

EEG-based Biomarkers of Fear of Falling in Immersive VR Environments among Older Adults

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Introduction

Falls are a leading cause of injury, reduced mobility, and loss of independence, particularly among older adults [1]. Fear of falling (FoF) is both a psychological and behavioral factor that can significantly contribute to fall risk, often leading to activity avoidance, deconditioning, and increased vulnerability [2]. FoF is commonly assessed either via one-item question or Iconographical Falls Efficacy Scale (ICON-FES) that use pictures of daily activities combined with short captions and facial expression icons [3]. FoF has been reported as one of the important fall indicators. However, few studies have conducted on understanding FOF.

In this study, we aimed to investigate electroencephalogram (EEG) based biomarkers of FoF by inducing FoF in a virtual reality (VR) environment [4]. Through using VR, this study also aimed to evaluate whether VR platform can be used as a new tool for FoF assessment.

Methods

We first implemented 10 scenes in VR named VR-FES that describe daily tasks, that is, getting dressed in the morning (scene 0 in Figure 1), taking a bath in a bathtub (1), taking a shower (2), shopping in grocery store (3), going down stairs (4), walking in neighborhood (5), fetching things above head using a step ladder (6), fetching things above head using a wooden chair (7), social event (8), and climbing on a ladder to clean the gutter (9). These ten scenes were aligned with those described in the ICON-FES 10-item assessment and were played in VR headset in a fixed order. Following an audio instruction, each scene lasted for 15 seconds. Thereafter participants selected their level of concern on falling while imagining they are doing the activity.

In total, 21 participants (>60 years old) were recruited for the data collection to complete cognitive assessment (MoCA), EEG baseline recording with 5 minutes eyes-opened and 5 minutes eyes-closed, VR-FES task while standing, Icon-FES, and then another EEG baseline at the end. The order of conducting VR-FES and ICON-FES is randomized. An online form with several questionnaires (Eq-5D, IPAQ, fall history, GAD7, and PHQ9) was required to complete before session for each participant.

EEG was recorded from 64 scalp electrodes (BrainVision, actiCAP, 10–10 layout, 1000 Hz, FCz reference) during the standing VR-FES task. Recordings were band-pass filtered (0.1–45 Hz), cleaned with independent component analysis, and average-referenced; spectral power (theta, alpha, beta) over fronto-central, sensorimotor, and parietal regions and frontal alpha asymmetry were computed for each scene. Linear mixed-effects models related trial-level features to self-reported concern, including a within-subject term and a random intercept per participant.

Results

Analyses of 21 participants confirmed reliable extraction of scene-wise EEG features during the VR-FES task. Fronto-central beta-band power (13–30 Hz) was significantly modulated across the ten scenes (repeated-measures ANOVA, $p < 0.001$), with high-beta (19–24 Hz) showing a comparable pattern ($p = 0.02$); these features were highly reliable within participants (split-half reliability > 0.9).

Within-VR variation across the 10 ordered scenes

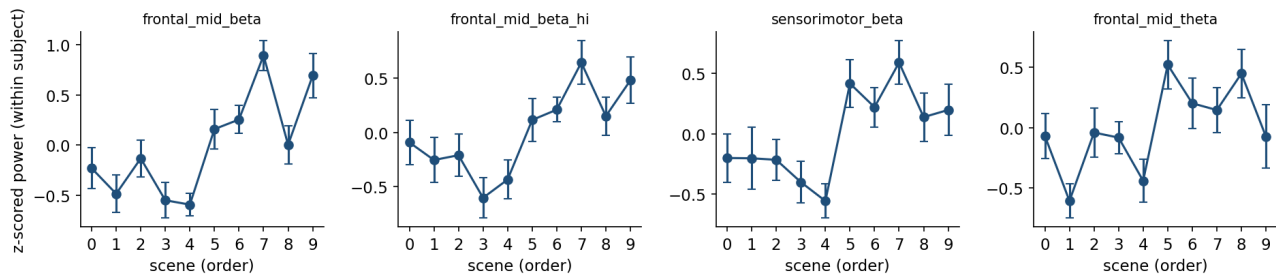


Figure 1. Scene-wise EEG features (mean $\pm$ 1std) during VR-FES among 21 participants. From scene 0 to scene 9: getting dressed in the morning (scene 0), taking a bath in a bathtub (1), taking a shower (2), shopping in grocery store (3), going down stairs (4), walking in neighborhood (5), fetching things above head using a step ladder (6), fetching things above head using a wooden chair (7), social event (8), and climbing on a ladder to clean the gutter (9).

Participants were identified as high-concern and low-concern groups based their total score in ICON-FES and VR-FES respectively (cut-off is >19). 20 out of 21 participants were identified as the same group in both ICON-FES and VR-FES.

Conclusions

Our findings indicate that EEG spectral features, particularly fronto-central beta power, are systematically modulated by VR scenes depicting daily activities of differing fall concerns, and can be reliably measured during immersive standing VR. Similar scores were achieved in ICON-FES and VR-FES indicating that VR platform can be used as a surrogate of ICON-FES. These results support immersive VR combined with EEG as a feasible platform for objective fear-of-falling assessment in older adults.

References

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