On the relevance of alpha-rhythm modulation to the generation of readiness potential

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Introduction

The readiness potential (RP) was discovered more than 50 years ago [1], but it was Libet [2] who introduced it to objective research on subjective agency. Although Libet's experiments were criticised for their design, it was clearly shown that **RP starts more than one second before awareness of the urge to move**.

- Strictly speaking, it means that the decision to move is formed in the brain before such decision is made consciously.
- An alternative is that RP may represent an artifact of averaging [3,4], which implies that readiness-potential-like events may happen even in periods without voluntary actions.

Along with RP, movement preparation is accompanied by changes in the amplitude of alpha and beta rhythms [5]. We hypothesise that **RP is at least partially generated by alpha rhythm via the baseline-shift mechanism** [6].

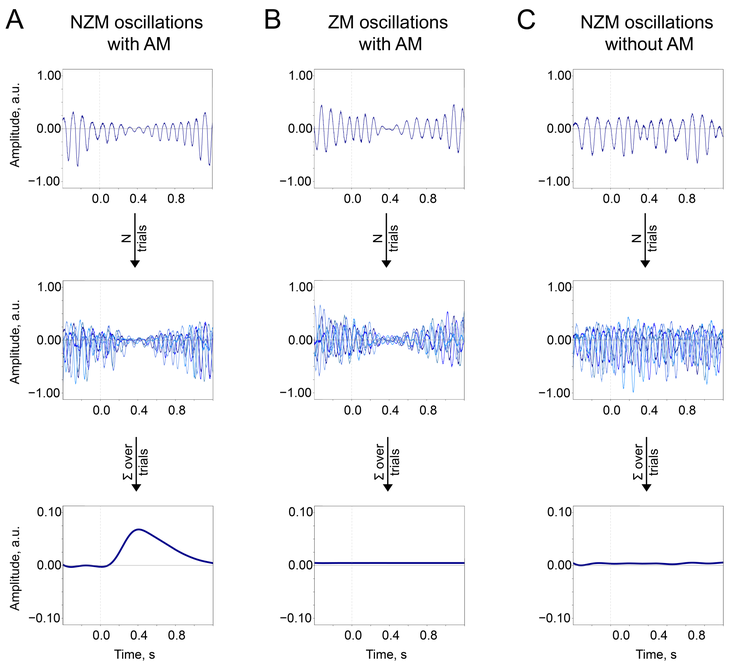


Figure 1. Two prerequisites of the baseline-shift mechanism—(1) non-zero mean (NZM) and (2) amplitude modulation (AM)—should occur together so ER would be generated. **A**. Non-zero mean oscillations when modulated in amplitude generate ER. **B**. If oscillations have a zero mean, then no ER is generated. **C**. If oscillations have a non-zero mean but do not systematically (trial-by-trial) experience modulation, then no ER is generated.

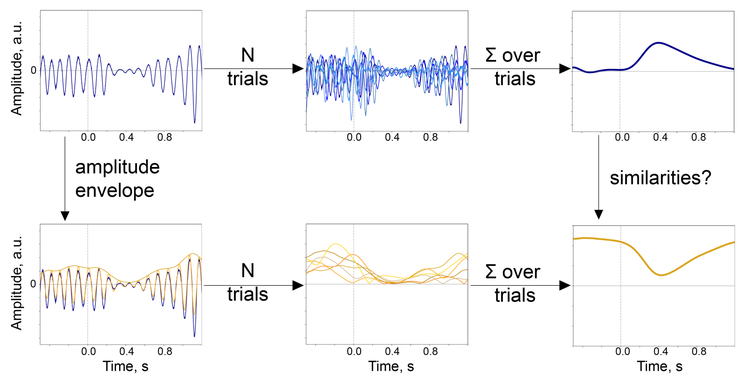
Methods

Experimental design: self-paced movements in a classical Libet's paradigm [7].

EEG, 30 electrodes

33 participants, mean age: 26

RP was obtained by averaging all epochs, and the alpha amplitude envelope was computed from each epoch via the Hilbert transform.



Results

We show that the temporal dynamics are similar for RP and alpha rhythm amplitude, i.e., the negative RP corresponds to the decrease in oscillations' amplitude. Moreover, there is a spatial similarity between the neuronal sources generating RP and oscillatory dynamics, where both processes are particularly pronounced over the central-frontal regions of the cortex.

Similarity between RP and the alpha amplitude envelope in sensor space

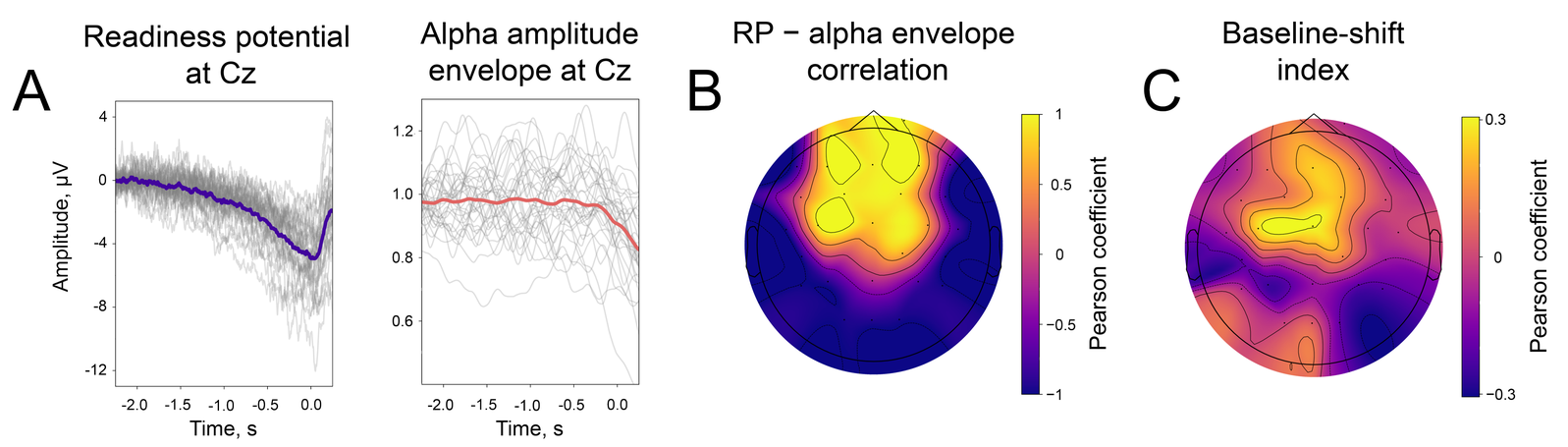


Figure 2. RP and alpha amplitude modulation demonstrate similarities in time course and spatial localisation. **A**. Time evolution of RP and alpha amplitude envelope that appeared before voluntary movements at the Cz electrode. Time "0" is the movement onset detected with EMG. Colored: averaged across the participants; gray: individual. **B**. The correlation between the RP and alpha amplitude envelope at each electrode that is computed with the Pearson correlation coefficient. **C**. The average values of the baseline-shift index (BSI [8]) at each electrode that are estimated from the resting-state data. BSI is an estimation of the non-zero mean of oscillations in a particular frequency range from the resting-state data. A negative slope of RP coincides with a decrease in alpha amplitude at central regions, which corresponds to positive mean oscillations, as estimated with BSI.

Similarity in source space

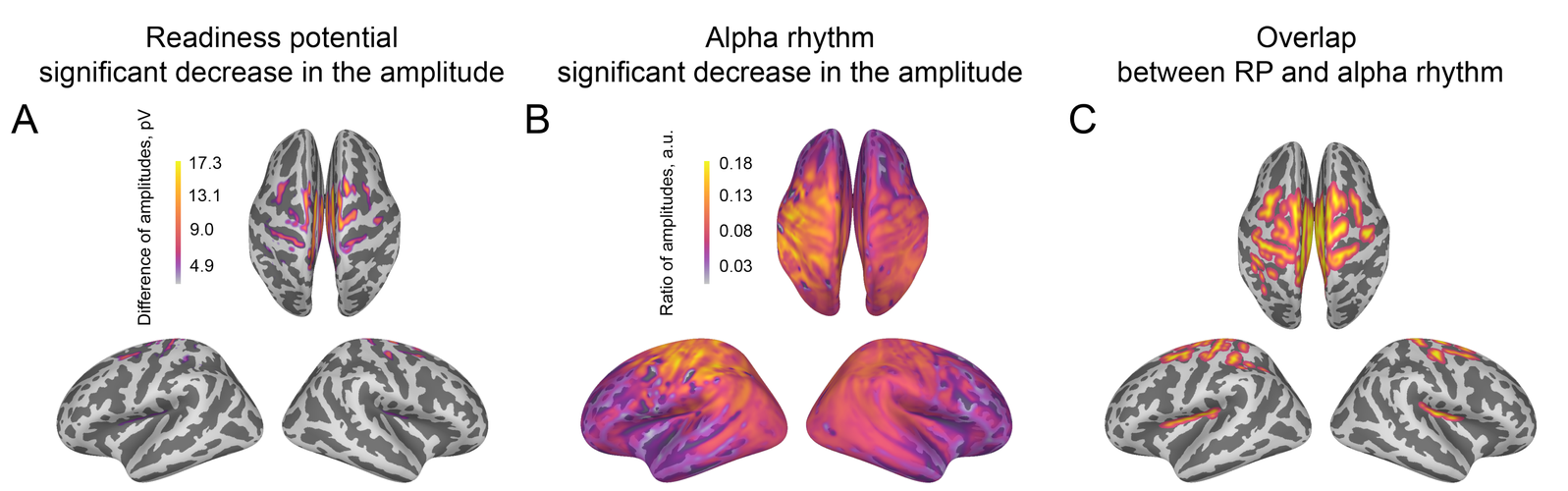


Figure 3. Reconstructed sources of both RP and alpha amplitude modulation overlap in motor regions of the cortex. **A**. Sources of RP. The source reconstruction was performed with eLoreta. The amplitude decrease was estimated as the difference between average amplitudes in time windows $(-2.2, -1.8)\,s$ to $(-0.3, 0.1)\,s$ (where 0 is the movement onset). Only spatial locations with significant decreases are displayed. Significance was estimated for each dipole location with a t-test and corrected for multiple comparisons with the Bonferroni method. p-value threshold was set to 0.01. **B**. Sources of alpha amplitude modulation. The amplitude decrease was computed as $(A_0 - A_{pre})/A_{pre}$. The time windows for averaging are identical to those for RP, i.e., $A_{pre} = (-2.2, -1.8)\,s$ and $A_0 = (-0.3, 0.1)\,s$. **C**. Overlap between RP and alpha amplitude modulation is localised in the sensory-motor cortex, paracentral lobule, superior frontal gyrus, and cingulate cortex.

Discussion

Modulation of the amplitude of alpha oscillations can partially explain the generation of RP. We suggest that the link between RP and alpha rhythm will improve the conditions for searching for readiness-potential-like events in continuous data and subsequently contribute to the current debate on the stochastic hypothesis of RP.

References

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