Neural Correlates of Accuracy and Confidence during Realistic Decision-Making in Noisy Environments

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Introduction

Every decision we make is accompanied by a degree of confidence. Previous studies have shown that it is possible to decode confidence from neural signals recorded with electroencephalography (EEG) in controlled conditions (Boldt et al., 2015; Valeriani et al., 2017). However, it is not clear if such neural correlates of decision confidence are strong enough to be also decoded in realistic scenarios, usually characterized by higher environmental noise than lab settings. Here, we investigate the possibility of decoding confidence from EEG signals recorded in a noisy environment (i.e., an MRI room) during a realistic decision-making task representing pandemic scenarios.

Methods

Eight healthy participants (5 females, age = 39.1 ± 14.4 years) undertook a decision-making experiment composed of six blocks of 30 trials. In each trial, participants were shown two pictures of an imaginary geographical map characterized by two regions for 500 ms. The first picture was used to familiarize participants with the regions, while the second picture included a number of colored dots in each region representing cases of an imaginary disease, where the color represented the severity of each case. Participants were asked to decide which region was most in danger within 2 seconds and to provide their degree of confidence in a scale from 1 to 4 within 2 seconds. Simultaneous functional MRI and EEG recordings were collected during the experiment using a 3T Siemens Prisma scanner and an MR-compatible, 128-channel EEG system (EGI). Gradient artifacts were removed from EEG recordings by template subtraction, while ballistocardiographic artifacts were removed using optimal basis sets (Niazy et al., 2005). EEG data were band-pass filtered between 0.5 and 40 Hz, and trials where EEG amplitudes were higher than 5 mV were discarded due to high contamination of muscular artifacts.

We extracted EEG epochs starting when the first picture was presented and lasting 1 second to dissociate neural correlates of decision-making from their behavioral responses (i.e., button presses for reporting decision and confidence). Grand averages across participants were calculated to compare correct and incorrect trials, and confident vs. not-confident trials. Statistical analysis was conducted using a Wilcoxon signed-rank test.

Results

We found distinct significant neural markers of accuracy (Figure 1A) and decision confidence (Figure 1B) in the occipital region (O1 and O2 locations). Neural markers of accuracy were found bilaterally, approximately 50 ms after the onset of the second picture. Neural correlates of decision confidence were only present in the left occipital region, approximately 170 ms before and 400 ms after the onset of the second picture.

Topographic maps showed consistent differences in correct (confident) vs. incorrect (not-confident) trials across the whole brain.

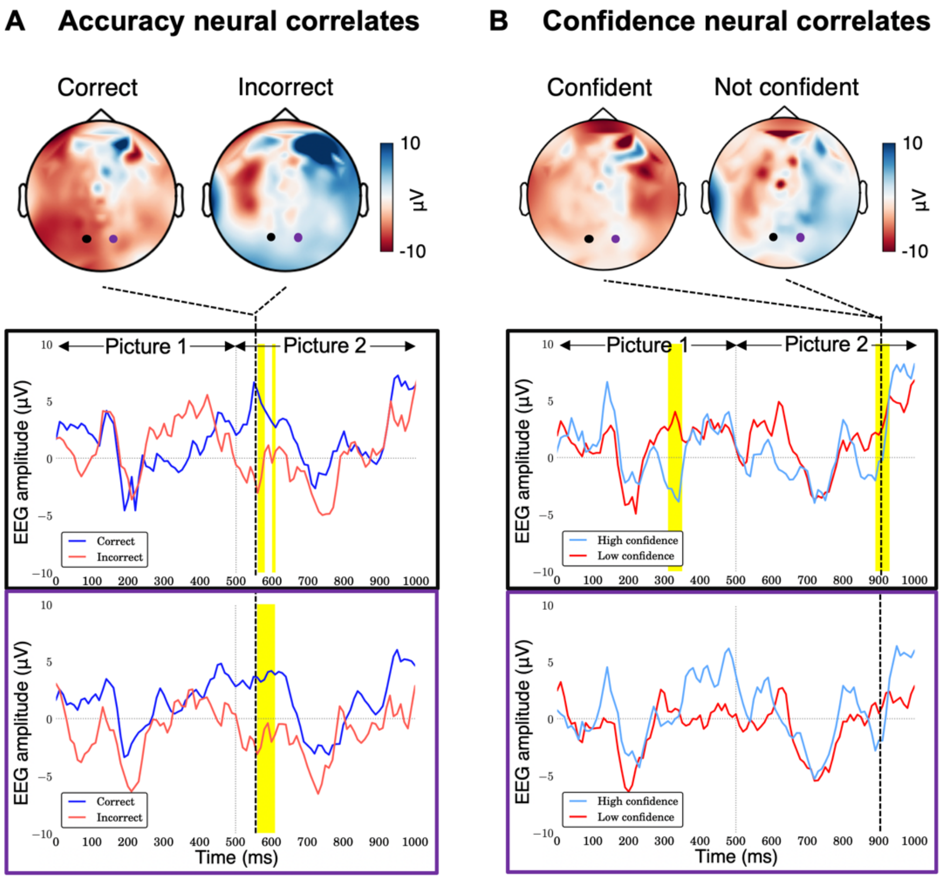

Figure 1. Grand averages of EEG signals recorded at occipital locations O1 (black) and O2 (purple) for correct vs. incorrect trials (A), and for confident vs. not confident trials (B). Yellow areas represent time samples where the two conditions were significantly different (Wilcoxon signed-rank test).

Conclusions

Distinct neural patterns of objective accuracy and decision confidence were found in the occipital region during a realistic decision-making task undertook in a noisy environment. Timing and spatial location of such patterns were consistent with previous studies (Zizlsperger et al., 2014; Molenberghs et al., 2016). These results show that advanced signal processing techniques enhance the signal-to-noise ratio of EEG recorded during MRI acquisition, allowing the neural correlates of decision-making to be reliably extracted from EEG recordings. This could enable the development of novel brain-computer interfaces (BCIs) that enhance human decision-making in realistic scenarios by leveraging the high spatial and temporal resolution of multimodal neural recordings. Future work should focus on decoding decision confidence from such multimodal neural patterns using machine-learning algorithms.

References

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