Augmenting group decision making accuracy in a realistic environment using collaborative brain-computer interfaces based on error-related potentials

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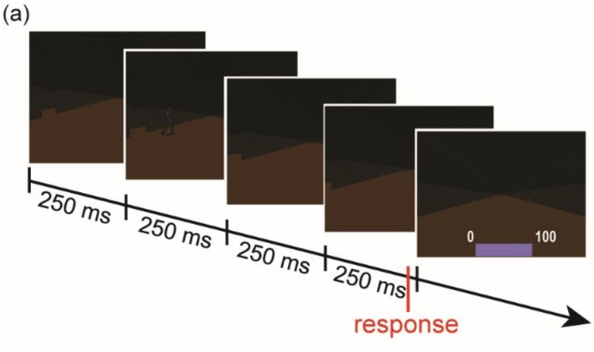
Introduction: In many circumstances, groups make better decisions than individuals [1]. In previous research we have shown that collaborative Brain-Computer Interfaces (BCIs) could be used to estimate the decision confidence of isolated users and improve group decision making in visual tasks involving static images [2][3]. The goals of this study are (a) to test whether such a collaborative BCI could improve group performance when users are exposed to video feeds from a realistic environment, and (b) to significantly reduce the number of EEG electrodes required to estimate the decision confidence.

Material, Methods and Results: 10 healthy participants (six females, four left-handed, mean age=35.4 years, SD=2.6) took part in an experiment split into 12 blocks of 28 trials. In each block (Figure 1(a)), a video sequence was presented (frame rate=4 Hz) representing the viewpoint of a user walking along a corridor, where individuals can appear from side doorways. Participants had to decide, within 2.5 s, whether the individual was wearing a helmet (left mouse button) or a cap (right mouse button). After the decision, participants were asked to indicate, within 2 s, the degree of confidence in their decision (0-100%) using the mouse wheel. Neural data were recorded at 2048 Hz using a BioSemi ActiveTwo EEG system with 64 electrodes and were referenced to the mean of the electrodes placed on the earlobes. Each channel was band-pass filtered between 0.15 and 40 Hz and ocular artefacts were removed with a standard subtraction algorithm. For each trial, response-locked epochs lasting 1.5 s and starting 1 s before the response were extracted from the EEG data, detrended, baseline corrected, and downsampled to 32 Hz. The error-related negativity (ERN) of each epoch was computed as the difference between the maximum voltage value recorded in the 150 ms preceding the response and the minimum voltage value recorded in the 150 ms following it at electrode FCz [4]. A logistic regressor was trained for each participant to predict whether a decision was correct or incorrect from the neural feature [3]. The confidence scores produced by the regressor were then used to weigh individual responses when making group decisions. We also tested the possibility of complementing the neural feature with the confidence value reported by the participant after each decision, as well as using those confidence values as weights directly. The results obtained using 8-fold cross-validation are shown in Figure 1(b). The collaborative BCI based only on the neural feature (orange) achieves significantly better performance than majority-based groups (black) for all group sizes 2-9 (one-tailed Wilcoxon signed-rank test $p<0.007$). When using the reported confidence to weigh decisions (blue), groups were significantly more accurate than groups not using it ($p<0.003$), with the best performance obtained by groups using both reported confidence and ERN (green, $p<0.003$).



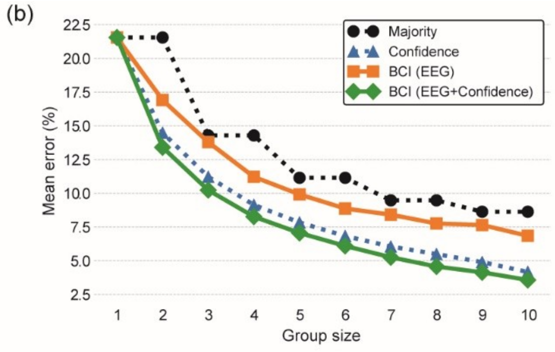


Figure 1. (a) Protocol of the experiment. (b) Mean performance of groups of increasing size using different decision-making methods.

Discussion: We found that our collaborative BCI improves group performance even with this realistic task using video feeds and by using only one neural feature extracted from FCz. Moreover, a hybrid BCI based on both neural and behavioural features achieved significantly better group performance than decision-making systems based on each feature individually.

Significance: Collaborative BCIs could augment group performance also in decision making in a realistic environment. The use of ERN features only requires EEG data gathered from one electrode to augment group performance, hence improving the practicality of the BCI.

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References:
[1] Surowiecki, J. (2005). The Wisdom of Crowds. Anchor. New York: Anchor.
[2] Valeriani, D., Poli, R., & Cinel, C. (2016). Enhancement of Group Perception via a Collaborative Brain-Computer Interface. IEEE Transactions on Biomedical Engineering, 64(6), 1238–1248.
[3] Valeriani, D., Cinel, C., & Poli, R. (2017). Group Augmentation in Realistic Visual-Search Decisions via a Hybrid Brain-Computer Interface. *Scientific Reports*, *7*(7772), 1–12.
[4] Nieuwenhuis, S., Ridderinkhof, K. R., Blom, J., Band, G. P., & Kok, A. (2001). Error-related brain potentials are differentially related to awareness of response errors: evidence from an antisaccade task. *Psychophysiology*, 38(5), 752–760.