Spatial Auditory Soundscapes for Developing Digital Neurobiomarkers or Cognitive Interventions in Early-onset Dementia Based on EEG and fNIRS Machine-learning Analysis

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***Abstract*—The correlation between hearing loss and early-onset dementia is an increasingly significant research focus in digital neurobiomarkers. This presents an opportunity for earlier identification, treatment, and prevention. Our brains rely heavily on processing complex spatial soundscapes in our daily lives. As age-related neurodegenerative diseases first impact the auditory brain, they can serve as an early warning sign of hearing damage, presenting a window for early intervention. Our proposed study utilizes spatial auditory soundscapes as stimulation in a passive brain-computer interface (BCI) setup, with EEG and fNIRS neurophysiological monitoring methods. By analyzing objective neurophysiological signals through machine learning, we can progress beyond basic tonal assessments to examine the brain's role in auditory cognitive dysfunction, considering the significant connection between the brain and peripheral hearing organs in dementia. This research introduces real-world hearing assessments that extend beyond simple tone perception, developing innovative neurofeedback cognitive stress tests and interventions for early-onset dementia neurobiomarking.**

I. Introduction and Discussion

Recent advancements in reactive brain-computer interfacing (BCI) have demonstrated the potential to enhance brainwave responses through the use of spatial auditory [1] or stream segregation [2] paradigms. For instance, researchers have modified sound delivery in spatial auditory BCI to assess cognitive load from EEG responses [1]. Accurate auditory signal transduction during spatial hearing or speech perception depends on precise integration of spectral and temporal information [3], which could be simulated in controlled soundscapes as in the recently developed *Soundtope™ for well-being* application [4], [5]. In cases of early-onset dementia, the neural circuits responsible for higher-order cognition are likely damaged, leading to an early disruption of such processing [3]. To investigate this further, we suggest extending the application called *Soundtope™ for well-being* [4] by adding sound spatialization. This allows us to evaluate the auditory pathway of the subjects in various cognitively challenging situations to identify cognitive decline, or mental load, correlations in EEG and fNIRS brainwaves. While collecting the multimodal brainwave EEG and fNIRS recordings, participants listen to a spatial auditory soundscape in a passive BCI setup. We then analyze the recordings to infer cognitive scores and assess the potential for a mild cognitive impairment (MCI) digital neurobiomarker using machine-learning approaches developed previously [6]. The pilot study initially focuses on inferring attention levels in young and healthy subjects. The study will then be expanded to include elderly individuals, revealing the potential for developing early-onset objective dementia neurobiomarkers and subsequent hearing interventions.

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