On EEG-Based Emotion Recognition

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1 Summary

- As an initial approach, the goal was to validate **where** and **how** to approach emotion recognition using EEG.
- Deep brain regions require complementary techniques beyond EEG. Classifications based on EEG are typically correlational, not causal.
- The publicly available Open Affective Standardized Image Set (OASIS) [1] can be used to elicit emotional responses. The images are grouped by emotional valence (positive, negative, neutral), allowing for consistent brain signal interpretation while incorporating essential resting intervals. A typical pipeline is summarized in Table 1.

Table 1: EEG-based emotion recognition pipeline

Stage	Techniques
1. Preprocessing	**ICA (Independent Component Analysis)**, **filtering**, REST (Reference Electrode Standardization Technique), **normalization (z-score, min–max)**, Kalman filtering
2. Feature Extraction	**Bandpower / Spectral analysis**, FAA (Frontal Alpha Asymmetry), **ERPs (Event-Related Potentials), Wavelet / STFT (Short-Time Fourier Transform)**, Connectivity (PLV, DCM, Granger)
3. Feature Selection	PCA (Principal Component Analysis), RFE (Recursive Feature Elimination), mutual information
4. Classification	SVM (Support Vector Machine), CNN (Convolutional Neural Network), RNN (Recurrent Neural Network), DNN (Deep Neural Network), KNN (K-Nearest Neighbors)
5. Validation	Cross-validation, AUC (Area Under the Curve), Sensitivity (True Positive Rate), Specificity (True Negative Rate), Kappa (Cohen's Kappa)

2 Neuroanatomical Relevance

To identify brain regions relevant to EEG-based emotion recognition, we reference the works of [2] and [3]. The goal is to map these areas by anatomical depth and determine whether they can be assessed non-invasively via BCI (Brain-Computer Interface).

- **Prefrontal Cortex (PFC):** Includes several subregions, as shown in Fig. 1. The location is **superficial**.

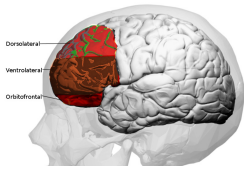

Figure 1: Prefrontal Cortex. Taken from [4].

- **Anterior Cingulate Cortex (ACC):** The most accessible part is the dorsal ACC (dACC), shown in Fig. 2. The location is **not superficial**.
- **Subcortical Regions (SR):** Includes the amygdala, thalamus, hippocampus, hypothalamus, and ventral striatum. These are near the areas in Fig. 3. Location is **not superficial**.
- **Insula (I):** Located deep within the cortex. It is **not superficial** (see Fig. 4).

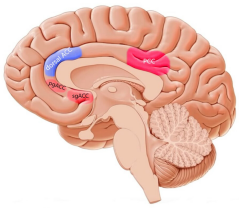

Figure 2: Anterior Cingulate Cortex. Taken from [5].

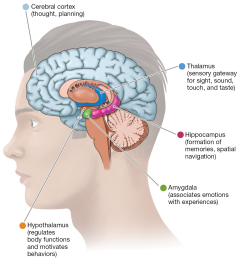

Figure 3: Subcortical Regions. Taken from [6].

- **Orbital Frontal Cortex (OFC):** Also a deep structure and **not superficial** (see Fig. 5).

The proposed EEG pipeline (Table 1) serves as a guideline for capturing emotion-related neural signatures.

3 Inner Speech Paradigm

The work by [3] introduces a publicly available EEG dataset focused on the "inner speech" paradigm. EEG recordings from ten participants are included across three mental tasks: inner speech, pronounced speech, and visualization. The brain regions primarily activated in this dataset are the **frontal, parietal, and occipital lobes**—all of which are **superficial** and can be studied non-invasively with EEG. These areas are shown in Fig. 6.

References

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[2] E. Gkintoni, A. Aroutzidis, H. Antonopoulou, and C. Halkiopoulos, "From neural networks to emotional networks: A systematic review of eeg-based emotion recognition in cognitive neuroscience and real-world applications," *Brain Sciences*, vol. 15, no. 3, 2025. DOI: 10.3390/brainsci15030220.

[3] N. Nieto, V. Peterson, H. L. Rufiner, J. E. Kamienkowski, and R. Spies, "Thinking out loud, an open-access eeg-based bci dataset for inner speech recognition," *Scientific Data*, vol. 9, no. 1, p. 52, 2022. DOI: 10.1038/s41597-022-01147-2. [Online]. Available: https://doi.org/10.1038/s41597-022-01147-2.

[4] Standring, Susan and Gray, Henry, *Neuroanatomy, Forebrain*, Accessed April 23, 2025, Treasure Island (FL), 2024. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK499919/.

[5] T. Thornton, "What is a mental disorder? an ontological perspective," *Theory & Psychology*, vol. 31, no. 3, pp. 349–365, 2021, Accessed April 23, 2025. DOI: 10.1177/23982128211007769. [Online]. Available: https://journals.sagepub.com/doi/10.1177/23982128211007769.

[6] W. W. Norton & Company, *Figure 2.16 The Forebrain: This drawing shows the location and functions of the forebrain regions (the cerebral cortex and the four subcortical structures)*, https://nerd.wwnorton.com/ebooks/epub/psychlife4/EPUB/content/2.2.3-chapter02.xhtml, Accessed April 23, 2025, 2024.

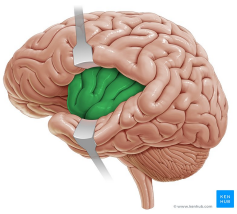

Figure 4: Insula. Taken from [6].

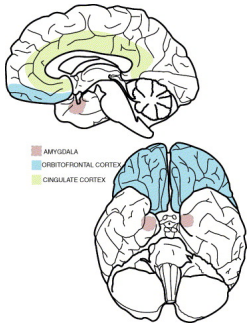

Figure 5: Orbital Frontal Cortex. Taken from [7].

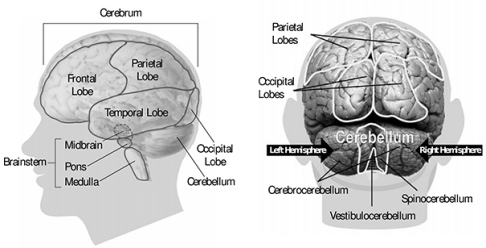

Figure 6: Frontal, Parietal, Temporal, and Occipital lobes. Taken from [8].

[7] M. L. Kringelbach and E. T. Rolls, "The functional neuroanatomy of the human orbitofrontal cortex: Evidence from neuroimaging and neuropsychology," *Progress in Neurobiology*, vol. 72, no. 5, pp. 341–372, 2004, ISSN: 0301-0082. DOI: https://doi.org/10.1016/j.pneurobio.2004.03.006.

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