Chapter 9
Neurocognitive and Psychophysiological Interfaces for Adaptive Virtual Environments

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ABSTRACT

The use of neuropsychological and psychophysiological measures in studies of patients immersed in high-fidelity virtual environments offers the potential to develop current psychophysiological computing approaches into affective computing scenarios that can be used for assessment, diagnosis and treatment planning. Such scenarios offer the potential for simulated environments to proffer cogent and calculated response approaches to real-time changes in user emotion, neurocognition, and motivation. The value in using virtual environments to produce simulations targeting these areas has been acknowledged by an encouraging body of research. Herein the authors describe (1) literature on virtual environments for neurocognitive and psychophysiological profiles of users' individual strengths and weaknesses; and (2) real-time adaptation of virtual environments that could be used for virtual reality exposure therapy and cognitive rehabilitation. Specifically, the authors discuss their approach to an adaptive environment that uses the principles of flow, presence, neuropsychology, psychophysiology to develop a novel application for rehabilitative applications.

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INTRODUCTION

While standard neurocognitive measures have been found to have adequate predictive value, their ecological validity may diminish predictions about real-world functioning. 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). Although today's neurocognitive assessment procedures are widely used, neuropsychologists have been slow to adjust to the impact of technology on their profession. While there are some computer-based neuropsychological assessments that offer a number of advantages over traditional paper-and-pencil testing (e.g., 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), the ecological validity of these computer-based neuropsychological measures is less emphasized. 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. Some promise has been found in virtual and augmented reality environments that aim to increase the ecological validity of neurocognitive batteries through using simulation technologies for diagnosis and treatment planning. A potential drawback of using such ecologically enhanced simulations is that scientific progress necessitates greater emphasis on experimental control. One way that researchers have attempted to move beyond this impasse is the use of psychophysiological assessments. Ultimately, the success of the virtual reality and psychophysiology research paradigms has led to a psychophysiological computing approach, in which psychophysiological data gleaned from persons interacting within a virtual environment are used to adapt the virtual environment in real-time.

The plan of this chapter will be as follows. In Section 2 we describe the potential of virtual environments for increasing the ecological validity of neurocognitive assessments. Of note, however is the fact that simply increasing the verisimilitude of the neurocognitive assessment is not enough. Without an increase in veridicality, virtual environments run the risk of having poor experimental control. In Section 3, we consider psychophysiological assessment as a way to enhance experimental control in virtual environments that are being used for clinical applications. Psychophysiological metrics provide an excellent measure of presence and autonomic arousal. Hence, they provide a profile of the user state and a validation of the impact of the virtual environment on the user. In Section 4, we look at psychophysiological computing as the next logical step in the evolution of the use of psychophysiological and neurocognitive profiling of user's responses while immersed in virtual environments. Psychophysiological computing represents an innovative mode of human computer interaction (HCI) wherein system interaction is achieved by monitoring, analyzing and responding to covert psychophysiological activity from the user in real-time. In Section 5, we turn to adaptive virtual environments and and four interrelated objectives or Technical Areas that are necessary for developing an adaptive environment. Next, in section 6, we discuss our development of an adaptive environment that uses the principles of flow, presence, neuropsychology, psychophysiology to develop a novel application for rehabilitative applications. Finally, in conclusion, we briefly summarize the main ideas of this chapter. From our perspective, adaptive virtual environments offer the potential for a broad empowerment process within the flow