# Brain-Computer Interfaces for Optimal Human-Machine Collaboration

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*Introduction*: Previous research has shown that brain-computer interfaces (BCIs) could be used to estimate the decision confidence of single users and improve group decision-making in visual tasks for human [1, 2] and human-machine teams [3]. While receiving advice from others is beneficial when we doubt [4], in other contexts, advice could negatively affect our performance [1]. Here, we investigate the neural correlates of openness to advice in a realistic decision-making task, with the aim of developing BCIs that could adaptively control the advice for maximizing group performance.

*Material, Methods and Results*: Ten healthy participants (6 females/4 males, age = 42.5 ± 13.8 years) took part in an EEG experiment split into six blocks of 30 trials. In each trial (Fig. 1A), participants were first shown a fictional geographical map of two regions for a duration of 500 ms, which was then overlaid with dots representing endemic cases, with the color of each dot indicating the endemic severity, for another 500 ms. They were asked to decide which region was most in danger (1 or 2) and to indicate their degree of confidence (1 to 4) using a keypad. Next, they were shown a feedback display with their decision and confidence as well as the decision and confidence of an artificial agent, and asked to make a final decision. Neural data were recorded at 512 Hz using a 128-channel EGI EEG system, band-pass filtered between 1 and 40 Hz, and downsampled to 50 Hz. Trials with EEG amplitude higher than 5 mV were discarded. EEG epochs were extracted starting from the feedback display and lasting 500 ms, and baseline corrected by subtracting the mean voltage recorded in 100 ms preceding the feedback display. For each participant, we computed the average EEG signal in (a) trials where participants changed their mind after receiving a disagreeing feedback from the artificial agent (trust), and (b) trials where they did not change their mind after disagreement (distrust). Statistical analysis was conducted by comparing the average EEG signals in trust and distrust trials using the Wilcoxon signed-rank test at $p \leq 0.05$.
We found significant differences in parietal and occipital cortices between trust and distrust trials around 100 ms and 400 ms after receiving feedback (Fig. 1B). Scalp maps showed stronger activation of these regions in trust than in distrust trials, which could be used to predict the final decision of the participant.

*Discussion*: Neural patterns of openness to advice were found in the occipital-parietal region. These results suggest the presence of biases that could be associated with trust and inform whether receiving feedback would be beneficial, hence enabling the development of optimally-collaborating machines.

*Significance*: EEG-based neural markers may inform the willingness to receive and consider external advice during realistic decision-making. This opens the possibility of developing BCIs to monitor the mental states of participants and adaptively decide whether it is worth to provide advice for optimal group performance in human and human-machine teams.

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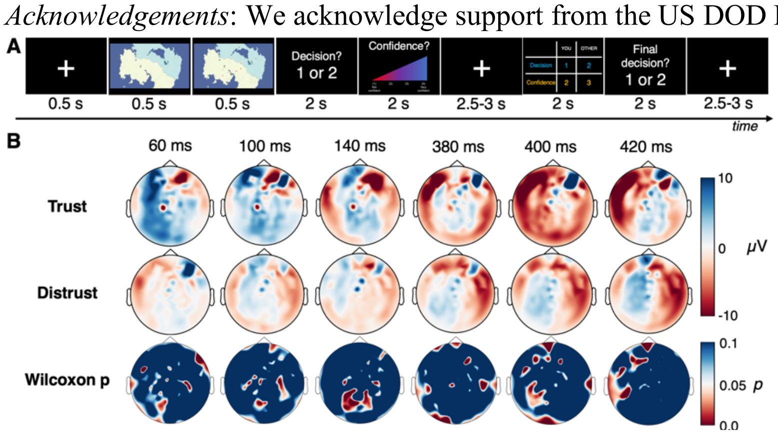


*Figure 1. (A) Experimental protocol. (B) Grand average scalp maps comparing trust vs. distrust trials, and corresponding Wilcoxon signed-rank test p values.*

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