Annual Review of Cybertherapy and Telemedicine 2011
B.K. Wiederhold et al. (Eds.)
IOS Press, 2011

doi:10.3233/978-1-60750-766-6-92

Validation of a Neuro Virtual Reality-based Version of the Multiple Errands Test for the Assessment of Executive Functions

Simona RASPELLI[a,1], Federica PALLAVICINI[a], Laura CARELLI[a,b], Francesca MORGANTI[b], Barbara POLETTI[d], Barbara CORRA[d], Vincenzo SILANI[d] and Giuseppe RIVA[a,c]

[a] *Applied Technology for Neuro-Psychology Lab, Istituto Auxologico Italiano, Milan, Italy*
[b] *Department of Human Sciences, University of Bergamo, Bergamo, Italy*
[c] *Department of Psychology, Catholic University of Milan , Milan, Italy*
[d] *Department of Neurology and Laboratory of Neuroscience, "Dino Ferrari" Center, University of Milan, IRCCS Istituto Auxologico Italiano, Milan, Italy*

Abstract. The purpose of this study was to establish ecological validity and initial construct validity of the Virtual Reality (VR) version of the Multiple Errands Test (MET) (Shallice & Burgess, 1991; Fortin et al., 2003) based on the NeuroVR software as an assessment tool for executive functions. In particular, the MET is an assessment of executive functions in daily life, which consists of tasks that abide by certain rules and is performed in a shopping mall-like setting where items need to be bought and information needs to be obtained. The study population included three groups: post-stroke participants (n = 5), healthy, young participants (n = 5), and healthy, older participants (n = 5). Specific objectives were (1) to examine the relationships between the performance of three groups of participants in the Virtual Multiple Errands Test (VMET) and at the traditional neuropsychological tests employed to assess executive functions and (2) to compare the performance of post-stroke participants to those of healthy, young controls and older controls in the VMET and at the traditional neuropsychological tests employed to assess executive functions.

Keywords. Virtual Reality, executive functions, Multiple Errands Test (MET), daily life tasks, NeuroVR

1. Deficits in Executive Functions and the Virtual Multiple Errands Test

Deficits in executive functions [1, 2] have, as the most common causes, neurological conditions including frontal lobe damage due to traumatic brain injury, pervasive central nervous system (CNS) damage such as stroke [3] and those with specific pathologies such as Parkinson's disease (PD). The assessment of executive deficits is traditionally performed through paper and pencil tasks such as the Stroop Test, the Wisconsin Card Sorting Test (WCST), the Tower of London test (TOL), the Progressive Matrices and Elithorn's Labyrinth, but there are also tools which represent

[1] Corresponding Author: Simona Raspelli, Applied Technology for Neuropsychology Laboratory, Istituto Auxologico Italiano, Milano; E-mail: s.raspelli@auxologico.it.

situations which similar to daily life tasks, such as the Behavioral Assessment of Dysexecutive Syndrome, the Dysexecutive Questionnaire (BADS & DEX) [4] and the *Multiple Errands Test (MET)* [2]. The MET is an assessment of executive functions in daily life originally developed by Shallice and Burgess specifically for use with high functioning patients and adapted into the simple version [5] and the hospital version [6]. It is performed at a real shopping mall or in a hospital environment and involves the completion of various tasks of different complexity levels (e.g. buy a small brown loaf of bread as compared to discovering a currency exchange rate), rules to adhere to and a specified time frame. After the tasks and the rules have been explained, patients are able to plan and choose the sequence of actions needed to complete the tasks. The executive functions stimulated are numerous, from the ability to plan a sequence of actions, to problem solving, to cognitive and behavioral flexibility. The tester follows the participant, recording different kinds of mistakes. It is a "real-life" multitasking test requiring the execution of very common daily actions, and so, it has good ecological validity [7], as well as good psychometric properties [8]. The assessment of executive functions in real-life settings has the advantage of giving a more accurate estimate of the patient's deficits than is possible within laboratory conditions [9], but it is also time-consuming since patients must be taken to the setting where the assessment will be carried out and should be able to walk independently in order to perform the assessment [10]. For this reason, the use of *simulated environments*, perceived by the user as comparable to real world objects and situations, can overcome the limits of the traditional MET, by maintaining its several advantages [11]. In addition to a first version of the Virtual Multiple Errands Test (VMET) developed by Rand, Rukan, Weiss and Katz [9] as an assessment tool for executive functions within the Virtual Mall (VMall) developed by Weiss et al. in 2004, we developed another VR-based MET using the NeuroVR software, a free VR platform based on open-source software.

Figure 1. A screenshot of the virtual supermarket

2. Method

The MET procedure was modified according to the structure and the features of the system involved in the study. In particular, subjects were instructed to buy items following a defined shopping list and to obtain information (e.g., the closing time of the supermarket) following specific rules (e.g., not to go into the same aisle more than once). While completing the MET procedure, specific variables were measured as the outcome measures: the *time of execution*, *total errors*, *inefficiencies*, *rule breaks*, *strategies*, *interpretation failures* and *partial tasks failures* (e.g., maintained sequence of the task, self corrected upon errors made during the task, no evidence of perseveration or sustained attention throughout the sequence of the task).

The virtual environments employed in the study present two different scenarios: a food market, for the training in navigation and of object selection and a supermarket, which is larger and more complex, for the experimental phase. The subject-environment interaction was based on semi-immersion (scenes were visualized on a 15-inch PC screen) and objects were selected using a wireless joy-pad.

A total of 15 participants in three groups were included in the study, including five post-stroke individuals and 10 healthy people in two age groups. The *five stroke participants* ranged in age from 50-70 years old (mean age=59.60 years, std.dev=9.236; mean number of school years=12 years, std.dev.=4.18; MMSE=28.17, std.dev.=1.39). In addition, *10 healthy participants* volunteered to participate in this study including *five young* participants with an age range between 20-30 years old (mean age=26, std.dev=2.12; mean number of school years=17.40, std.dev.=1.34; MMSE=30, std.dev.=.00) and *five older participants* with an age range between 50-70 years old (mean age=56.40 years, std.dev=4.93; mean number of school years=13 years, std.dev.=.00; MMSE=28.69, std.dev.=.67). All groups were fully independent in activities of daily living and instrumental activities of daily living. The stroke participants were recruited from the Stroke Unit of Istituto Auxologico Italiano and were selected according to the severity of impairment. The ethics committee approved the study and all participants signed informed consent forms. Patients were excluded from the study based on severe cognitive impairment (MMSE<19), severe motor impairment (Barthel index [cut-off≥45/100], Stroke scale and the National Institute of Health Stroke Scale (NIHSS), auditory language comprehension difficulties (Token Test within the Brief Neuropsychological Examination, Token Test<26,5), object recognition impairments (Street Completion Test<2,25), spatial hemi-inattention and neglect, as assessed by the Star Cancellation Test within the Behavioral Inattention Test, excessive state and trait anxiety (State and Trait Anxiety Index>40) and excessive depression state (Beck Depression Inventory>16). Besides the VMET, participants also underwent an exhaustive neuropsychological assessment with the aim to obtain an accurate overview of their cognitive functioning in order to be compared with the performance on the experimental test. In particular, the following neuropsychological tests were employed: the Brief Neuropsychological Examination (ENB) and the Test of Everyday Attention (TEA), Stroop Test, Iowa Gambling Task and Dysexecutive Questionnaire (DEX) to assess different executive functions.

3. Results

Data analyses were carried out using SPSS for Windows, version 17.0. Due to the small group sample size non-parametric statistics were used, specifically, Pearson correlation coefficients to examine the relationships between the various scores of the neuropsychological tests employed to assess executive functions and the outcome measures of the VMET for each group separately, while the Kruskal-Wallis procedure was used for the comparison of the scores of the same tests between the post-stroke participants and both groups of healthy controls.

The main correlations between neuropsychological tests and the variables of the VMET emerged in each group of participants are provided in the following tables.

Table 1. Correlations for patients.

	Time (VMET) *r*	*p*	Total errors (VMET) *r*	p	Rule Breaks (VMET) r	p
Attention shift test (TEA)	.90	.037	.96**	.00		
Incompatibility test (TEA)			-.95	.014		
Go/NoGo test (TEA)					.90	.037
DEX					-.99	.00

Table 2. Correlations for adult control group.

	Inefficiencies (VMET) *r*	*p*	Interpretation errors (VMET) *r*	p	Strategies (VMET) r	p	Rule breaks (VMET) r	p	Time (VMET) r	p
Disadvantageous deck (IGT)	.947	.014								
Incompatibility test (TEA)			-.889	.044						
Visual exploration (TEA)					1	.00				
Go/NoGo test (TEA)							.975	.005		
Interference Test Stroop									.900	.032

Table 3. Correlations for young control group.

	Time (VMET) *r*	*p*	Interpretation errors (VMET) *r*	p	Inefficiencies (VMET) r	p	Rule breaks (VMET) r	p	Strategies (VMET) r	p
Exploration test (TEA)	.90	.037								
Divided attention test (TEA)			-.89	.044						
Sustained attention test (TEA)					.895	.040				
Working memory (TEA)							.894	.041		
Visual exploration (TEA)									1	.000

Table 4. Kruskal-Wallis and Mann-Whitney tests.

	Kruskal-Wallis H Chi-square (p)		Mann-Whitney
Time (V-MET)	6.080	(.048)	Patients < Adults < Youngs
Inefficiencies (V-MET)	6.395	(.041)	Youngs < Adults < Patients
Rule breaks (V-MET)	5.862	(.05)	Youngs < Adults < Patients
Mean Intermodal Comparison (TEA)	7.220	(.027)	Patients < Adults < Youngs
Mean Flexibility (TEA)	11.06	(.004)	Patients < Adults < Youngs
Mean Spatial Incompatibility (TEA)	7.233	(.027)	Patients < Adults < Youngs

According to the Kruskal-Wallis and Mann-Whitney tests, Table 4 shows main results.

4. Discussion and Conclusions

The ecological validity of the VMET has been demonstrated by significant correlations between the VMET and some tests employed for the measurement of executive functions within the experimental groups. For example, correlations with the Test of Everyday Attention or for patients, the correlation between rule breaks in the VMET and the Dysexecutive Questionnaire (DEX). As for the adult control group, other important results were correlations with the Stroop Test and the Iowa Gambling Task. The lack of correlation between the VMET and the Stroop Test in patients and young control groups could be interpreted as referring to the fact that VMET protocol has no conflicting tasks: perhaps, adding announcements in the supermarket which interrupt the main task. Finally, significant differences among groups emerged from the Kruskal-Wallis procedure. The direction of these differences was as expected: for example, patients are less efficient and commit a higher number of rule breaks than the other two groups.

Concerning possible conclusions, results support the ecological validity of the VMET as an assessment tool of executive functions. Moreover, it was able to differentiate between two age groups of healthy participants and between healthy and post-stroke participants, thus demonstrating that it is sensitive to brain injury and aging. However, further psychometric data on temporal stability are needed, and further research using the VMET as an assessment tool with larger groups and use in additional populations is also recommended.

Acknowledgments

The work in preparing this paper was supported by the project "Immersive Virtual Telepresence (IVT) for Experiential Assessment and Rehabilitation", IVT2010, RBIN04BC5C.

References

[1] Burgess, P. W., Veitch, E., Costello, A., & Shallice, T. (2000). The cognitive and neuroanatomical correlates of multitasking. *Neuropsychologia, 38,* 848–863.

[2] Shallice, T., & Burgess, P. W. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain, 114*, 727-741.

[3] Baddeley, A. D., & Wilson, B. (1988). Frontal amnesia and the dysexecutive syndrome. *Brain and Cognition, 7*, 212–230.

[4] Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., & Evans, J. J. (1996). *Behavioural assessment of the dysexecutive syndrome*. London: Harcourt Assessment.

[5] Alderman, N., Burgess, P. W., Knight, C., & Henman, C. (2003). Ecological validity of a simplified version of the multiple errands shopping test. *Journal of the International Neuropsychological Society, 9*, 31– 44.

[6] Knight, C., Alderman, N., & Burgess, P. W. (2002). Development of a simplified version of the multiple errands test for use in hospital settings. *Neuropsychological Rehabilitation, 12*, 231–255.

[7] Burgess, P. W., Alderman, N., Forbes, C., Costello, A., Coates, L. M. A., Dawson, D. R., Anderson, N. D., Gilbert, S. J., Dumontheil, I., & Channon, S. (2006). The case for the development and use of

"ecologically valid" measures of executive function in experimental and clinical neuropsychology. *Journal of the International Neuropsychological Society, 12,* 194–209.

[8] McKinlay, A., Kaller, C. P., Grace, R. C., Dalrymple-Alford, J. C., Anderson, T. J., Fink, J., & Roger, D. (2008). Planning in Parkinson's disease: a matter of problem structure? *Neuropsychologia, 46*, 384-389.

[9] Rand, D., Weiss, P. L. (T.), & Katz, N. (2009).Training multitasking in a virtual supermarket: A novel intervention after stroke. *American Journal of Occupational Therapy, 63*, 535–542.

[10] Fortin, S., Godbout, L., & Braun, C. M. J. (2003). Cognitive structure of executive deficits in frontal lesioned head trauma patients performing activities of daily living. *Cortex, 39*, 273-291.

[11] Rizzo, A. A., & Kim, G. (2005). A SWOT analysis of the field of virtual rehabilitation and therapy. *Presence, 14*, 1-2.

[12] Nys, G. M. S., van Zandvoort, M. J. E., de Kort, P. L. M., Jansen, B. P. W., de Haan, E. H. F., & Kappelle, L. J. (2007). Cognitive disorders in acute stroke: prevalence and clinical determinants. Cerebrovascular disease, 23, 408-416.

[13] Mc. Dowd, J. M., Filion, D. L., Pohl, P. S., Richards, L. G., & Stiers, W. (2003). Attentional abilities and functional outcomes following stroke. *Journal of Gerontology, 58,* 45-53.