan world uses virtual environments to assess and treat combat related trauma, such as posttraumatic stress disorder (PTSD) and traumatic brain injury (TBI). This example is used because it represents the evolution from 1) paper-and-pencil and automated computer assessments to a virtual world environment (Virtual Reality Cognitive Performance Assessment Test); 2) extension of VRCPAT to a virtual reality exposure therapy; and 3) finally an instantiation of in Second Life.

First, in one set of these environments at USC/ICT, Thomas Parsons (Parsons et al., 2008a, 2008b, 2008c, 2009b) and colleagues have recycled the virtual graphic assets built for the combat tactical simulation training game, Full Spectrum Warrior, to develop a Virtual Reality Cognitive Performance Assessment Test (VRCPAT). The VRCPAT project is embedding the metrics and 2D stimulus presentations from a well established computerized assessment battery of cognitive function known as the Automated Neuropsychological Assessment Metrics (ANAM) and validating the results on standard paper-and-pencil measures. Preliminary results suggest that the VRCPAT measures a capacity that is a valid test that provides a unique opportunity to reliably and efficiently study cognitive function within an ecologically valid environment.

Second, in related work at USC/ICT, Albert Rizzo, Parsons, and colleagues, are using the same Virtual Iraqi/Afghani environment for virtual reality exposure therapy (VRET) with soldiers who have experienced trauma resulting in disrupted affect. The Virtual Iraq/Afghanistan system built from a user-centered design process has been tested in an open clinical trial with PTSD-diagnosed active duty service members. The participants were service members who recently redeployed from Iraq and who had engaged in previous PTSD treatments (e.g., group counseling, SSRIs, etc.) without benefit. The VRET exposure exercises followed the principles of graded prolonged behavioral exposure and the pace was individualized and patient-driven. Initial analyses of results from the first 20 Virtual Iraq treatment completers have indicated positive clinical outcomes. Of the first twenty patients to complete treatment 16 no longer meet diagnostic criteria for PTSD at post treatment. It is important to note that the VRCPAT and the VRET for combat-related PTSD projects developed at USC/ICT are not online virtual worlds. Instead, the Virtual Iraqi/Afghani world uses an offline immersive virtual environment.

Third, virtual world environments that mimic USC/ICT's VRET approach have been developed at USC/ICT in Second Life by Jackie Morie. The Second Life instantiation is called the Transitional Online Post-deployment Soldier Support in Virtual Worlds (TOPSS-VW). The TOPSS-VW project uses the facility of online virtual worlds to create a place of camaraderie and healing for returning United States military veterans—virtual space that can help them deal with problems related to their time of service and also assist in their reintegration into society (Morie et al., 2009). Finally, Parsons and Morie at USC/ICT are currently planning to implement VRCPAT in a Second Life Virtual Iraq/Afghanistan. The goal will be to development and validate a handful of internet-based neurocognitive assessment measures using Second Life.

CONCLUSION

The historical development of neuropsychology has resulted in a "normal science" that is informed by developments in psychology, neuroscience, neurology, psychiatry, and computer science. Each of these "informing disciplines" has gone through changes that challenge theory and praxes of neuropsychological assessment. Developments in the area of neuropsychological assessment parallel several of Kuhn's observations concerning the nonlinear trend of progress in the history of science. For example, the naive assumption that traditional neuropsychological assessment procedures would continue to maintain prominence following the advent of neuroimaging characterized an earlier status quo, a period Kuhn referred to as normal science. The untenable presumption that traditional paper-and-pencil batteries (or automated computerized versions) were generally capable of forming accurate judgments about the everyday functioning (i.e., ecological validity) of persons tested on the basis of observation was another received belief that characterized this soon to be archaic era of practice.

A further development of this emerging paradigm for clinical neuropsychologists may be found in the expanding metaverse of virtual worlds such as Second Life. Within virtual worlds, it is possible to systematically present cognitive tasks targeting neuropsychological performance beyond what are currently available using traditional methods. Reliability of neuropsychological assessment and treatment of affective and cognitive disorders can be enhanced in virtual worlds by better control of the perceptual environment, more consistent stimulus presentation, and more precise and accurate scoring. Virtual worlds may also improve the validity of neurocognitive measurements via the increased quantification of discrete behavioral responses, allowing for the identification of more specific cognitive domains. Virtual worlds could allow for cognition and affect to be assessed and treated in situations that are more ecologically valid. Participants can be evaluated in a virtual world that simulates the real world, not a contrived testing environment. Virtual worlds offer the option to produce and distribute identical "standard" simulation environments in which performance can be measured and treated. Within such digital scenarios, normative data can be accumulated for performance comparisons needed for assessment/diagnosis and for treatment/rehabilitation purposes. In this manner, reusable archetypical virtual worlds constructed for one purpose can also be applied for applications addressing other clinical targets.

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KEY TERMS AND DEFINITIONS

Crisis State: According to Kuhn, this occurs where a new paradigm has emerged and draws allegiances because of problems with the current paradigm.

Ecological Validity: To establish ecological validity of neuropsychological measures, neuropsychologists focus on demonstrations of either (or both) verisimilitude and veridicality. By verisimilitude, ecological validity researchers are emphasizing the need for the data collection method to be similar to real life tasks in an open environment. For the neuropsychological measure to demonstrate veridicality, the test results should reflect and predict real world phenomena.

Neuropsychological Assessment: A neuropsychological assessment typically evaluates multiple areas of cognitive and affective functioning. In addition to measures of intelligence and achievement, it examines a number of areas of functioning that also have an impact on performance in activities of daily living.

Normal Science: Kuhn's idea that the theory and praxes of a scientific community (e.g., neuropsychologists) are firmly based upon one or more past scientific achievements that the scientific community acknowledges for a time as supplying the foundation for its further practice.

Paradigm: Kuhn defines a scientific paradigm as having the following: 1) that which the researchers in the scientific community choose to observe and scrutinize; 2) the kind of questions that are supposed to be asked by researchers in the scientific community; 3) the structure of these questions; and 4) the ways in which the results of scientific investigations should be interpreted.

Paradigm Shift: From a Kuhnian perspective, this represents a shift in professional commitments to shared assumptions that occurs when an anomaly subverts the existing tradition of scientific practice.

Scientific Community: Kuhn's idea of a scientific community entails that neuropsychologists as a community cannot practice its trade without some set of received beliefs.

Virtual Reality: An advanced form of human–computer interaction, in which users are immersed in an interactive and ecologically valid virtual environment.

Virtual Worlds and Metaverse Platforms:

New Communication and Identity Paradigms

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