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

Simon Kojima[1,2], Reiko Shiba[3,4], Yota Morimoto[5], Kiyoshi Furukawa[3], Shin'ichiro Kanoh[2], Tomasz Komendziński[6], Mihoko Otake-Matsuura[1], and Tomasz M. Rutkowski[1,6]

1. RIKEN Center for Advanced Intelligence Project (AIP), Tokyo, Japan
2. Shibaura Institute of Technology, Tokyo, Japan
3. Tokyo University of The Arts, Tokyo, Japan
4. RIKEN Center for Brain Science (CBS), Saitama, Japan
5. Waseda University, Tokyo, Japan
6. Nicolaus Copernicus University, Toruń, Poland

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.

Background & Objective

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 [1]. To investigate this further, we suggest extending the application called Soundtope™ for well-being [2,3] by adding sound spatialization. *Soundtope™ for well-being* is an application that can be operated by each individual to automatically compose music based on a model of natural phenomena [2,3]. 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. This pilot study 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.

Materials and Methods

Five healthy individuals (one female) with normal auditory function participated in the experiment. Two sessions were conducted for each subject, one in the morning and one in the evening.

During each session, participants were asked to create soundscapes they found comfortable using Soundtope with sound spatialization. EEG (8 channels) and fNIRS (8 channels) were measured during task execution. Additionally, cognitive assessments (task switching and memorability) were conducted at each session's end. Recorded EEG and fNIRS signals were analyzed using an ordinal partition network (OPN) approach [5].

Results and Discussions

From the EEG analysis of OPN-analysis-resulting numbers of edges and nodes, the soundscape mixing task (music versus nature) resulted in a significantly higher (p_r<0.05) number of edges in the second (evening) session. In the case of fNIRS for all the runs, the numbers of nodes and edges were significantly higher (p_r<0.05) number of edges in the second (evening) session.

These findings demonstrate the feasibility of estimating awareness and cognitive load levels of subjects actively controlling spatial auditory soundscapes using the OPN approach from neurophysiological signals but also suggest a promising direction for future research potential benefits of multimodal neurophysiological measurements in this context.

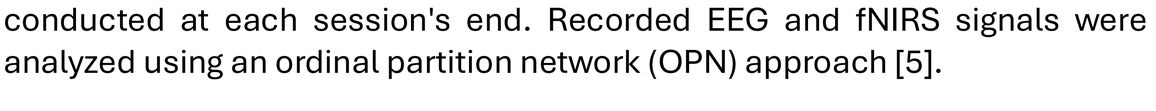

Figure 1. The touch-screen with Soundtope's control of soundscape and spatial settings.

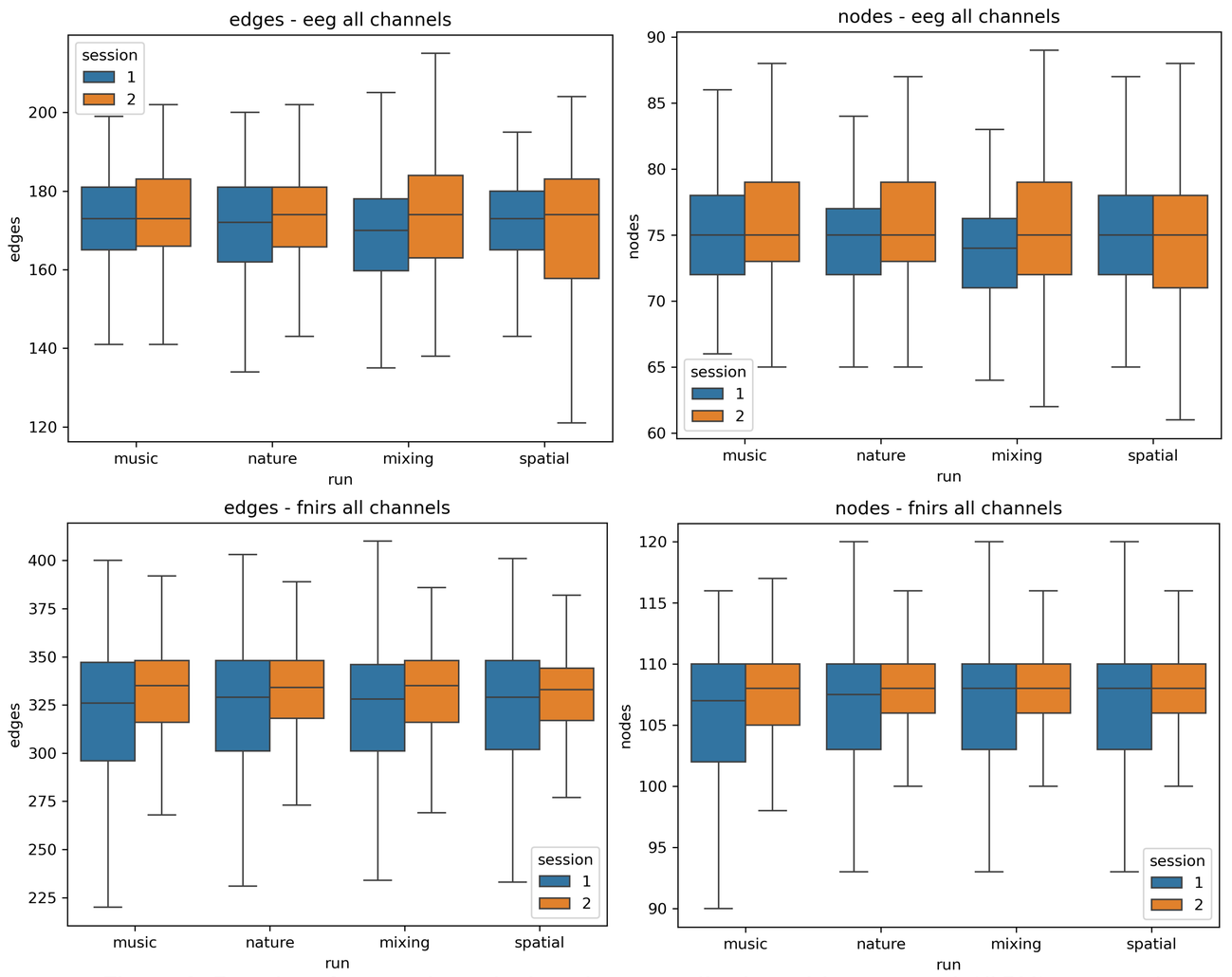

Figure 2. Results of network analysis using an ordinal partition network (OPN) approach.

Figure 3. Reaction times during cognitive assessment.

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Funding: This research has been partially supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI (grants JP22H04872 and JP22H00544) and the Japan Science and Technology Agency (grants JPMJCR20G1, JPMJPF2105, and JPMJMS2237).