Aging Naturally: Virtual reality nature vs real-world nature's effects on executive functioning and stress recovery in older adults

Sara LoTemplio, PhD[1]; Sharde Johnson[1], Micaela Rice[1], Rachel Masters[1], Sara-Ashley Collins[1], Joshua Hoefecker[1], Jordan Rivera[1], Dylan Schreiber[1], Victoria Interrante, PhD[2], Francisco Ortega, PhD[1], Deana Davalos, PhD[1]

[1]Colorado State University, [2]University of Minnesota

2024 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW) | 979-8-3503-7449-0/24/$31.00 ©2024 IEEE | DOI: 10.1109/VRW62533.2024.00327

Abstract

Development of Alzheimer's Dementia & other related dementias (ADRD) is characterized by decline in executive functioning (EF), and onset risk of ADRD is increased by stress. Previous work has shown that spending time in nature or virtual reality nature can improve EF and improve stress recovery in younger adults. Yet, little work has examined whether these benefits can extend to older adults. We examine how spending time in either nature or an equivalently designed virtual reality natural environment can affect EF and stress in older adults compared to a lab control condition.

Keywords: Virtual reality nature, attention restoration theory, stress recovery theory, forest bathing

1 Introduction

In recent years, the prevalence of cases associated with pathological aging and Alzheimer's disease and related dementias (ADRD) specifically, have increased, with 14% of those reaching the age of 65 meeting criteria for ADRD.[1] Currently, no known cure for ADRD exists. Therefore, identification of preventative measures to help individuals avoid ADRD and to age healthily are of the utmost importance. One of the first cognitive abilities to decline with ADRD is executive functioning (EF)—broadly defined as the ability to direct one's attention and inhibit behavior.[2] Perhaps unsurprisingly, having better EF abilities appears to be protective against cognitive decline of all forms.[3] Therefore, research has focused on targeted interventions that improve EF and reduce symptoms of cognitive decline. One such option is exposure to nature. Recent meta-analyses on younger adult populations have found that acute (less than 1 hour) exposure to nature improves all three core EF abilities: working memory, cognitive flexibility, and inhibition,[4] and improves mood/affect.[5] Meta-analyses also show that nature increases vagally mediated heartrate variability (HRV),[6] a measure of stress recovery that is linked to ADRD-related outcomes[7]. However, despite widespread evidence that nature exposure improves EF abilities and increases HRV/stress recovery in younger adults, there is currently **a lack of experimental research on how nature exposure specifically affects these outcomes in older adults**, highlighting a research gap.

In considering accessibility issues, not everyone can access real-world nature safely. Therefore, virtual reality nature (VR nature) might also be a useful substitute, particularly for older adults with disabilities or who live in long-term care. Indeed, research has found that younger adults who spend time in virtual natural environments experience increased HRV and improved EF.[8,9] While some direct comparison work indicates these VR effects are slightly lesser than real-world equivalents,[10] they may still be a viable option for people who cannot access nature. VR techniques with older adults are an established method of providing experiences and interventions to promote wellbeing.[11] There is even some evidence that VR nature interventions can improve self-reported outcomes in patients with dementia.[12] However, to our knowledge, no work has examined whether VR nature can improve EF, HRV, and stress in healthy older adults, before disease onset.

Therefore, the present study will examine how both acute nature and virtual reality (VR) nature exposure affects HRV, EF, and subjective mood and stress compared to an indoor do-nothing control (to control for repeated assessment).

2 Method

In the present study, our research team has collected data on how HRV, EF, and perceived stress may change in older adults in both real-world and VR nature environments compared to an indoor lab control. We collected data from 22 healthy older adults (55+) in three environmental conditions: VR nature (n = 8), real-world nature (n = 9), and lab control (n = 7). We assessed participants' EF, stress, and HRV before and after a 30-minute exposure to their assigned environment (see Figure 1).

VR Nature, Real-world Nature, and Control Conditions: The real world nature condition took place at CSU's Heritage Park Arboretum. We designed the VR nature environment to match Heritage Park as closely as possible, in order to understand if it could serve as an effective substitute. To design the VR nature condition, we used the Unreal Game Engine (version 5) and ran the experience on the Oculus Quest 3. For the Control comparison condition, participants sat in a windowless laboratory (Figure 1).

Measures: To assess HRV, we used Resting Sinus Arrythmia (RSA) and Root Mean Square of the Successive Differences (RMSSD), two measures that are thought to reflect parasympathetic vagal tone, specifically. To assess EF, we used the Trailmaking Test B as well as the Repeated Battery for the

Figure 1. Images of real-world nature (top left), the VR environment (top right), the lab condition (bottom left), and VR set up (bottom right)

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DOI 10.1109/VRW62533.2024.00327

Assessment of Neuropsychological Status (RBANS). The RBANS assesses various types of cognition, including measures thought to contribute to EF, such as working memory (e.g., Digit Span) and semantic fluency. We also assessed stress using the Perceived Stress Scale (PSS).

3 Results

For PSS, we found a significant interaction ($\chi2(2)=8.19$, $p = 0.02$) such that perceived stress only significantly decreased in the nature condition ($\beta = 1.00$, $SE = 0.33$, $t(21) = 3.03$, $p < .01$). For our HRV variables, RMSSD and RSA, we found no significant main effects or interactions, except for a main effect of condition in RSA ($\chi2(2)=8.15$, $p = 0.02$), such that RSA was significantly lower in the nature condition overall compared to VR nature ($\beta = -1.81$, $SE = 0.63$, $t(21) = -2.87$, $p = .02$). For Trailmaking Task B, there was a main effect of assessment ($\chi2(1)=7.24$, $p<.01$), such that all participants improved (reduced their time) from pre intervention to post intervention ($\beta = 11.1$, $SE = 4.06$, $t(21) = 2.72$, $p = .01$), but no interaction with condition. For the RBANS, there were no significant main effects or interactions (all ps $> .05$). We also examined two subscores of the RBANS: the Digit Span and Semantic Fluency. We found no significant main effects or interactions on Total Semantic Fluency Score (all ps $>.05$), however, on Digit Span Total Score, we found a significant effect of condition ($\chi2(2)=5.97$, $p = 0.02$), such that overall, Digit Span Score was higher in the VR condition than in the nature condition ($\beta = -2.15$, $SE = 0.88$, $t(21) = -2.433$, $p = .06$) only. Though not significant, note that Digit Span Score increased after VR nature exposure, and not real-world nature (see Figure 2).

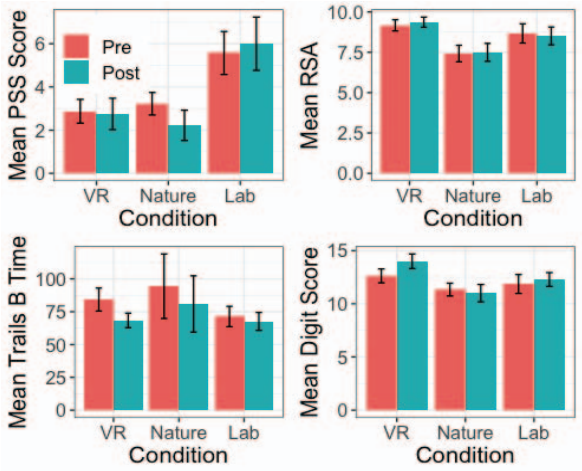

Figure 2. Results of VR, Real world, and lab environment on PSS, RSA, Trails B and Digit Score.

4 Conclusion

In summary, we find preliminary evidence that real-world nature reduces perceived stress in older adults more so than VR nature or control. However, puzzlingly, we see that VR nature appears to increase performance on Digit Score more than real-world nature. This suggests that VR nature could be a viable method to improve focus and cognitive performance in older adults. Perhaps most importantly, we were able to determine a **viable plan of action for testing older adults outdoors in real-world nature and develop a working VR environment that was designed to match the real-world environment**. However, future follow up work should be conducted to overcome the following limitations 1) our relatively small sample size 2) lack of outdoor control group 3) lack of baseline stress task. Results suggest that VR nature has potential for positive health effects, though further work is needed. This work was supported in part by NSF 2327569, NSF 2238313, and ONR N00014-21-1-2949

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