

Investigating Depth of Cognitive Processing in the Brain Dynamics of Oscillations

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Introduction: Human-Computer Interaction (HCI) may benefit from accessing implicit information about the user state as it allows a fluid adaptation to the current situation. As one piece in this undertaking, we have studied the feasibility of quantifying how deeply presented information is processed in the brain by tapping the corresponding components of brain activity. The neural components arising from cognitive processes have been considered in the event-related potentials [1] and are here investigated in the spectral domain. The long-term goal is to estimate the momentary level of cognitive processing from the ongoing electroencephalography (EEG), and dynamically adapt the corresponding BCI application. The applicability ranges from human-computer interaction, like information seeking, to industrial workplaces (e.g. operator monitoring).

Material, Methods and Results: We developed a specific visual stimuli paradigm [1] in which we modulated the required amount of cognitive processing by task instructions in three domains: memory, which required visual/auditory memory recall of stimuli; language - which considered phonemic representations of the words that represents the stimuli, such as syllables; and visual imagery - which used quantitative measurements for differentiation. A shallow level of processing is given by short-term retention of information, e.g. color appearance, and a deep process level requires intense processing of the stimuli, e.g. semantic correlations.

The data was recorded from 17 participants using 64 channels EEG (Brain Products). We applied artifact removal techniques for muscular artifacts, eye blinks and loose electrodes. Subsequently, we assessed changes in the oscillatory power generated at different frequencies by extracting the spectrum (3-40Hz) with Fourier transform using Kaiser window (Fig. 1).

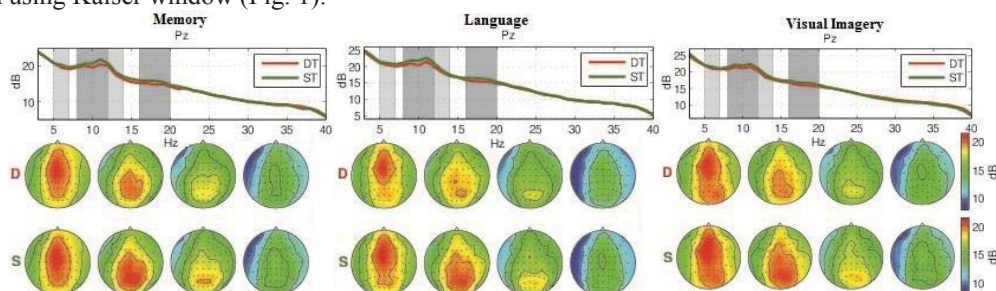


Figure 1. Spectral analysis on grand average for deep (D) and shallow (S) processes in memory, language and visual imagery, over Pz. The top plots show the power log at different frequency bands and the grey shaded areas refer to the bottom scalp maps.

We investigated the neurophysiological markers that represent the cognitive processes by evaluating the neural activity generated in theta (5-7Hz), alpha (8-10Hz) and beta (12-20Hz) frequency bands. Discriminative information can be observed over the alpha and low beta (12-14Hz), showing desynchronization (2-3 dB less) during deep processing with respect to the shallow processing. This corresponds to complex mental activities, such as concentration, focus and memory access. Theta (5-7Hz) and mid beta (16-20Hz) bands do not show significant difference.

Discussion: The log power spectrum shows that the levels of cognitive processes in different modalities can be distinguished, demonstrating the feasibility of monitoring the depth of cognitive processing for neuro-technological applications in BCI. Future developments will consider a regression approach to estimate ongoing level of cognitive processing.

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References

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