# Comparative Analysis of Brainwave Activity In Visual Events: Insights from Scalp EEG Data and Ear-EEG during Walking

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## Introduction

Brain-Computer Interfaces (BCIs) are vital for aiding individuals with impairments, enabling communication and device control through decoding brain signals [1]. In BCI research, challenges persist in extracting features from dynamic EEG signals. [2]. Our study addresses these challenges by integrating scalp EEG and ear EEG recordings, especially during activities like walking. to enhance Event-Related Potential (ERP) classification in practical BCIs [3]-[6]. Building upon existing research, we analyze brain wave dynamics, comparing target and non-target events in scalp EEG, extending our analysis to walking conditions. Using advanced tools like Hermes and BCI Toolbox, we visualize and explore statistical differences. This research significantly contributes to advancing BCI technology, aiming to integrate BCIs more effectively into real-world environments[7].

# Materials and Methods

## Materials

Utilized EEG data, specifically Track #5 EEG(+Ear-EEG)-based ERP detection during walking, obtained from the Deep BCI Database, as a crucial component in our research investigation

## Dataset Description

The methodology involved a comparative analysis of brainwave activity, focusing on Target ('000') and Non-Target ('XXX') events in scalp EEG data. Hermes application for GC (Granger Causality) and PSI(Phase Slope Index) values, dimension reduction, and T-tests on a masked GC and PSI dataset were employed. The study also compared conditions across datasets and conducted network analysis using the BCI Toolbox, revealing significant findings in brainwave activity and networks.

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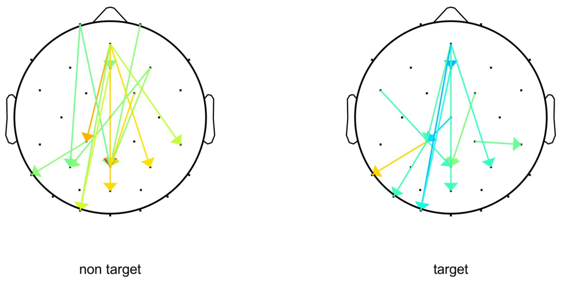
The second study phase utilized Ear-EEG with 14 channels, comparing Rest and Stimulus periods. The hypothesis proposed reduced auditory cortex sensitivity to visual stimuli during activity. Statistical analysis with the PSI metric explored changes in auditory responsiveness between pre-stimulus and stimulus presentation states, emphasizing the impact of visual stimuli on auditory processing.

# Results

### Experiment 1: A Comparative Study between Target ('OOO') and Non-Target ('XXX')



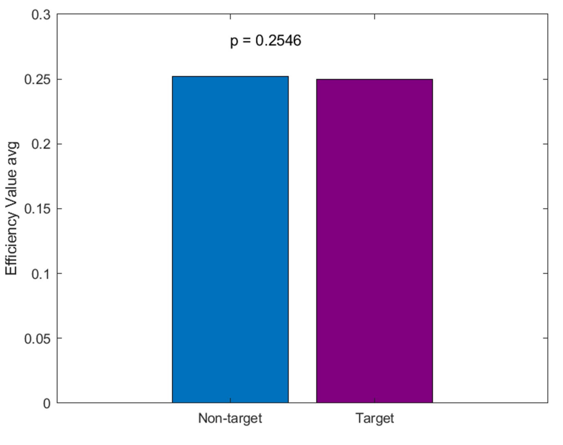




*figure 1-a. granger causality(GC) of non-target and target topology image (edges are only p value < 0.05) in SCALP EEG*
*figure 1-b. average of efficiency values (p-value = 0.2546)*

GC is employed for topology construction, revealing edges with p-values ≤ 0.05. The constructed topology includes the top 25% of edges, with slightly lower values for target edges compared to non-target edges. [**Figure 1-a**]

Average global efficiency values for non-target and target. A p-value of 0.2546 confirms the absence of a statistically significant difference. [**Figure 1-b**]

### Experiment 2: Comparative Study between Rest (Pre-stimulus) and Stimulus

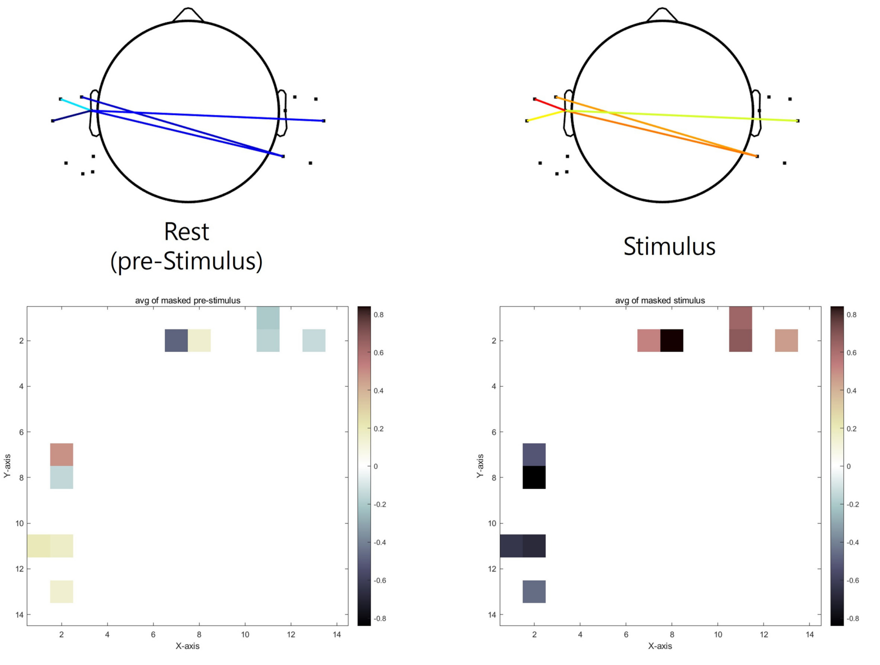



*figure 2-a. Phase Slope Indexes (PSI) of Rest and stimulus topology image (edges are only p value < 0.05) in EAR EEG.*
*figure 2-b. Phase Slope Indexes of Rest and stimulus hitmap image (edges are only p value < 0.05)*

Topology construction using PSI reveals edges with p-values below 0.05. PSI is low in the Rest condition and increases with the arrival of Stimulus. [**Figure 2-a**]

Heatmap using PSI shows selected edges ($p < 0.05$). PSI is near 0 in Rest and increases upon Stimulus arrival. [**Figure 2-b**]

# Conclusions

### Experiment 1:

Results confirmed directional activation from frontal to occipital lobes during both stimuli, highlighting their roles in cognitive function and visual processing. Visual stimulation (0.5-1.5 seconds) triggered predictive brain activity, enabling early engagement in processing future stimuli. While the target was slightly lower than non-target, global efficiency analysis indicated an insignificant difference.

### Experiment 2:

The PSI was utilized to measure the phase gradient difference between time series, indicating synchronization strength. Synchronization between nodes was well achieved during Rest, but reduced during Stimulus, suggesting weakened communication and less efficient information processing between brain regions. This weakening of synchronization, particularly in the temporal lobes, was linked to reduced attention in the auditory part, aligning with findings from previous studies.

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