Reference layer adaptive filtering (RLAF) in simultaneous EEG-fMRI

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Introduction

Simultaneous electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) combines advantages of both methods: high temporal resolution of EEG and high spatial resolution of fMRI. EEG recordings are, however, afflicted by severe artifacts caused by fMRI scanners. Average artifact subtraction (AAS) is a common method to reduce those artifacts [1]. Recently, we introduced an add-on method that uses a reusable reference layer EEG cap prototype in combination with adaptive filtering, to improve EEG data quality substantially [2, 3]. The methods applies adaptive filtering with reference layer artefact data to optimize artefact subtraction from EEG and is named reference layer adaptive filtering (RLAF).

Methods

The reference layer cap was developed by GUGER TECHNOLOGIES OG, Austria, see Figure 1 panel A, B and C. It consists of 30 double-layer electrode pairs and 2 additional ECG electrodes. 29 electrode pairs are capturing EEG and one electrode pair serves as common ground/reference electrode. The reference layer itself is a system of saline-water filled tubes and galvanically isolated from the scalp except at the common ground/reference electrode.

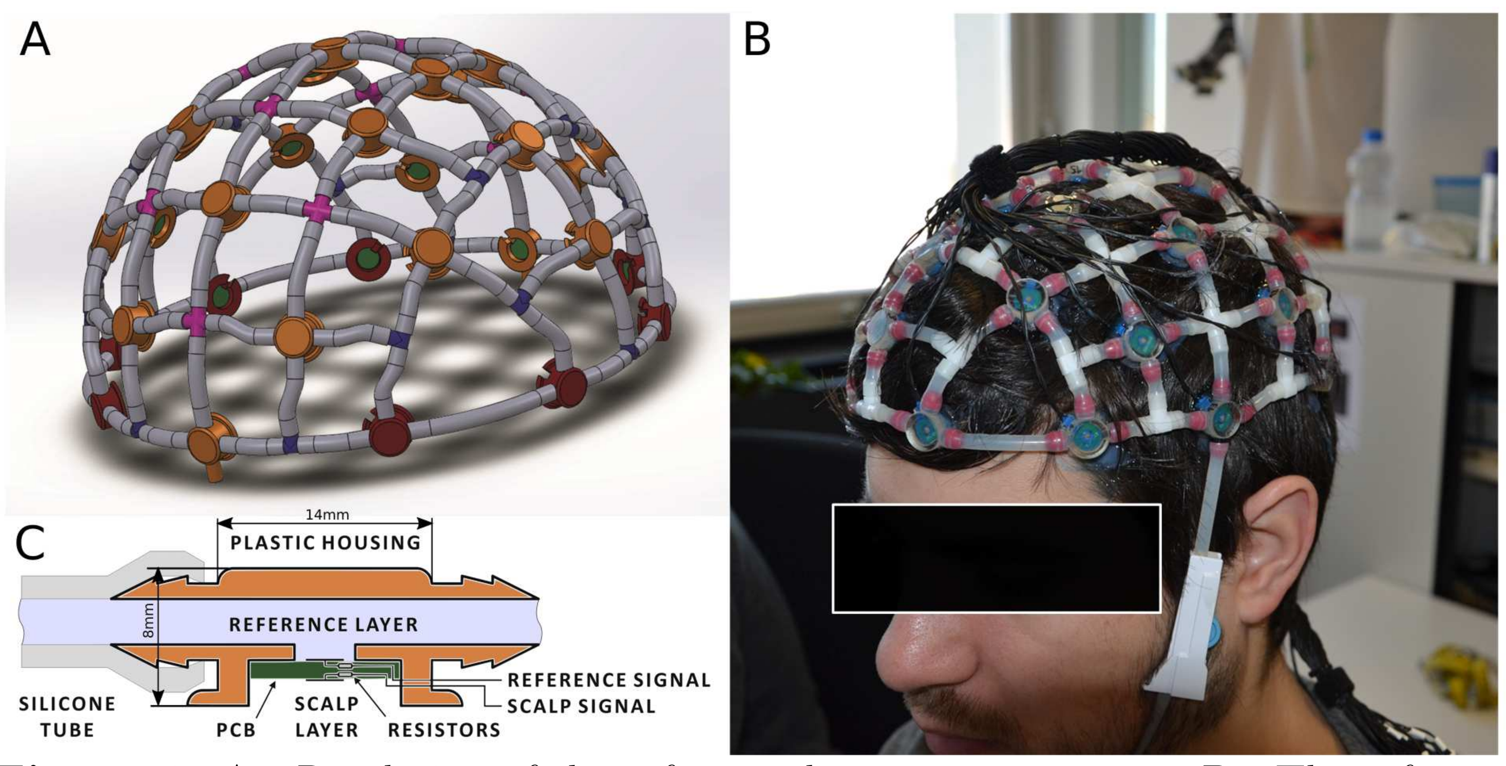

Figure 1: A - Rendering of the reference layer cap prototype. B - The reference layer cap in use. C - Schematics of the double layer electrode pairs.

The experiment was designed to evaluate visual evoked potentials (VEPs) and alpha-rhythm changes between opened and closed eyes. The two participants underwent inverse checker-board stimuli to trigger VEPs (1200 inversions). Subsequently, 10 min of resting EEG during closed eyes was recorded.

The signal processing is depicted in Figure 2 and included a 1 Hz high-pass, AAS of the gradient artefact (GA, 50 epochs for averaging), down-sampling to 250 Hz, AAS of the pulse artefact (PA, 50 epochs), a 50 Hz notch filter and finally the adaptive filtering.

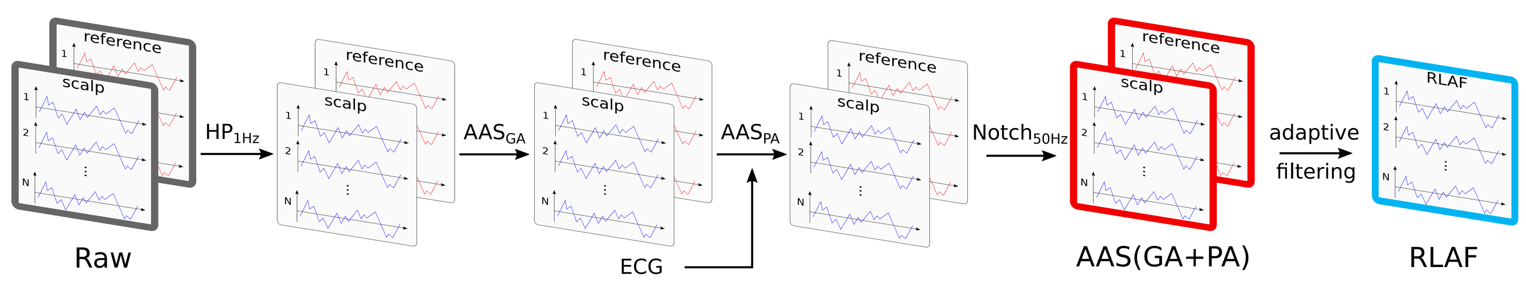

Figure 2: Signal processing scheme.

We optimized the step width of the adaptive filtering to guarantee stability and fast convergence of the method ($7 \cdot 10^{-6}$ to $1.5 \cdot 10^{-4}$).

Results

We used a similar evaluation procedure as used by Jorge et al. [4]. All results are depicted in Figure 3.

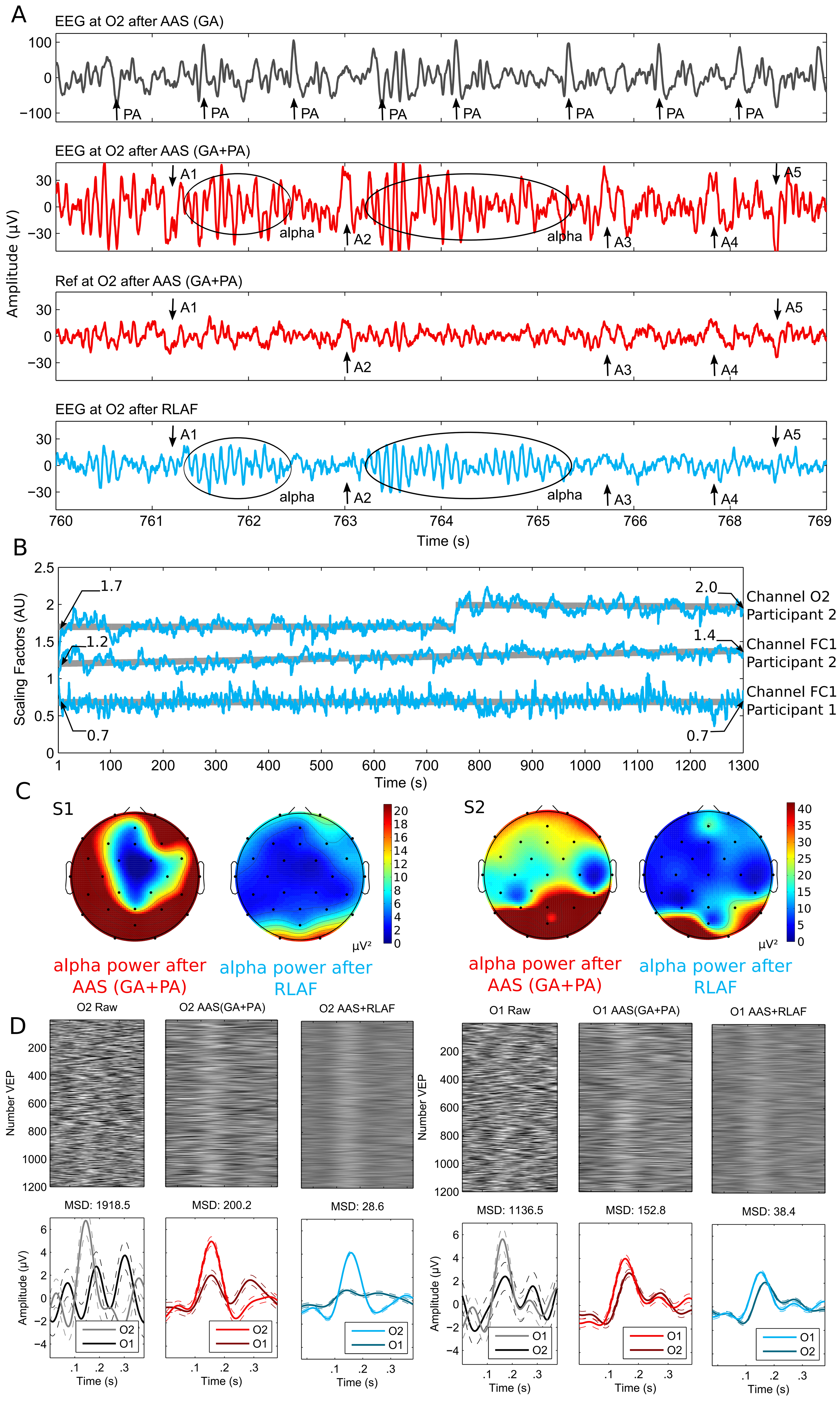

Figure 3: A - EEG time course comparison after artefact reduction in participant 1. B - Adaptive filter coefficients' course over time. C - Alpha power spatial distribution. D - Selected single and average VEPs of participants 1 and 2.

Discussion

The adaptive filter scaling values are changing over time, which indicates the necessity of adaptive filtering. Our results demonstrate that RLAF reduces artefacts while it preserves EEG phenomenons as evoked potentials and the occipital alpha rhythm. Hence, RLAF is able to improve the quality of EEG of simultaneous EEG-fMRI experiments.

References

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