

Impact of Distractors on Executive Control in Older Adults: Construct-Driven and Function-Led Approaches to Neuropsychological Assessment

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Abstract. Whilst virtual environment-based neuropsychological assessments have been presented as potential aides in enhancing ecological validity, many were modelled on construct-driven approaches found in traditional assessments. Recently, neuropsychologists have been arguing for a new generation of function-led neuropsychological assessments that are developed from directly observable everyday behaviors. In the current project, we review findings from both construct-driven and function-led VE-based neuropsychological assessments of cognitive functions in 45 undergraduate students (mean age: 19.96; SD: 2.85) and 40 older adults (mean age: 75.56; SD = 7.43). For the construct-driven assessment, we used a Virtual Apartment with an embedded bimodal Stroop task that included distraction and no distraction conditions. For the function-led assessment, we used a Virtual Multiple Errands Test, wherein participants were immersed in a virtual grocery store and asked to carry out various tasks. Findings suggest that virtual reality-based construct-driven and function-led neuropsychological assessments appear to have potential for increased ecological validity using a virtual environment with real world distractors.

Keywords. Neuropsychology, Virtual Reality, Ecological Validity, Aging

1. Introduction

Laboratory-based neuropsychological studies of relationships between various cognitive constructs and functional abilities in aging populations suggests that there are many factors that contribute to functional decline, including memory [1] and executive functioning [2]. Distracting stimuli may hinder attention by increasing perceptual and cognitive load, limiting ability to perform important cognitive processes [3]. As individuals age, their attentional control may be more affected by distraction [4].

Researchers interested in ecological validity argue that lab-based assessments are not ecologically valid and fail to assess the impact of distractors on everyday activities in the real world. The issue of ecological validity in neuropsychological assessment has

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been expressed a number of times over the years via discussions of the limitations of generalizing sterile laboratory findings to the processes normally occurring in people's everyday lives. Some researchers have countered these arguments with the claim that the ecological approach lacks the internal validity and experimental control needed for scientific progress.

One methodology that has potential for a laboratory and everyday functioning rapprochement is virtual reality. Virtual environments (VE) are increasingly considered as potential aids in enhancing the ecological validity of neuropsychological assessments [5]. Given that VEs represent a special case of computerized neuropsychological assessment devices they have enhanced computational capacities for administration efficiency, stimulus presentation, automated logging of responses, and data analytic processing. Since VEs allow for precise presentation and control of dynamic perceptual stimuli, they can provide ecologically valid assessments that combine the control and rigor of laboratory measures with a simulation that reflects real life situations. Additionally, the enhanced computational power allows for increased accuracy in the 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 three-dimensional objects are presented in a consistent and precise manner [6].

2. Construct Driven Virtual Environments

A number of virtual environments have been developed that superimpose construct-driven stimuli (e.g., Stroop; Go/No-go) upon some aspect of the environment. These tests are adaptations of conceptual and experimental frameworks found in traditional neuropsychological assessments. For example, the ClinicaVR Virtual Apartment (Digital Media Works) superimposes construct-driven stimuli (e.g., Stroop; continuous performance task) onto a large television set in the living room. The ClinicaVR Virtual Apartment (Digital Media Works) Stroop has been found to be capable of eliciting the Stroop effect with bimodal stimuli. Moreover, the ClinicaVR Virtual Apartment (Digital Media Works) Stroop has been found to be significantly correlated with other neuropsychological measures of attention [7]. Results from regression analyses indicated that commission errors and variability of reaction times in the ClinicaVR Virtual Apartment (Digital Media Works) Stroop were significantly predicted by scores of the Elevator task and the CPT-II. These preliminary results suggest that the ClinicaVR Virtual Apartment (Digital Media Works) Stroop has potential as a clinically useful measure of cognitive and motor inhibition for adults.

3. Function Led Virtual Environments

In the past decade a number of virtual environments with enhanced graphics (and usability) have been developed to model a function-led approach to neuropsychological assessment. The "function-led approach" to creating neuropsychological assessments includes neuropsychological models that proceed from directly observable everyday behaviors backward to examine the ways in which a sequence of actions leads to a given behavior in normal functioning; and the ways in which that behavior might

become disrupted [5; 7]. For example, the Virtual Environment Grocery Store [8] offers an advanced computer interface that allows the clinician to immerse the patient within a computer-generated simulation that reflects activities of daily living. While in the Virtual Environment Grocery Store, the participant takes part in a number of errands that must be completed following certain rules that require problem solving. Since the Virtual Environment Grocery Store allows for precise presentation and control of dynamic perceptual stimuli, it has the potential to provide ecologically valid assessments that combine the control of laboratory measures within simulations that reflect real life situations.

4. Research protocol and preliminary results

In the current project, we review findings from both construct-driven and function-led VE-based neuropsychological assessments of cognitive functions. We compare performance of older adults on virtual environment-based assessments of memory and executive functioning with that of college-age adults.

4.1. Participants and procedure

Participants: The participant sample included 45 undergraduate students (mean age: 19.96; SD: 2.85) recruited from a pool of undergraduate students in psychology at the University of North Texas; and 40 older adults (mean age: 75.56; SD = 7.43) recruited from independent living retirement communities. Exclusion criteria included history of neurological illness, physical, or psychiatric disorder that might impair performance.

Procedure. This study was approved by the university Institutional Review Board, and informed consent was received from all participants before beginning the study. For the construct-driven assessment, we used the ClinicaVR Virtual Apartment (Digital Media Works) with an embedded bimodal Stroop task that included distraction and no distraction conditions. The ClinicaVR Virtual Apartment (Digital Media Works) presents Stroop stimuli on a display within a virtual apartment as colors are spoken aloud.



Figure 1. ClinicaVR Virtual Apartment (Digital Media Works) Stroop Task

Participants respond to congruent verbal and visual cues—replicating conditions of the traditional paper-and-pencil Stroop. Each section of the Virtual Apartment Stroop task is performed with and without visual, auditory, and visuo-auditory distractors.

For the function-led assessment, we used the Virtual Environment Grocery Store, wherein participants were immersed in a virtual grocery store and asked to carry out various tasks (see Figure 2).



Figure 2. Virtual Environment Grocery Store

After completing the virtual shopping task, participants were asked to recall the items shopped for using free recall and cued recall methods. Fifteen minutes following the completion of the short-delay recall, with a distractor task in between, participants were assessed via long delay free and cued recall.

4.2. Results

Repeated-measures ANOVAs were performed to examine the effects of distracting stimuli on each sample. The aging sample was significantly impacted by distractors, as evidenced by higher distraction condition response times for color-naming ($F = 11.492$, $p < .005$), word-reading ($F = 6.017$, $p < .05$), and interference ($F = 15.896$, $p < .001$) conditions (see Figure 3).

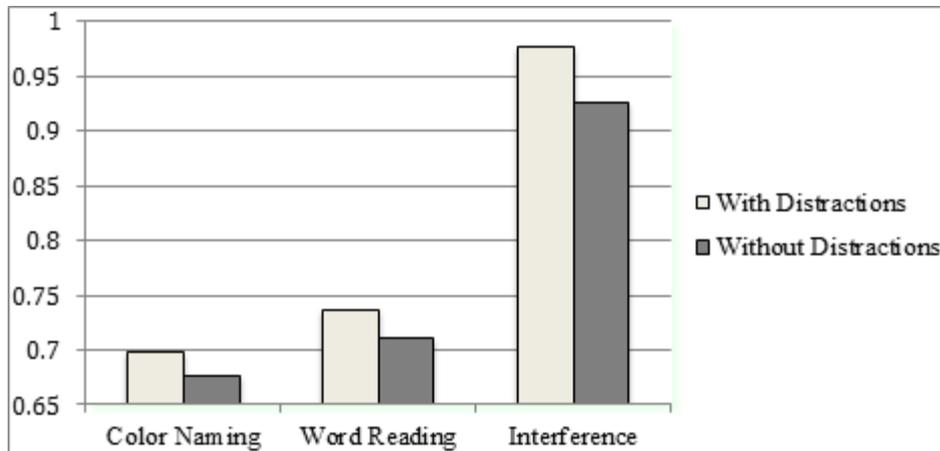


Figure 3. Aging Sample Response Times on the Virtual Apartment Stroop

The college-aged sample was less affected by distractors, only showing higher distraction response times in the color-naming condition ($F = 8.506, p < .01$; see Figure 4).

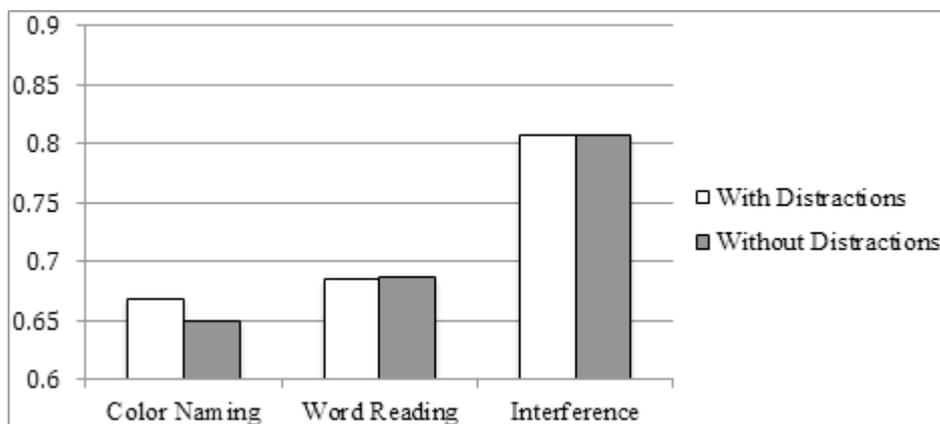


Figure 4. College-Aged Sample Response Times on the Virtual Apartment Stroop

Results of function-led assessment revealed significant differences (favoring younger adults) for all aspects of the evaluation. Specifically, older aged individuals were more vulnerable to external disturbance (e.g., ambient noise and distractors in a virtual environment) than younger age controls. Results of one-way ANOVAs reveal significant differences (favoring younger adults) for short-delay free recall ($F(1, 100) = 36.67, p < 0.001$); short-delay cued recall ($F(1, 100) = 21.06, p < 0.001$); long-delay free recall ($F(1, 100) = 31.24, p < 0.001$); and long-delay cued recall ($F(1, 100) = 24.16, p < 0.001$).

5. Conclusions

Virtual environments provide a unique opportunity to study memory and executive functioning within an ecologically valid environment. Our findings indicate that memory and executive functioning in older aged individuals may be more vulnerable to external disturbance (e.g., ambient noise and distractors in a virtual environment) than younger age controls.

Performances on both a construct-driven ClinicaVR Virtual Apartment (Digital Media Works) Stroop task and a Virtual Environment Grocery Store revealed that geriatric individuals were more impacted than a college-aged sample by distractors. The potential for increased ecological validity using a virtual environment with real world distractors supports the notion that these results may generalize to the day-to-day lives of aging persons, indicating this cohort may have decreased attention when confronted by distractions.

Whilst the results from the comparison between an older age cohort and a college cohort revealed significant differences, these findings need to be compared to well standardized neuropsychological assessments. For now, these findings suggest that the virtual reality based shopping task may offer a platform for assessing cognitive performance in an environment that represents everyday functioning

In conclusion, the use of virtual reality-based construct-driven and function-led neuropsychological assessments appears to have potential for increased ecological validity using a virtual environment with real world distractors.

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