Master thesis : Clarifying the Neuronal and Neurovascular Properties of the fMRI Global Signal Amplitude During Mind-Blanking Reports

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MASTER'S THESIS: CLARIFYING THE NEURONAL AND NEUROVASCULAR PROPERTIES OF THE FMRI GLOBAL SIGNAL AMPLITUDE DURING MIND-BLANKING REPORTS

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Abstract

Spontaneous thinking can be seen as the internal mechanisms of consciousness that arise unintentionally and without deliberate effort. These thoughts include the dynamic processes that occur during wakefulness, but notably, they also involve periods where active cognition is absent. One such example of spontaneous thinking is mind-blanking, which refers to moments when a person experiences a complete lack of cognitive activity. Based on previous studies, this state is linked to increased slow-wave activity, which refers to low-frequency brain oscillations associated with deep sleep or drowsiness during wakefulness.

Research using functional magnetic resonance imaging (fMRI) has found that during episodes of mind-blanking, there is a noticeable increase in the fMRI global signal amplitude, which is defined as the time course across all voxels, and can reflect various underlying physiological and neuronal processes. However, because the global signal is complex and can be influenced by multiple factors such as physiological (e.g., heart rate), neuronal, and technical artifacts, it has been unclear which specific components are responsible for the observed increases during mind-blanking.

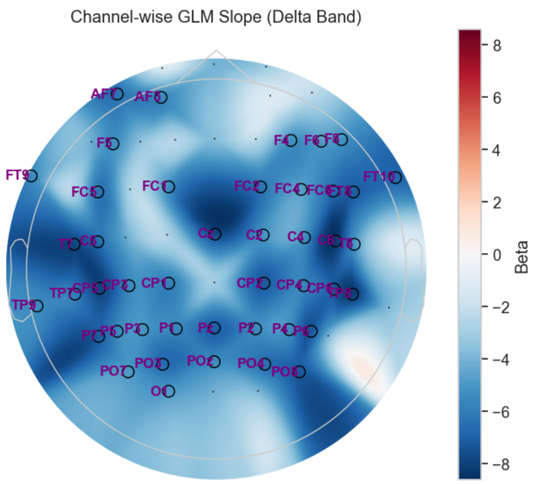
The objective of this study is to identify and clarify the specific components of the fMRI global signal during mind-blanking. Understanding how these components contribute to the phenomenon can shed light on the underlying neural and physiological mechanisms driving this state.

To achieve this, we analyzed multimodal data collected from electroencephalogram (EEG), fMRI, and electrocardiogram (ECG) recordings. Participants performed the Sustained Attention to Response Task (SART) and were asked to report their mental state and level of alertness throughout the experiment. From these data, key features were extracted: fMRI global signal amplitude, heart rate variability from ECG, and the amplitude of EEG oscillations across different frequency bands (delta, theta, alpha, gamma).

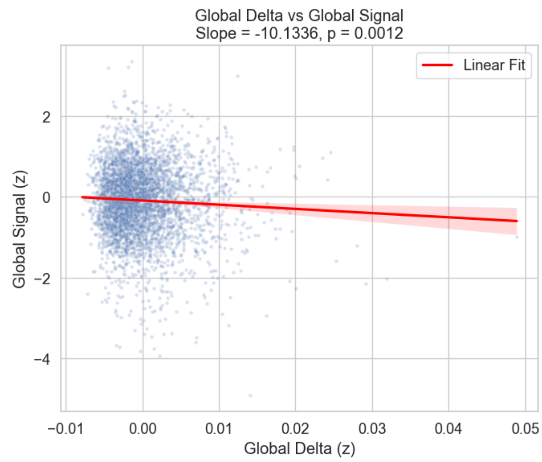
Then, we used linear mixed-effects models to examine the relationships between these physiological and neuronal signals and the global signal amplitude. Our analysis focused especially on how these relationships present during mind-blanking, but also considered other mental states such as mind-wandering and the on-task condition.

The results indicated that during reports of mind blanking, the amplitude of the global signal was significantly negatively correlated with delta and theta EEG activity (Fig. 1), meaning that as slow-wave activity increased, the global signal amplitude decreased in these bands. Conversely, there was a modest positive correlation with ECG variability, suggesting a physiological contribution (Fig. 2). When examining the entire dataset regardless of mental state, we found that the global signal amplitude positively correlated with theta oscillations and negatively correlated with alpha oscillations, consistent with some previous studies.

In summary, these findings suggest that mind blanking, which is associated with increased slow-wave EEG activity, can also involve a physiological contribution, particularly heart rate variability as reflected by the global brain signal. The observed increase in the global signal amplitude appears to be primarily driven by physiological changes, which can provide insights that mind blanking is not a purely neuronal process and can be associated with increased heart rate activity as well.



(a) GLM Slopes Reveal Significant Delta-Band EEG Suppression in Parietal, Occipital, Posterior and Temporal Regions, which shows local negative correlation with GSA during MB reports



(b) Results of the GLM for GSA and mean EEG signal amplitude in delta band during MB reports reveal global negative correlation with GSA

Figure 1: Delta-band EEG–fMRI relationship during MB. **(a)** Beta values across EEG channels reflect channel-wise GLM slopes with the global signal. **(b)** Linear model fit between global delta amplitude and GSA across time points during MB reports

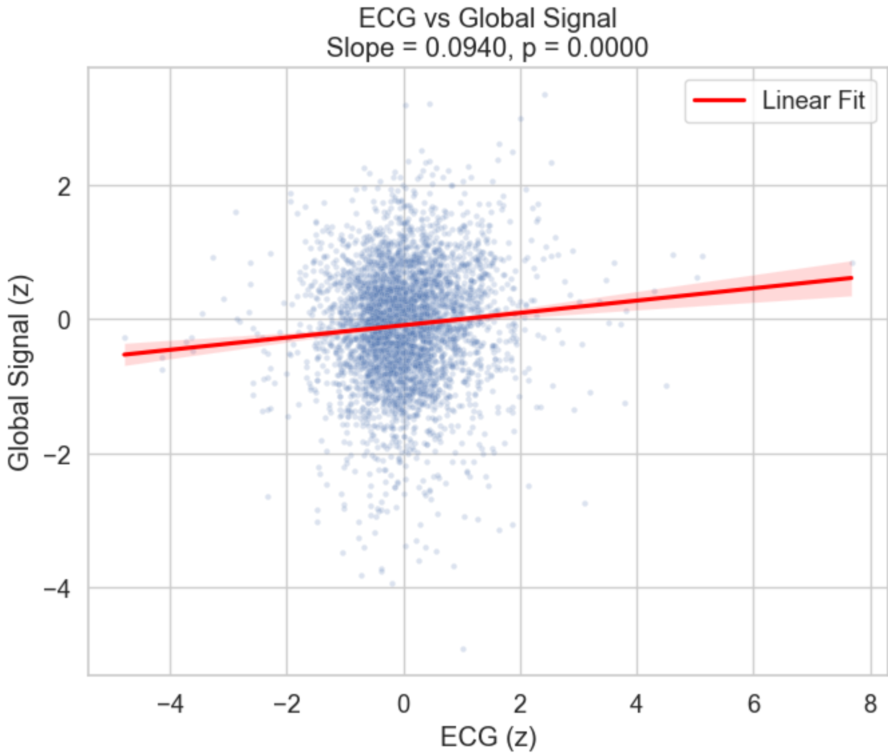


Figure 2: Linear model fit between ECG variation and GSA across time points during MB reports