Assessment of cognitive and functional performance using a Virtual Environment Grocery Store with environmental distractors

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Abstract. Distractions found in everyday life can disrupt activities of daily living in older adults. The conflicting evidence related to aging participants’ reports of everyday memory functioning and results from traditional paper-and-pencil memory assessments may reflect the limited ecological validity of traditional assessments. The Virtual Environment Grocery Store (VEGS) offers a virtual environment for neuropsychological assessment of episodic memory with real world distractors. This study compares the impact of distractors on VEGS memory performance between 19 older adults and 25 young adults. Results revealed that the older aged group performed significantly worse than the younger aged group on all measures of episodic memory. Moreover, the older aged group performed significantly worse than the younger aged group on prospective memory and all measures of everyday shopping activities. The findings suggest that the VEGS offers a virtual reality-based neuropsychological assessment that can be useful for differentiating between age groups.

Keywords. Aging, episodic memory, neuropsychological tests, virtual reality

1. Introduction

Distractions found in everyday life can disrupt activities of daily living in older adults [1, 2]. It is important that neuropsychologists understand the increased impact of distractors on older aged cohorts so that they can make predictions about their patients’ abilities to perform everyday activities. Assessments are needed that can measure the impact of everyday distractors on recall of information (e.g., episodic memory) and planned activities (e.g., prospective memory) in aging cohorts. Everyday activities often involve the concurrent performance of distinguishable tasks. Episodic and prospective memory capacities are significant features of everyday memory that impact everyday activities. Episodic memory includes storing and recall of particular events or experiences associated with explicit times and places. Prospective memory includes memory for intentions like remembering to go to a coupon machine at a certain time (time-based prospective memory) or remember to listen for one’s prescription (event-based prospective memory) while shopping for items learned earlier (episodic memory). Consequently, episodic and prospective memory make up central components involved in the execution of daily activities.

Most episodic memory measures include free recall, cued recall, and recognition

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tasks. While traditional neuropsychological assessments of memory like the California Verbal Learning Test (CVLT) are considered “gold standard” measures, evidence suggests that performance on these measures may not represent everyday memory complaints [3]. Moreover, correlations between participants’ subjective memory reports and objective results on paper-and-pencil memory measures suggest limited ecological validity [4]. This may be due to the fact that while subject reports reflect everyday activities that can be filled with various distractions, objective tests (e.g., CVLT) are delivered in sterile laboratory environments with little to no distractions.

The Virtual Environment Grocery Store (VEGS) has been developed to offer a virtual reality-based neuropsychological assessment that taps into several neurocognitive, affective, and social domains. The VEGS Memory Module includes several neuropsychological tests for assessing episodic and prospective memory. While immersed in the VEGS, participants navigate throughout the virtual shopping environment and perform various tasks. Participants navigate to the pharmacy, drop off a prescription with a virtual pharmacist, receive a number, and must remember to listen for that number (ignoring distractions like other numbers; announcements over the public-address system; and virtual humans), while remembering to shop for items that were learned earlier. Participants also must remember to go to the coupon machine after two minutes (time-based prospective memory). In addition to these focused memory tasks, the participants are also scored on additional tasks, including: Navigation: Navigate through VEGS via specified routes through the aisles; List Items: Find and select items from the shopping list; Intrusions: Items that were not on the shopping list are to be ignored; Budget Score: Select items in a manner that maintains a predetermined budget. When the participant hears their number over the public-address system, they are to return to the pharmacist to pick up their prescription (event-based prospective memory). At the completion of the VEGS, the participant performs delayed free (VEGS LDFR) and cued recall (VEGS LDCR) of the VEGS shopping items.

Parsons and McMahan [5] explored the construct validity of the VEGS via comparison of traditional neuropsychological measures of memory and executive functioning with both low distraction and high distractions conditions of the VEGS. Performances on the VEGS memory tasks in the low distraction condition and the traditional neuropsychological assessments of memory were positively correlated, indicating that memory for VEGS content was similar to memory for traditional paper-and-pencil measures. Comparison of performances on the VEGS memory tasks in a high distraction condition also revealed significant correlations with the traditional neuropsychological assessments of memory, indicating that memory for VEGS content was similar to memory for traditional paper-and-pencil measures. The addition of distractors resulted in significant correlations with traditional measures of inhibitory control. In another validation study of the VEGS, Parsons and Barnett [6] found performances on the VEGS memory tasks and the traditional neuropsychological assessments of memory were positively correlated, indicating that memory for VEGS content was similar to memory for traditional paper-and-pencil measures. In the low distractor condition, older adults performed significantly worse than young adults on the VEGS and the CVLT. The executive functioning measure (Stroop task) failed to differentiate the groups. In the current study, we were interested in seeing if the addition of distractors into the VEGS would significantly differentiate between younger and older-aged cohorts on VEGS-based measures of episodic memory; prospective memory; and everyday shopping activities.

2. Methods

To compare the performance of younger and older age cohorts on an episodic memory task with real world distractors, a newly developed virtual reality measure of memory, the VEGS, was administered to 19 older adults and 25 young adults.

2.1. Participants

The University’s Institutional Review Board approved the study. Participants included 19 community dwelling older adults (Mean Age = 77.05; Standard Deviation = 7.12;
Mean Education 15.89 years; Standard Deviation = 1.49; Mean Full Scale IQ = 107.58; Standard Deviation = 7.19 and 25 young adults (Mean Age = 21.08; Standard Deviation = 4.81; Mean Education 14.92 years; Standard Deviation = 2.76; Mean Full Scale IQ = 103.52; Standard Deviation = 8.82). Older adults were recruited via flyers at independent living retirement communities in the southwestern United States. Young adults were recruited through a research website and received course credit. No significant differences were found for gender, IQ, or education. Following informed consent, basic demographic information was recorded. A medical health history logged any mental or physical disorders that may have hindered their performance. No participants were excluded for responses given on this form.

2.2. Design and measures

The VEGS was run on the Windows 10 operating system of a high technology computer (HTC) with an Intel Core i7 (16GB RAM) and an NVIDIA GeForce GTX 1060. The HTC Vive head-mounted display was used. The HTC Vive uses an organic light-emitting diode (OLED) display with a resolution of 2160 × 1200 and a refresh rate of 90 Hz. The participant’s head position was tracked with embedded inertial measurement units while the external Lighthouse tracking system cleared the common tracking drift with a 60 Hz update rate. The VEGS includes a number of cognitive memory (episodic and prospective memory) tasks. Before the participant was immersed in the VEGS, they took part in a learning task (encoding phase) and a familiarization task. Immediate recall performance was recorded verbatim by a microphone and was logged for each of the immediate recall trials (Trials 1–3). Following the encoding and familiarization phases, the participant was informed that they were going to need to drop off a prescription once the VEGS protocol starts. They were also told that they needed to remember to go to the coupon machine after two minutes of shopping (VEGS Time-Based Prospective Memory). Furthermore, they were instructed that after they dropped off their prescription, they were to shop for items from the list that they learned earlier. After 10 min, the virtual pharmacist announced the participant’s prescription number. At that time, the participant needed to return to the virtual pharmacist and clicked on her to end the simulation (VEGS Event-based Prospective Memory score). At the completion of the VEGS, the participant was asked to perform free (VEGS Long Delay Free Recall) and cued delayed recall (Long Delay Cued Recall).

The movement of the VEGS from a low distraction condition with ambient noise and no customers in the virtual environment to a high distraction condition involved populating the virtual store with an additional 20 virtual human avatars that walked around in the environment (see Figure 1). Some virtual human avatars walked throughout the store, while others stood in lines at the checkout counter and at the pharmacy. Other avatars spoke to each other in small groups of two and still others spoke on virtual phones as they ignored the participant. The environment also included a crying baby avatar. In addition to the avatar distractions, there were increased audio distractors: announcements given over the public-access system; human laughter; coughing; dropped merchandise; baby crying; and various ring tones on cellphones.
2.3 Data Analytics

All data were analyzed using SAS version 9.1. Descriptive statistics were calculated for participant demographics and for results of the VEGS-based neuropsychological tests. Missing data were imputed by either mean substitution or last case carried forward. Analyses of variance were completed to assess group differences.

2.4 Results

For all VEGS-based tasks the older aged cohort performed worse than the younger aged cohort. Results were consistent with findings from Parsons and Barnett [6] that the VEGS is able to differentiate between younger and older cohort performances on memory and shopping tasks. The large differences between the two different age cohorts on memory measures with a high level of distractors supports the generalization of findings from Parsons and McMahan’s [5] study with younger aged participants. Analysis of variance between younger and older-aged cohorts on VEGS measures of episodic memory (e.g., recall of shopping list items) revealed that the older aged group performed significantly worse than the younger aged group on all measures of episodic memory: VEGS Short Delay Free Recall (F = 25.28; p < .001); Long Delay Free Recall (F = 17.46; p < .001); Long Delay Cued Recall (F = 9.76; p = 003). Analyses of variance between younger and older-aged cohorts on VEGS measures of prospective memory (e.g., remembering to go to the coupon machine at a certain time and to listen for prescription number) revealed that the older aged group performed significantly worse than the younger aged group on prospective memory (time-based: F = 9.34; p = 004; and event-based: F = 37.81; p < .001). Analyses of variance between younger and older-aged cohorts on VEGS measures of everyday activities (e.g., shopping, maintaining a budget) revealed that the older aged group performed significantly worse than the younger aged group on all measures of everyday shopping activities: number of times looked at shopping list (F = 20.41; p < .001) and Shopping List Items Picked Up (F = 4.10; p < .05).

3. Discussion

In summary, participants were able to tolerate the virtual environment and participants endorsed comfort with the environment. There were no reports of nausea/discomfort. Moreover, additional distractors in the VEGS condition resulted in the older aged group performing significantly worse than the younger group on all measures of episodic memory, prospective memory, and everyday shopping activities. These findings replicate the VEGS-based performance differences (relative to high versus low distractions) for younger adults to the older adults found in this study. [5] These results extend findings from an older aged study using only the low distraction condition [6] to reveal even greater differences for older adults placed in a high distraction condition of
the VEGS. The VEGS has the advantage over traditional measures of providing objective measurement of individual components of memory in simulations of everyday activities that include everyday distractors. While traditional paper-and-pencil assessments are performed in sterile laboratory environments, the VEGS assesses episodic memory and in the presence of real-world distractors. Moreover, the findings suggest that there are significant differences between groups on all measures. This suggests that the VEGS is sensitive to age related differences in memory performance. The results support the potential of virtual environments for enhanced assessment of everyday activities [7, 8].

References