A Virtual-Reality Approach for the Assessment and Rehabilitation of Multitasking Deficits

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ABSTRACT

Virtual reality technology can be used for ecologically valid assessment and rehabilitation of cognitive deficits. This article expands the scope of applications to ecologically valid multitasking. A commercially available driving simulator was upgraded by adding an ever-changing sequence of concurrent, everyday-like tasks. Furthermore, the simulator software was modified and interfaced with a non-motorized treadmill to yield a pedestrian street crossing simulator. In the latter simulator, participants walk on through a virtual city, stop at busy streets to wait for a gap in traffic, and then cross. Again, a sequence of everyday-like tasks is added. A feasibility study yielded adequate "presence" in both virtual scenarios, and plausible data about performance decrements under multi-task compared to single-task conditions. The present approach could be suitable for the assessment and training of multitasking skills in older adults and neurological patients.

KEYWORDS

INTRODUCTION

It has repeatedly been proposed that neurocognitive assessment and rehabilitation should include ecologically valid procedures, i.e., it should be realistic, functionally relevant and as complex as daily life (e.g., Chaytor & Schmitter-Edgecombe, 2003; Schultheis & Rizzo, 2001; Wollesen & Voelcker-Rehage, 2014). At the same time, procedures should allow the examiner to fully control ambient conditions, stimulus presentation and registration of behavioral responses, as is the case in typical laboratory research. Virtual reality (VR) offers the potential for fulling both requirements: it can be designed such as to be ecologically valid *and* well-controlled (Schultheis & Rizzo, 2001).

VR technology has been applied with success for the assessment and rehabilitation of neuropsychological disorders (for recent reviews, see Howard, 2017; Jovanovski & Zakzanis, 2017), including attention deficits (Rizzo et al., 2000), spatial neglect (Ogourtsova, Souza Silva, Archambault, & Lamontagne, 2015), and upper limb dysfunction (Laver, George, Thomas, Deutsch, & Crotty, 2015). Our study presents a VR approach for the assessment and rehabilitation of multitasking deficits.

The ability to process multiple tasks at the same time is critical for a wide range of everyday activities such as car driving, pedestrian walking, grocery shopping and meal preparation. It is degraded in patients suffering from stroke (Burgess et al., 2006), Parkinson's disease (Willemsen, Grimbergen, Slabbekoorn, & Bloem, 2000), Alzheimer's disease (Esposito et al., 2010) or schizophrenia (Laloyaux et al., 2014), as well as in healthy older adults (Verhaeghen, Steitz, Sliwinski, & Cerella, 2003). Assessment and rehabilitation of multitasking skills is typically administered by computer software which displays abstract stimuli on a monitor and registers participants' responses with a joystick, computer mouse or keyboard. This approach lacks ecological validity for several reasons: stimuli often are abstract rather than realistic, the number of concurrent tasks rarely exceeds two, and participants' responses are not natural (e.g., participants "walk" through a displayed scene by depressing keys rather than by moving their legs).

VR scenarios for ecologically valid multitasking are already available, mainly for grocery shopping and food preparation (e.g., Rand, Weiss, & Katz, 2009; Zhang et al., 2001). VR scenarios for car driving and pedestrian street crossing have been established as well, but all past approaches were limited to two instead of multiple concurrent tasks: driving and street crossing has been combined either with music listening (Neider et al., 2011) or with phone conversation (Horberry, Anderson, Regan, Triggs, & Brown, 2006; Horrey & Wickens, 2006), mobile internet use (Byington & Schwebel, 2013), text messaging (Drews, Yazdani, Godfrey, Cooper, & Strayer, 2009), cockpit instrument manipulation (Horberry et al., 2006), object detection (Cassavaugh & Kramer, 2009), or arithmetic operations (Chaparro, Wood, & Carberry, 2005). The present study introduces an approach which, for the first time, combines driving and street crossing with a whole battery of realistic concurrent tasks. Preliminary data illustrate that this approach is indeed sensitive to the effects of multitasking on driving and street crossing.

HARD- AND SOFTWARE

Basic Configuration

The present approach utilizes a commercially available, moderately priced, research-grade driving simulator (Carnetsoft, Groningen, NL). It consists of

- A virtual environment generation module, in which the experimenter can define road segments, traffic signs, buildings, trees, and other design elements
- A traffic system module which controls the motion of other traffic participants such as cars and pedestrians, based on general as well as participant-specific sensors and decision rules. These rules include environmental conditions such as road friction and wind force. One component of this module simulates the car driven by the user; it uses information from the pedals and a gear shifter to calculate vehicle dynamics and to send force feedback to the steering wheel
- A scenario generation module in which the experimenter can define which data are to be sampled and stored, and which external events (e.g., verbal announcements or visual stimuli) are to be generated under which logical condition. Logical conditions can be internal (e.g., car speed > 60 km/h and distance from last intersection > 50 m) or they can be provided by external devices via an Ethernet connection (e.g., button presses). Scenarios are defined by script files, making it easy for the experimenter to change data storage and event generation as needed.

The driving simulator uses the Panda3D rendering engine to generate a left, central and right view for three monitors, each covering a horizontal visual angle of 65° with a resolution of 5760 x 1080 px. Hardware consists of a modified Logitech steering wheel, pedal and gear stick assembly, a single computer with a suitable graphics board and four monitors: one for the operator and three for image rendering. For the present work, the latter three monitors were replaced by 48 inch TV

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