Distinct dimensions of emotion in the human brain and their representation on the cortical surface

Review

Vasilescu Andreea

University of Bucharest
Faculty of Mathematics and Informatics

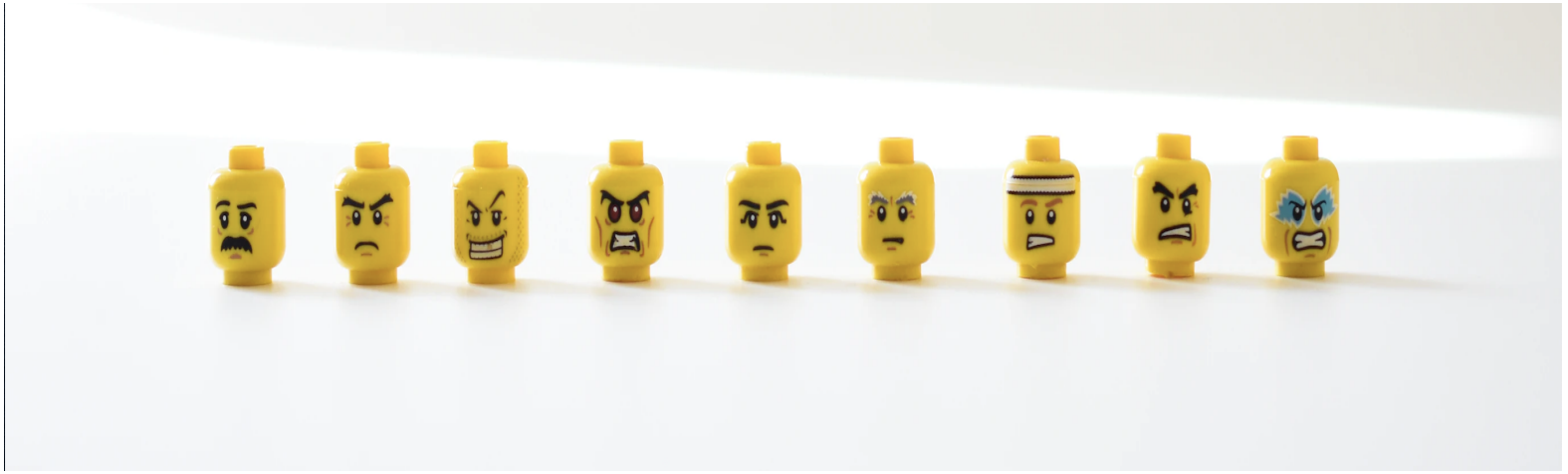
May 2023

Table of contents

1. Overview
   - Motivation
   - Introduction
2. Materials & Methods
   - Materials
   - Experimental Design
3. Emotions
   - Emotion Categories
   - Emotion ratings and Preprocessing
   - Model fitting
4. Results
   - Correlation between emotion ratings and BOLD responses
   - Cortical map of the semantic space of emotions
   - Strengths
   - Weaknesses
   - Limitations

Table of contents

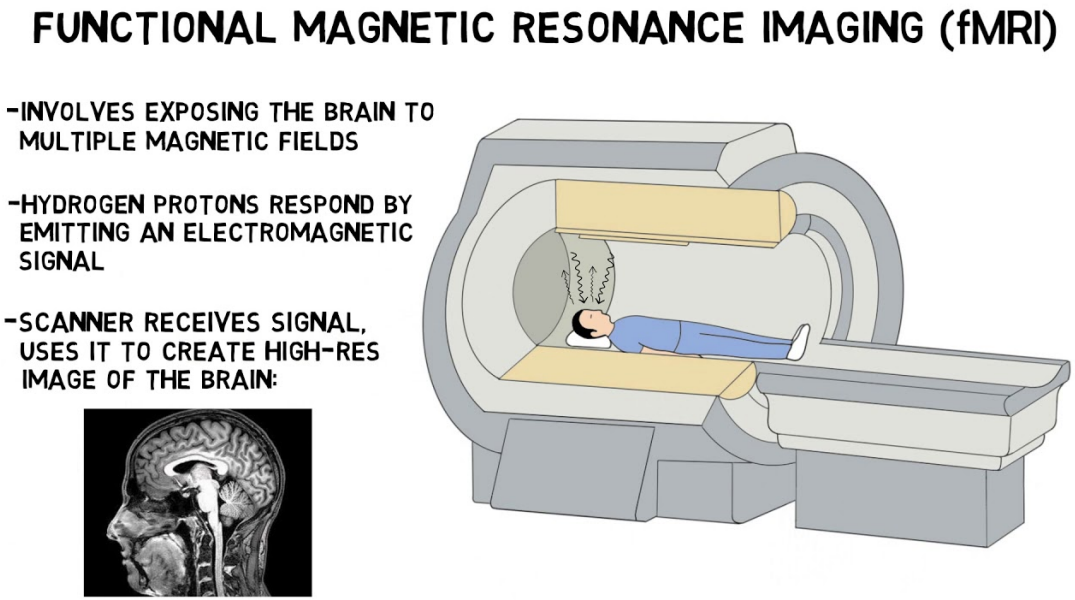
Motivation



- In daily life, people experience a rich variety of emotions ranging from vivid feelings of anger or joy, to more subtle and sensitive, such as awe or empathetic pain,
- The fundamental goal of affective neuroscience is to determine how emotions are represented in the human brain

About the experiment

- Functional Magnetic Resonance Imagining (MRI) was measured to obtain blood-oxygen-level-dependent(BOLD) responses from subjects.



- **Cortex is responsible for language, memory, reasoning, thoughts, learning, decision-making, emotion & intelligence**

Data

For a comprehensive understanding of the brain representation in terms of emotion, FMRI was measured to obtain Blood Oxygen Level Depended (BOLD) responses in human subjects that watched:

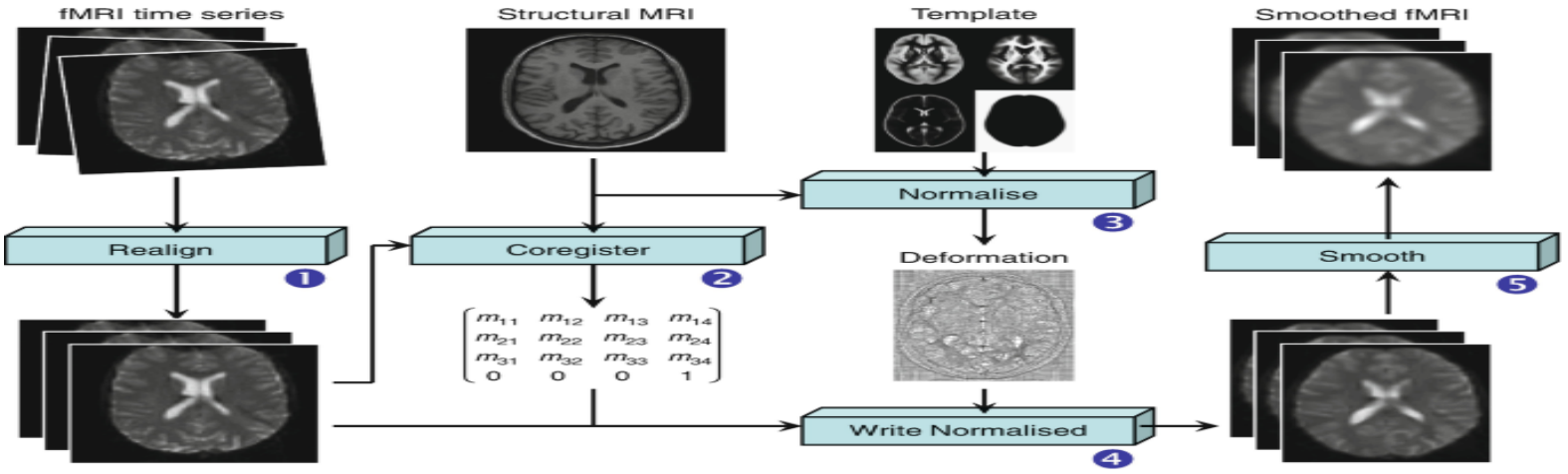
- 3T Siemens Trio TUN scanner
- - 3h of audiovisual movies that induce various types of emotions
- - 720 clips
- - 80 distinct emotion categories
- - data was collected over 3 separate sessions over 3 or 4 days.

Aim to collect samples to probe as small potential differences as possible, instead to examine the category set that has known to be distinctive in the existing literature. By using these many categories, our modeling approach aims to examine how many of these categories indeed form distinctive dimensions from the aspect of brain representations

Subjects

- - 8 subjects (S1 - S8), 4 female, 4 male
- - normal subjects that consented to watch extreme content
- - none of them has risk associated whit fMRI factors (pregnancy, metal implants, claustrophobia, pregnancy, experience of epileptic seizures, experience of head surgery).
- - 80 distinct emotion categories
- - All analyses were performed on individual brain space for each subject.
- The ethics and safety committees of the National Institute of Information and Communications Technology approved the experimental protocol.

fMRI data preprocessing



- - EPI data was preprocessed using Statistical Paramter Mapping toolbox (offer flexibility, uses Matlab)
- - Motion correction was based on the first image of the first scan for each subject
- - for each subject, cerebral cortex was segmented into 156 regions of the Destrieux Atlas using FreeSurfer.

Emotion Categories Selection

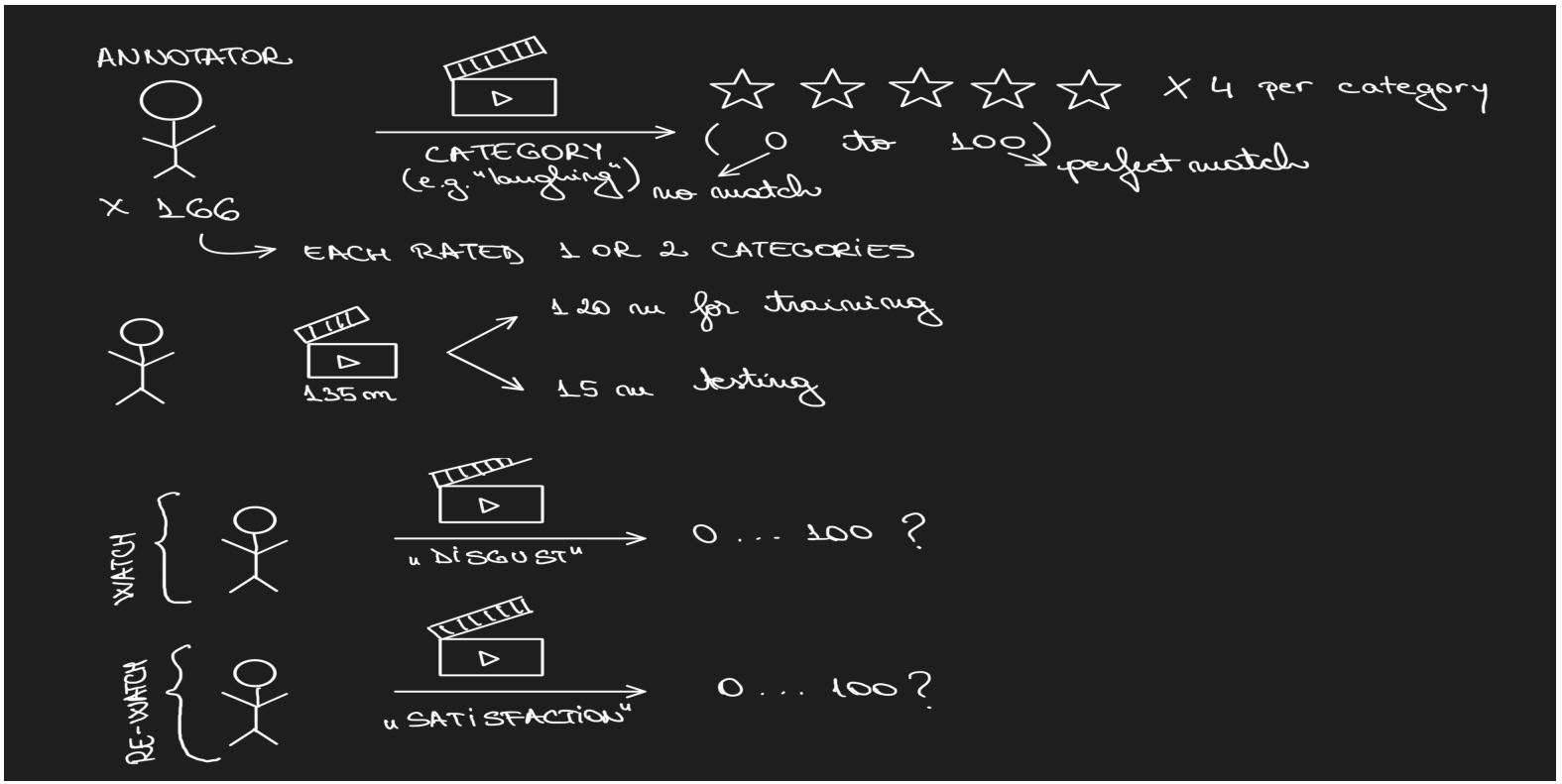
80 categories of emotion were selected from various reports as follows:

- Basic emotion theory (Plutchik, 1991),
- Core affective states(Russell and Barrett, 1991),
- A recent meta-analytical paper of emotion studies (Weidman et al., 2017),
- WordNet-Affect (Strapparava and Valitutti, 2004),
- 27 emotion categories reported in a recent behavioral study (Cowen and Keltner, 2017).
  In addition, to select emotion categories that are relevant to emotional experiences induced by movies, affective labels used on the movie review site as emotion categories was used.

Eighty emotion categories

Emotion Rating

- 166 annotators who **did not** participate in fMRI experiment were recruited.
- 4 independent ratings were collected for each of the 80 categories.
- Each annotator rated 1 or 2 movies, as follows:



Preprocessing

- The ratings for each annotator and each emotion were detrended by subtracting the results of median filtered signals (300 s time window).
- For each emotion category, the preprocessed ratings were averaged across those for the four annotators at 2-s resolution (i.e. BOLD sampling rate) and z-score normalized.
- *Z-Score value is to understand how far the data point is from the mean. Technically, it measures the standard deviations below or above the mean. It ranges from -3 standard deviation up to +3 standard deviation.*

Model fitting

To estimate the BOLD-response patterns to 80 emotion categories the below presented steps were followed:

- a **voxel-wise linear regression** model to explain the BOLD responses was constructed
- **L2-regularization** in the regression mode (due to its usage in previous neuroimaging studies)
- used an **input vector with annotator-averaged emotion ratings** (80 dimensions corresponding to 80 emotion categories) and **sensory factors** (visual and auditory features of 1000 dimensions each).
- remove spurious correlation caused by visual and auditory responses in the BOLD signals

Model fitting

- concatenated the emotion ratings with the sensory factors and used the resulting 2,080-dimensional stimulus vector as regressors.
- stimulus vector was concatenated with three temporal delays (6240 dimensions)
- model weights were optimized by least squares with L2-regularization
- regularization coefficient was optimized in 10-fold cross validation using 10 unique training- validation. **Highest accuracy across 10 repetitions within the cross validation.**
- A regression model with the best gamma using the training data (3600 samples) and computed the prediction accuracy using the test data (1800 samples).

To construct the semantic space of emotion, voxels with high prediction accuracy was employed (uncorrected $p < 0.0001$) for the test data (18,684–34,066 cortical voxels per subject).

Removing spurious correlation between emotion ratings and sensory information

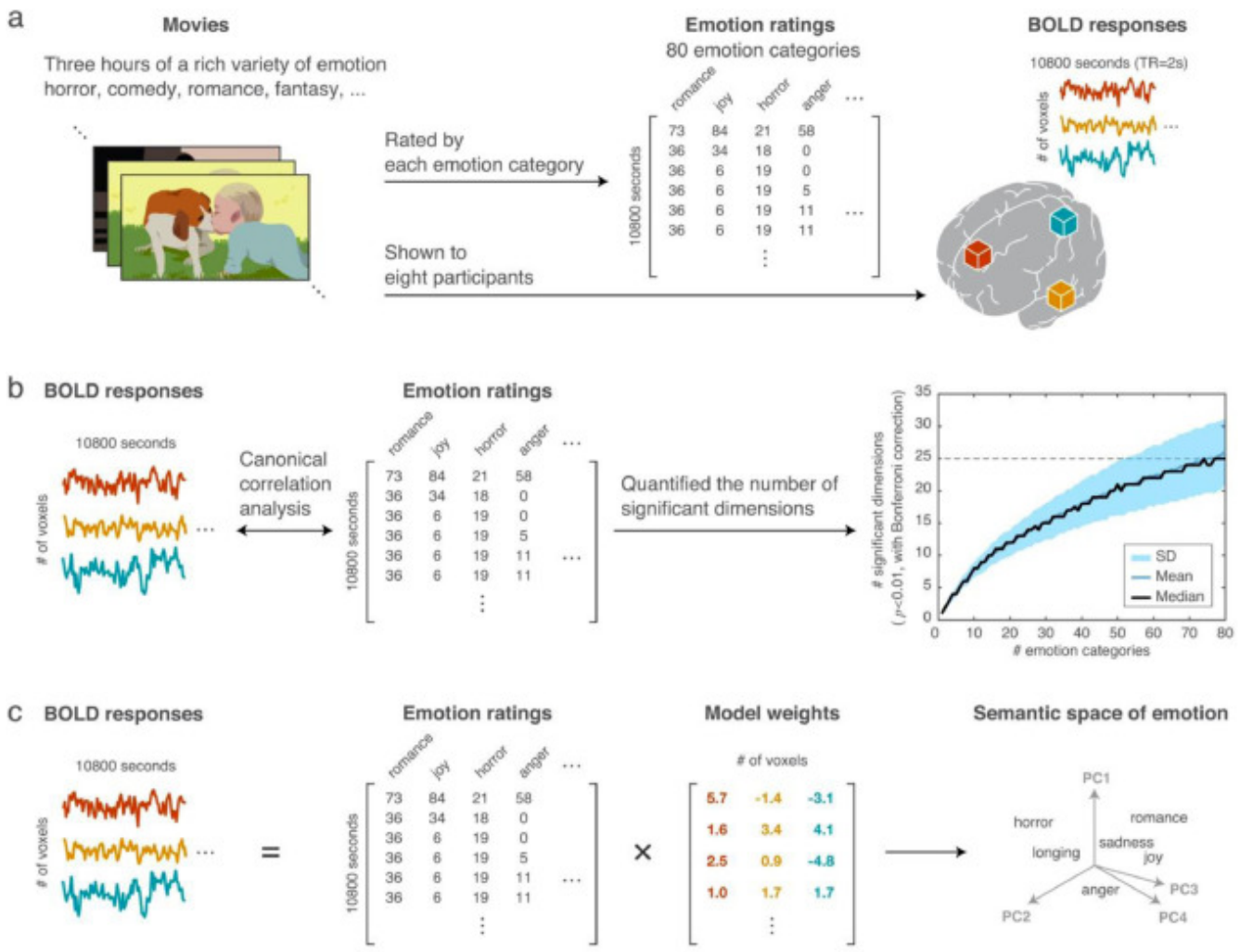
- concatenated the emotion ratings with the sensory factors and used the resulting 2,080-dimensional stimulus vector as regressors.
- stimulus vector was concatenated with three temporal delays (6240 dimensions)
- model weights were optimized by least squares with L2-regularization
- regularization coefficient was optimized in 10-fold cross validation using 10 unique training- validation. **Highest accuracy across 10 repetitions within the cross validation.**
- A regression model with the best gamma using the training data (3600 samples) and computed the prediction accuracy using the test data (1800 samples).

Correlation between emotion ratings and BOLD responses

25 dimensions of emotion ratings were significantly correlated with the BOLD responses

- The sudy aimed to elucidate the represenation of a rich variety of emotions, using 8- categorical emotion labels.
- Researchers used numbers from 1 to 80 for emotion categories.
- The number of significant dimensions ranged from 18 to 36 across subjects, and the median was 25.

Representation of correlation between emotion ratings and BOLD responses

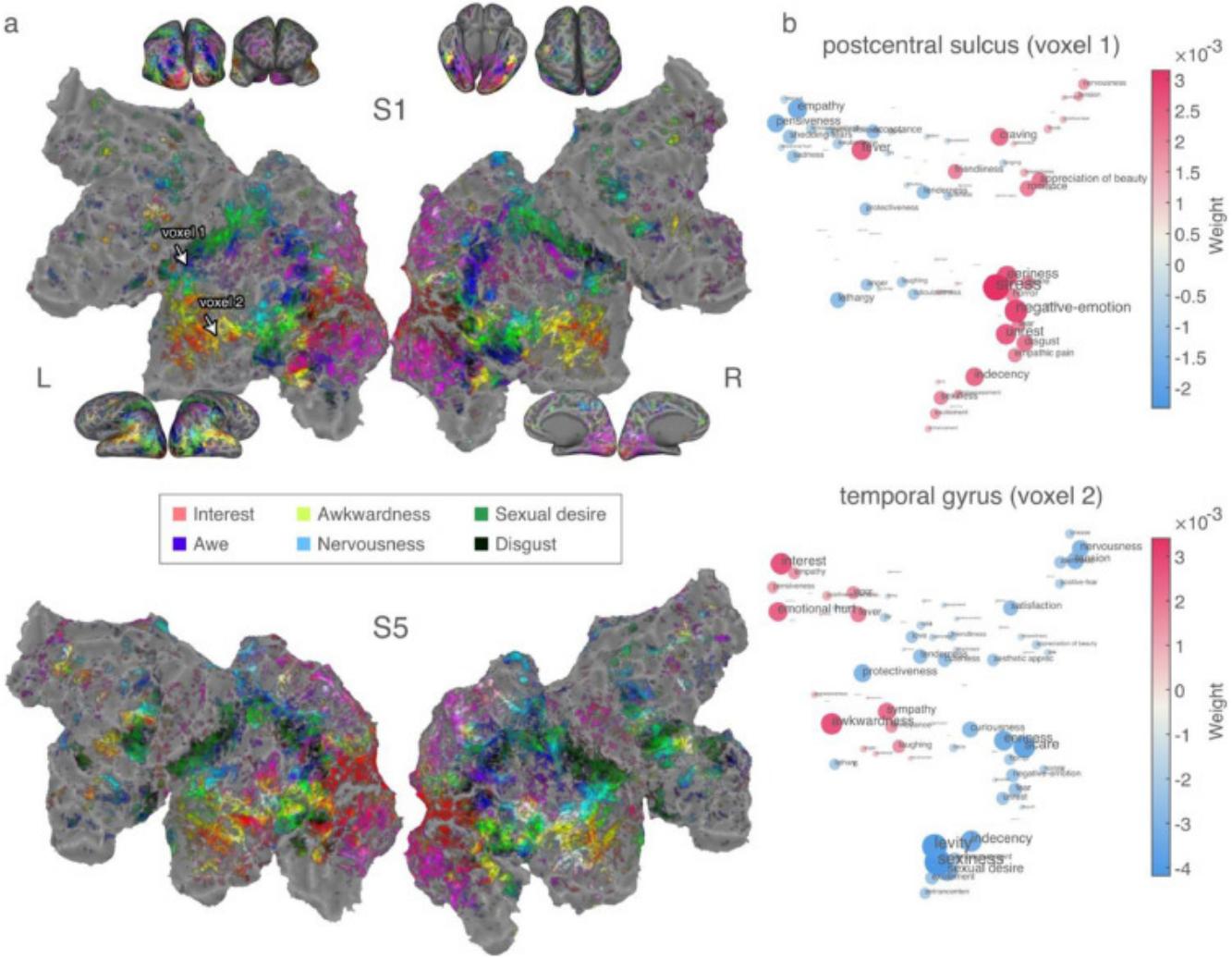


Legend:

Fig. 1. Schematic of the experiment and procedure for constructing a semantic space of emotion.

- a. BOLD responses for eight subjects were measured while they watched emotion-inducing movies for 3 h. Each movie scene was rated according to 80 emotion categories.
- b. Canonical correlation analysis was performed to examine how many distinctive dimensions of the 80 emotion categories were informative to explain the associated BOLD responses.
- c. The voxel-wise response was modeled as a linear weighted sum of the emotion ratings using an L2-regularized regression procedure. A semantic space was constructed by performing a dimension reduction on the estimated model weights.

Cortical map of the semantic space of emotions



Legend:

- a. Cortical maps for two subjects (S1 and S5). Emotion representations were visualized by assigning RGB colors according to the three main components of the semantic space (see Materials and Methods). The legend presents six representative colors and the corresponding emotion categories. In each cortical map, we show the results only for voxels showing significantly high prediction accuracy ($p<0.0001$, uncorrected).
- b. Examples of the weight distribution for two voxels in the postcentral sulcus and the temporal gyrus of a single subject (S1). The positions of the two voxels are indicated on the cortical map of S1. Red denotes positive weight and blue denotes negative weight.

Summary of strengths

- Subjects have been chosen carefully
- How the 80 categories of emotion were selected from various scientific reports.
- Ethics and Safety committees approved the study
- Scientific paper is very organized and clear, providing brief explanations
- Novel technologies and performant fMRI scanner were used

Summary of weaknesses

- I consider this paper to be interesting, but it's a bit too specific when speaking of medical terms, so it took me way more than I expected to go through it, as I wanted to be aware of everything that was presented.

Limitations

- As mentioned in the paper as well, the study demonstrated the localization of emotion categories in the entire cortex, but not in the sub-cortex alone. This is to be mentioned, because studies conducted prior to this one focused on localization of the basic emotions in **sub-cortical ares**