Decoding the Interaction between Emotional and Cognitive Processes with Functional Near-infrared Spectroscopy

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Abstract: We investigated brain activation patterns of emotional speech distraction (negative and positive emotion) and task-induced cognitive load (low and high load) combining functional near-infrared spectroscopy (fNIRS) with a multivariate decoding approach. The four experimental conditions could be predicted from the brain signals above-chance level. The weight maps derived from the decoding models indicated that the left dorsolateral prefrontal cortex was involved in decoding the valence of emotional speech, while the right inferior frontal gyrus was predictive of the current cognitive load level.

Introduction: A recent functional near-infrared spectroscopy (fNIRS) study identified the left inferior frontal gyrus (IFG) as a key region for integrating distracting negative and positive emotional speech and load-related cognitive processes [1]. However, the reported univariate statistics are constrained by assumptions about inter-individually shared anatomical and functional neural origins, among other factors [2,3]. A decoding approach, in which stimulus features are predicted based on brain activation patterns, can enhance statistical power by exploiting fine-grained multivariate information present in neuroimaging data [2,3]. **Methods:** We re-analyzed the preprocessed fNIRS data from eighteen participants engaged in a monitoring-control task with either low or high cognitive load and concurrent negative or positive emotional speech distractions [1]. For the within-subject decoding, a supervised machine learning pipeline reported in [4] and linear discriminant analysis (LDA) was used to classify the four conditions based on interpretable statistical features extracted from non-overlapping time intervals of 10 s (i.e., the HbO and HbR average, max, and peak-to-peak per channel). Informative features were identified using sequential feature forward selection (SFS). Decoding performance was statistically evaluated using the mean and its confidence interval (CI) of the weighted f1-score obtained via Monte Carlo Simulation-based bootstrapping (5000 iterations) over cross-validation folds (5 folds á 20 repetitions). **Results:** In the SFS, the max HbR in channels overlying the right and left dorsolateral prefrontal cortex (dlPFC) were frequently chosen to distinguish the four conditions (Figure A). Decoding performance was above-chance level (25%) with an F1 score of 65.1% (95%CI[64.01, 66.02]) for an SFS-optimized feature set and 47.65% (95%CI[47.01, 48.31]) for the HbR max feature set. The HbR max model weights included the left and right IFG as well as the left dlPFC (Figure B). **Discussion**: We could predict the combination of emotional distraction and cognitive load experienced by an individual from the fNIRS brain signals. The results indicated that the left dlPFC decoded the valence of emotional speech, while the right IFG was predictive of the current cognitive load level. **Conclusion:** The multivariate statistic allowed us to investigate the interplay between emotion and cognition in a close-to-naturalistic experimental environment and small dataset. However, further research is required to enhance the interpretability of such models [2,3] and align individual feature spaces to facilitate cross-subject generalisation.

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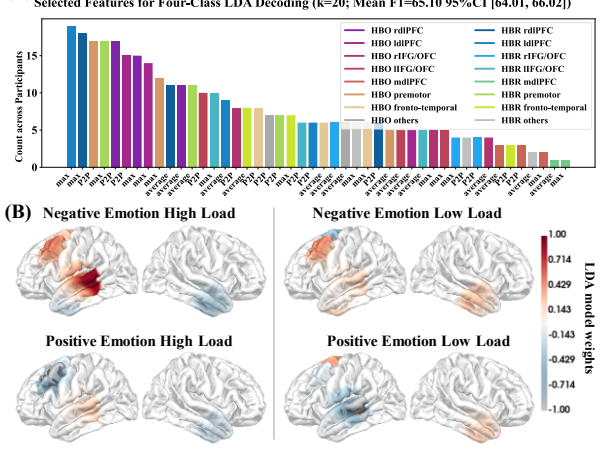

Figure: (A) Count of features and channel positions clustered by regions of interests across participants (k = max number of selected features in the SFS). (B) LDA weights of the HbR max feature set (averaged across subjects, corrected with the standard error across subjects and masked for enhanced interpretability using univariate bootstrapped means and confidence intervals of the contrast *High – Low Load Negative – Positive Emotion*).