Computers in Human Behavior 54 (2016) 414–424

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Literature review

Task difficulty of virtual reality-based assessment tools compared to classical paper-and-pencil or computerized measures: A meta-analytic approach

Alexandra Neguţ [a, *], Silviu-Andrei Matu [b], Florin Alin Sava [c], Daniel David [d, e]

[a] Evidence-based Assessment and Psychological Interventions Doctoral School, The International Institute for the Advanced Studies of Psychotherapy and Applied Mental Health, Babeş-Bolyai University, No. 37, Republicii Street 400015, Cluj-Napoca, Cluj, Romania
[b] Department of Clinical Psychology and Psychotherapy, Babeş-Bolyai University, No. 37, Republicii Street 400015, Cluj-Napoca, Cluj, Romania
[c] Department of Psychology, West University of Timişoara, No. 4, Vasile Pârvan Bulevard 300223, Timişoara, Timiş, Romania
[d] Department of Clinical Psychology and Psychotherapy, Babeş-Bolyai University, No. 37, Republicii Street 400015, Cluj-Napoca, Cluj, Romania
[e] Icahn School of Medicine at Mount Sinai, New York, USA

ARTICLE INFO

Article history:
Received 28 May 2015
Received in revised form
25 July 2015
Accepted 23 August 2015
Available online xxx

Keywords:
Virtual reality
Neuropsychological assessment
Task difficulty

ABSTRACT

Virtual reality-based assessment tools arise as a promising alternative for classic neuropsychological assessment with an increased level of ecological validity. Because virtual reality cognitive measures recreate tasks that resemble with the demands from the real world it is assumed that they require additional cognitive resources and are more difficult than classical paper-and-pencil or computerized measures. Although research has focused on comparing the performance obtained on virtual reality-based measures with classical paper-and-pencil or computerized measures, no meta-analysis has been conducted on this topic. Thirteen studies met our inclusion criteria: assessed any cognitive process using virtual reality and analogous classical or computerized assessment tools of the same process. Based on a random effects model, the results indicated a moderate effect size in favor of classical and computerized tests ($g = -0.77$) revealing an increased task difficulty in virtual reality. Overall, results from the current meta-analysis point out that cognitive performance obtained in virtual reality is poorer than the one in classical or computerized assessment which might suggest that tasks embedded in virtual reality have an increased level of complexity and difficulty and require additional cognitive resources.

Contents

* Corresponding author.
E-mail addresses: alexandra_negut@yahoo.com (A. Neguţ), silviu.matu@ubbcluj.ro (S.-A. Matu), afsava@gmail.com (F.A. Sava), danieldavid@psychology.ro (D. David).

http://dx.doi.org/10.1016/j.chb.2015.08.029
0747-5632/

1. Introduction

Virtual reality consists of a human–computer interface that is based on an interactive and advanced computer technology. By using a wide ranges of technological tools like head-mounted displays (HMDs) for the visual input, trackers, headphones for acoustic input, video capture systems, data gloves or joysticks a 3D environment is generated (Gamberini, 2000; Ku et al., 2003; Parsons, 2012; Rand et al., 2005; Schultheis, Himelstein, & Rizzo, 2002). The virtual environment generated by the technological tools is a computerized representation of the real world. The person is immersed in the virtual environment and is able to interact with it. Immersion generates a sense of presence in the world, as if he is actually present in the computer-generated world (Elkind, Rubin, Rosenthal, Skoff, & Prather, 2001; Ku et al., 2003; Lalonde, Henry, Drouin-Germain, Nolin, & Beauchamp, 2013; Rheingold, 1991).

1.1. Main approaches to cognitive assessment

Neuropsychological assessment is considered an applied science that focuses on the evaluation of specific activities in the central nervous system that are associated with observable behaviors (Lezak, 1995). Classic paper-and-pencil psychometrics, as well as computer-based assessment instruments, represents the current standard assessment tools used in neuropsychological evaluation (Podell, DeFina, Barrett, McCullen, & Goldberg, 2003). They consist of a certain amount of stimuli delivered to the subjects in a highly systematic and controlled environment via written paper or a computer screen. A recent study (Holzinger et al., 2011) shows that when taking into account the performance of medical professionals in a real-life setting on visual productivity between classical paper presentation and computerized screens no differences emerge, but the use of paper presentation is more preferred (Holzinger et al., 2011). Also, scoring and test interpretation are conducted either by a trained practitioner or automatically by the computer (Bauer et al., 2012; Podell et al., 2003). However, because the task characteristics associated with classical and computerized assessment do not replicate the complexity and challenges found in everyday life, their predictive power for real life performance in is limited (Armstrong et al., 2013; Elkind, 1998; Rizzo, Schultheis, Kerns, & Mateer, 2004; Schultheis et al., 2002). Considering these drawbacks, there is need to develop other assessment instruments with increased ecological validity (Alvarez & Emory, 2006; Elkind, 1998; Schultheis et al., 2002).

Virtual reality neuropsychological assessment might represent an efficient alternative to classical or computerized tests, given that it provides a higher level of ecological validity. Ecological validity implies a close link between the challenges imposed by the assessment procedures and the challenges that the subject has to confront in real life situations (Wasserman & Bracken, 2003). Virtual reality-based tests can increase the ecological validity of the assessment because they simulate real-life stressors and replicate the challenges and distractors found in day to day situations (Pugnetti et al., 1998; Rizzo et al., 2004; Schultheis et al., 2002). In addition, they may have potential to predict real life functioning due to the characteristics of test administration and assessment context (Elkind, 1998; Rizzo et al., 2006).

Virtual reality instruments are used for the neuropsychological assessment of executive functions, attention, and impulsivity, cognitive and motor inhibition (Adams, Finn, Moes, Flannery, & Rizzo, 2009; Elkind, 1998; Henry, Joyal, & Nolin, 2012; Ku et al., 2003; Parsons, Courtney, Arizmendi, & Dawson, 2011), memory and learning (Gamberini, 2000; Matheis et al., 2007; Parsons & Rizzo, 2008; Pugnetti et al., 1998), spatial abilities (Parsons et al., 2004), and visuospatial neglect (Broeren, Samuelsson, Stibrant-Sunnerhagen, Blomstrand, & Rydmark, 2007). Results of these studies support the use of virtual reality scenarios in neuropsychological assessment because they discriminate between healthy and clinical populations and their accuracy is similar to classical tests. Furthermore, results show a good equivalence between the performance obtained in the virtual world and in the real world (Rand, Basha-Abu Rukan, Weiss, & Katz, 2009; Sorita et al., 2013).

1.2. Overview of the current study

Due to the high similarity with the real world demands, it seems that virtual reality-based assessment has an increased task difficulty and triggers more cognitive resources than classical or computerized psychometrics (Elkind, 1998; Gamberini, 2000). Further on, the visual complexity of an interface influences the overall performance (Stickel, Ebner, & Holzinger, 2010) and virtual reality has an increased visual complexity compared to classical or computerized assessment, because it recreates a real environment. Overall, virtual reality scenarios replicate more accurately the complexity of real world situations which can lead to poorer performance on cognitive tasks conducted in virtual environments than on classical or computerized measures (Armstrong et al., 2013; Broeren et al., 2007; Gamberini, 2000; Parsons & Courtney, 2014; Parsons, Courtney, & Dawson, 2013). However, despite the fact that previous research has provided a useful database on the topic of virtual-reality based neuropsychological assessment and a reasonable number of theoretical reviews provide useful information about the core aspects and advantages of virtual reality assessment (Elkind, 1998; Myers & Bierig, 2000; Riva, 1998; Rizzo et al., 1999) no meta-analysis has been conducted in order to investigate the task difficulty hypotheses of virtual reality