Population Coding of Affect Across Stimuli, Modalities and Individuals

Chikazoe J, Lee DH, Kriegeskorte N, Anderson AK. (2014). Nature Neuroscience.

What is affect?

Circumplex Model

Philosophy: aspects of perception that are inherently the most subjective (Wundt W, 1897)

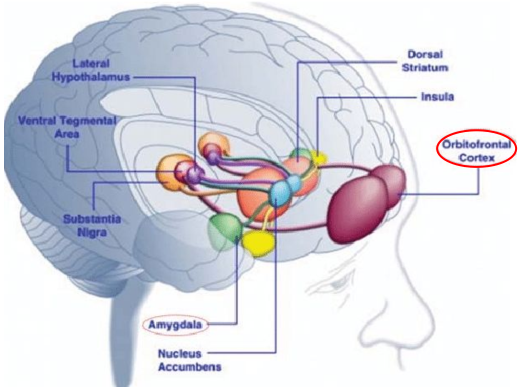
Psychology: a circumplex model - valence & arousal (Russell JA, 1980)

Neuroscience:

- Hemisphere (emotion lateralization)
- Population
- Single neuron (valence-tuning cells)

Background & Questions

Orbitofrontal Cortex (OFC)



mOFC is sensitive to affective (neg-pos) visual stimuli (Shenhav A et al., 2013)

Valence-coding neurons (neg-pos-both) in monkey's Walker's area 13. (Morrison SE et al., 2009)

1. **How**
   - Discrete vs Continuous

2. **Where**
   - Single Unit vs Network
   - Inside vs Outside of perceptual cortex

3. **Universality**
   - Sensory modalities
   - Cross subjects

Research Framework

Experiments

16 Subjects

Visual
(128 images)

Gustatory
(100 taste solutions)

Data Collection

Perceptual Rating
(Positivity & Negativity)

BOLD-MRI Signal

Analysis

Representational Similarity Analysis (RSA)

Searchlight Analysis

Classification

...

Conclusion

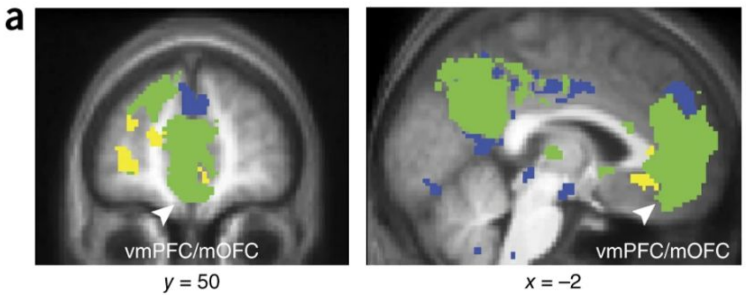
How?

Where?

Universal?

Exploratory Results - Visual

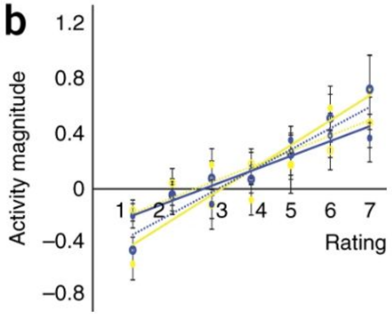
1. Valence-sensitive Regions (activation)



Positive 17.1%

Negative 7.2%

Both 75.7%



In common region:

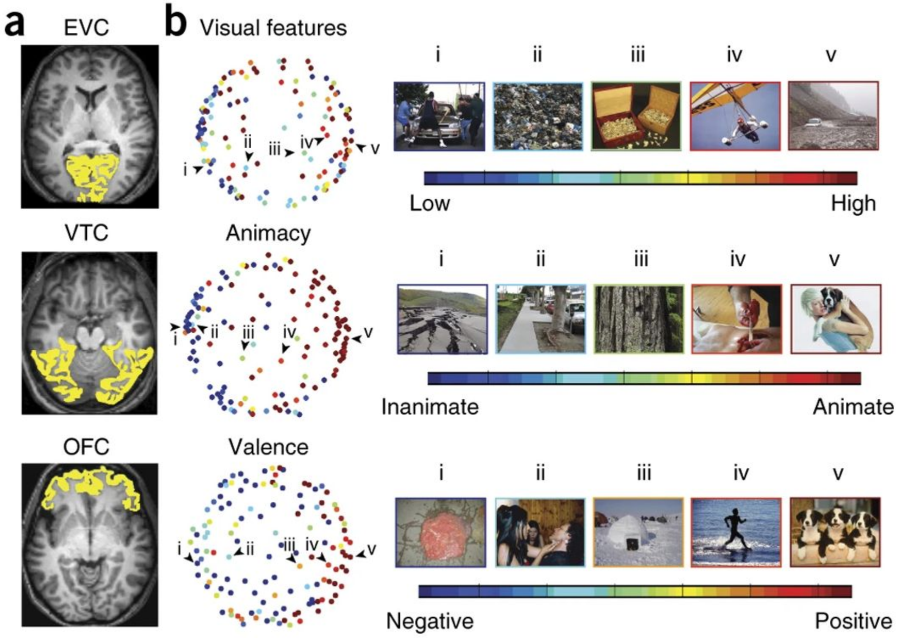
- Peak Pos Voxel - Pos Rate
- Peak Pos Voxel - Neg Rate
- Peak Neg Voxel - Neg Rate
- Peak Neg Voxel - Pos Rate

Takeaways: (1) OFC is an affect-sensitive region; (2) Large overlap of pos- and neg-sensitive regions across the brain

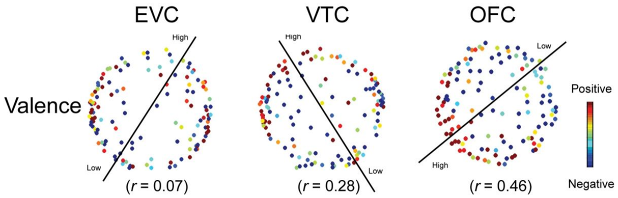
Takeaways: Higher activation, higher rating (neg, pos). However, arousal may be a confound.

2. RSM

ROI **MDS** **Images**

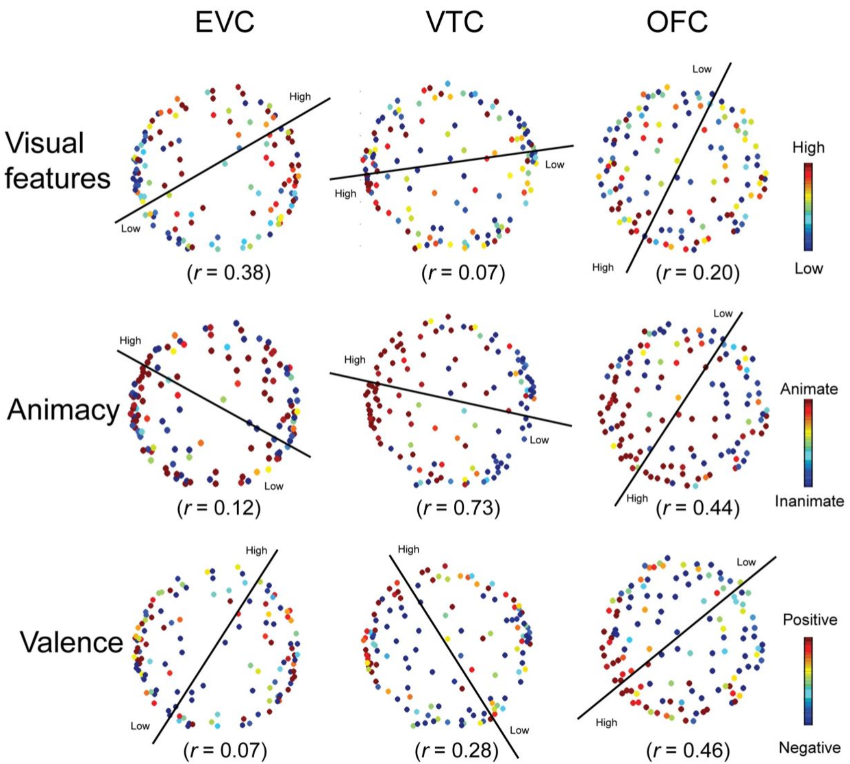


Takeaways: response patterns are organized maximally by gradations of valence rating in the OFC



Correlation between projections on the best-fitting axis and valence rating

2. RSM



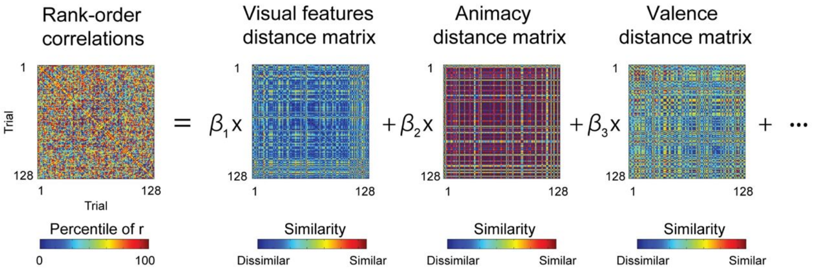
EVC
VTC
OFC
Visual features
Animacy
Valence
High
Low
(r = 0.38)
(r = 0.07)
(r = 0.20)
(r = 0.12)
(r = 0.73)
(r = 0.44)
(r = 0.07)
(r = 0.28)
(r = 0.46)
Animate
Inanimate
Positive
Negative

Where and How?

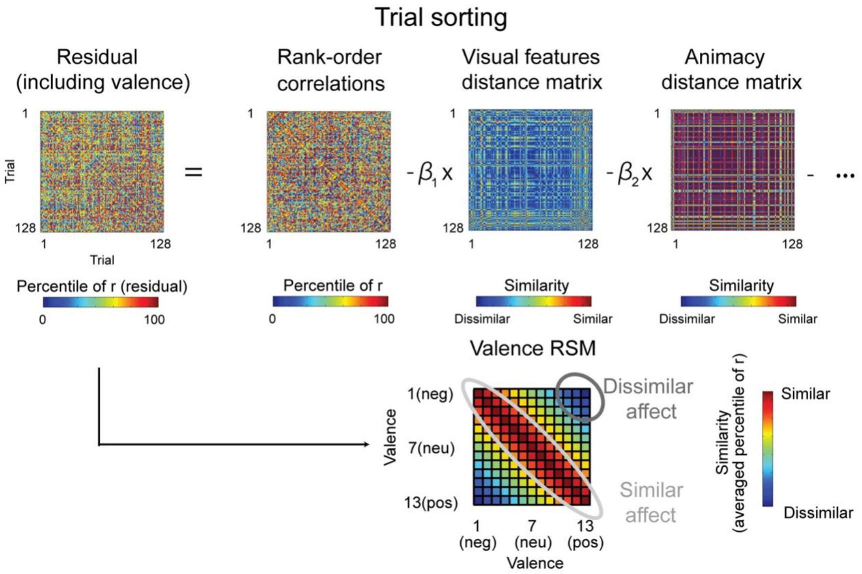
3. Residual RSM

Perform GLM Decomposition and examine the representation similarity of residuals

Model

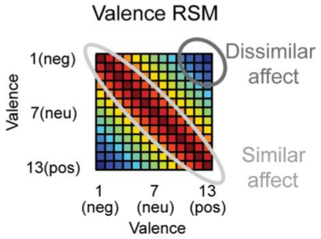


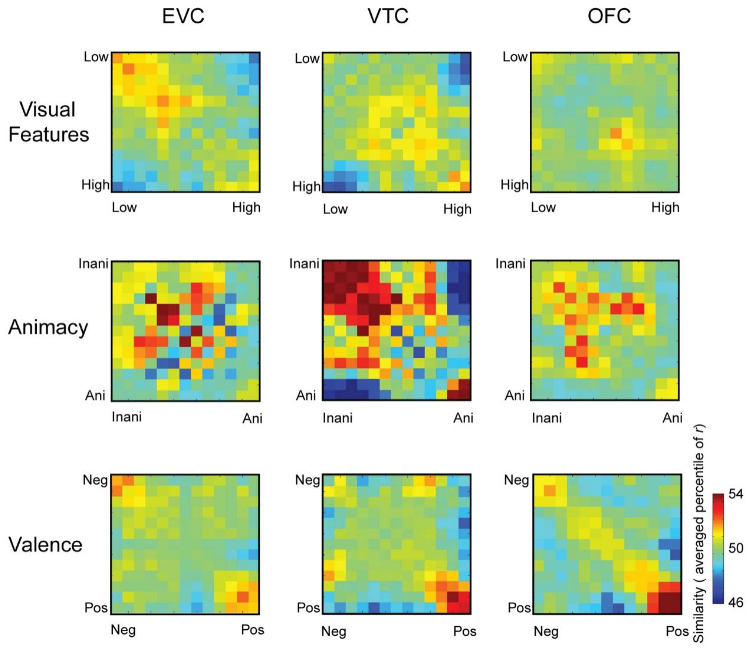
Residual

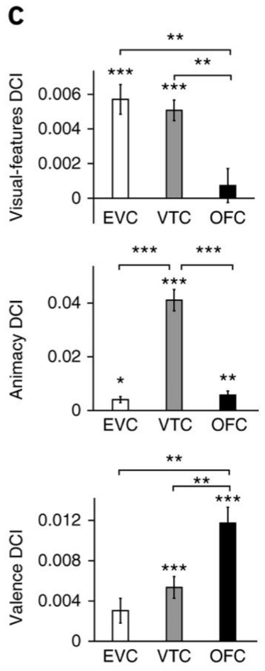


3.1 Residual RSM - Cortex Level

Ideal



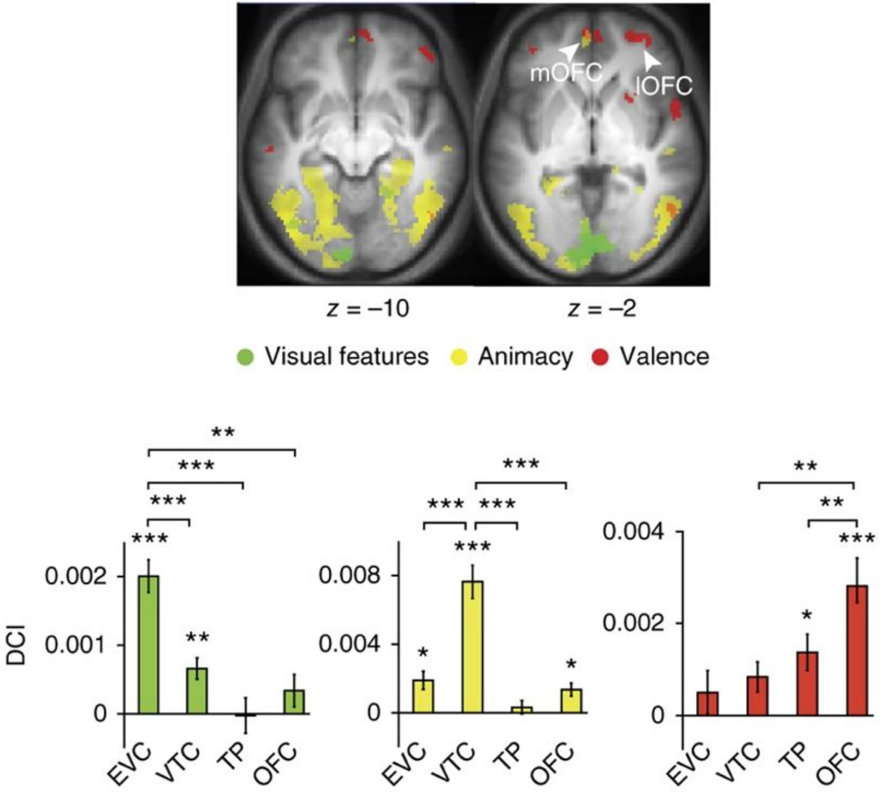




Error bar measures individual variability

Takeaways: Visual scenes differing in objective visual features and animacy, but evoking similar subjective affect, resulted in similar representation (1) mostly in the OFC; (2) also in VTC

3.2 Residual RSM - Regional Level



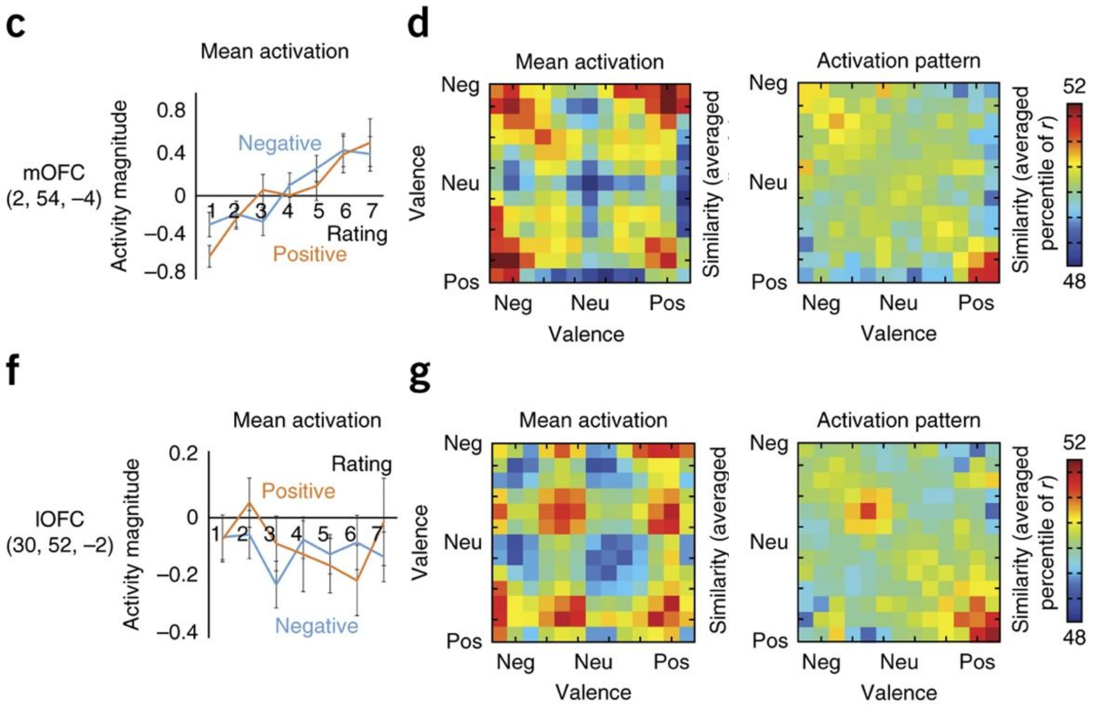
Takeaways:

(1) posterior-anterior pattern in representing hierarchical information;

(2) valence was maximally represented in the vmPFC (medial, lateral OFC) and moderately represented in the ventral and anterior temporal regions (temporal pole);

(3) Object and affect representations are not only represented as distributed activation patterns across large areas of cortex, but are also represented as distinct region-specific population codes (1cm2 cube)

4. Intensity or Valence?



Takeaways:

(1) Mean-based GLM decomposition analysis revealed a lack of valence specificity in mean magnitude;

(2) Pattern-based approach showed a clear separation of valence with positive and negative valence lying on opposite ends of a continuum.

Main Findings

1. **How**
    - Discrete vs Continuous

    Population activity in a region supported a continuous dimension of positive-to-negative valence.

2. **Where**
    - Single Unit vs Network
    - Inside vs Outside of perceptual cortex

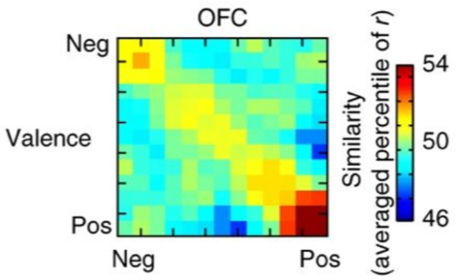
    A complex scene is transformed from a basic perceptual features and higher level object categories into affective population representations.

3. **Universality**
    - Sensory modalities
    - Cross subjects

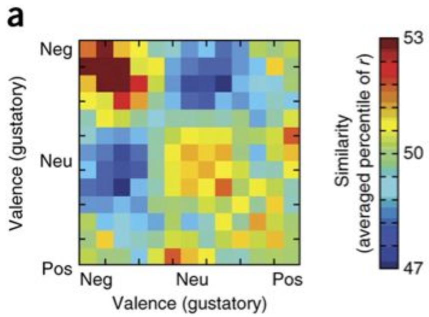
Universal (Modality)?

5. Visual-Gustatory RSM - Cortex Level

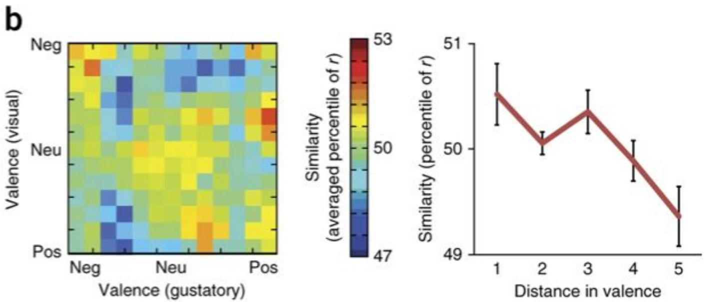
Visual-Visual



Gustatory-Gustatory



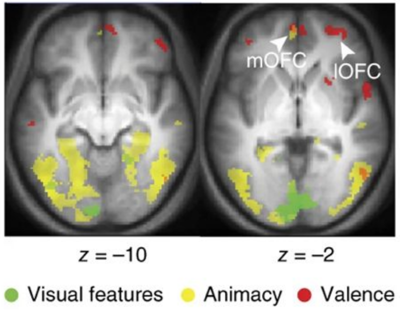
Visual-Gustatory (OFC)

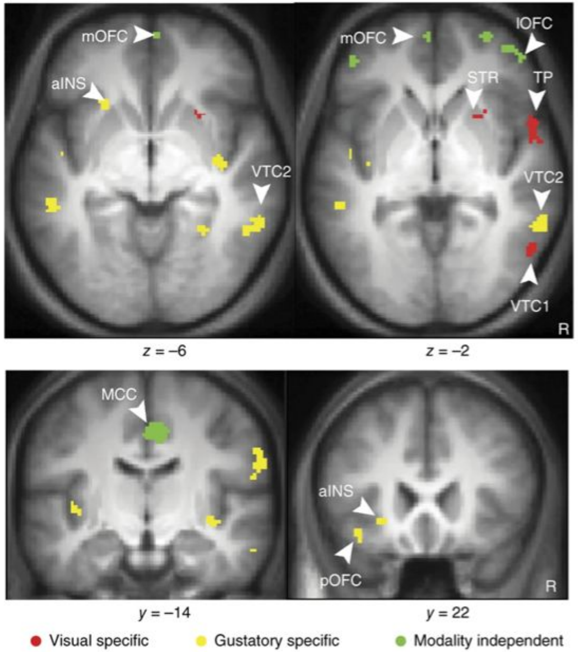


Observation: The V-G pattern is not as “ideal” as V-V or G-G.

6. Modality-specific vs Supramodal Code of Valence

Visual Only





Takeaways:

(1) vmPFC (medial, lateral OFC) and Midcingulate Cortex (MCC) for supramodal coding of valence;

(2) Posterior cortical representation in the temporal lobe and insular cortices were unique to the sensory modality of origin.

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3. **Universality**
   - Sensory modalities

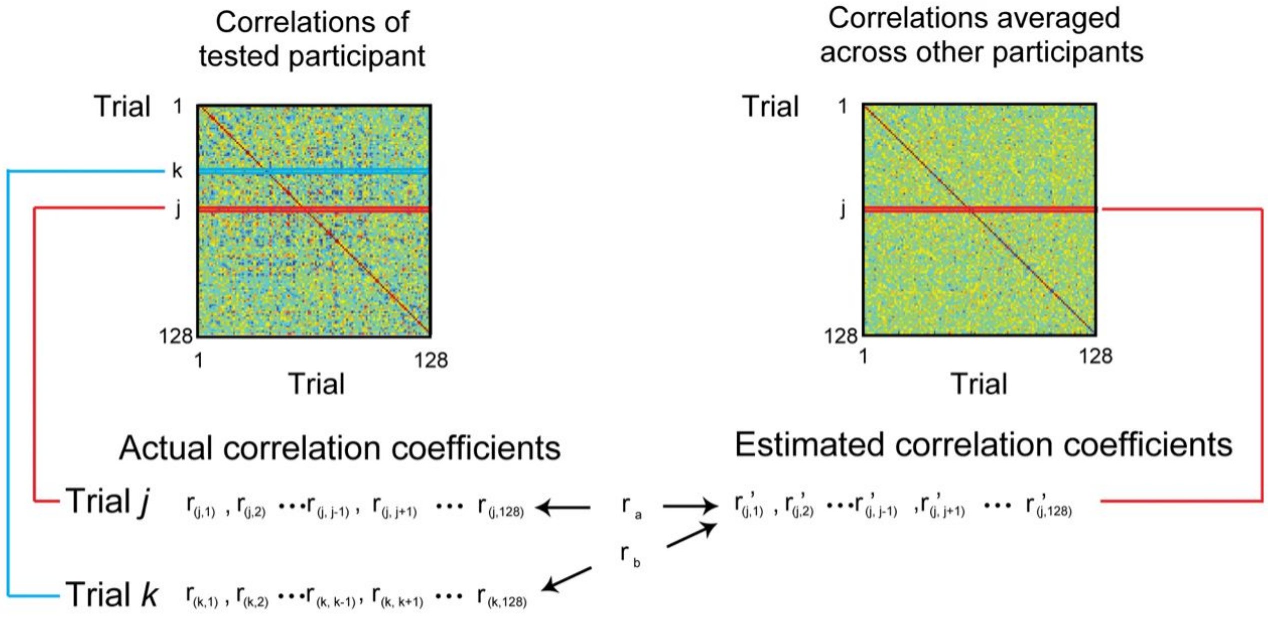
     Both sensory specific and sensory independent

     posterior part (temporal lobe and insular cortices) were unique to the sensory modality

     more anterior part (medial and lateral OFC) afforded a translation across modalities
   - Cross subjects

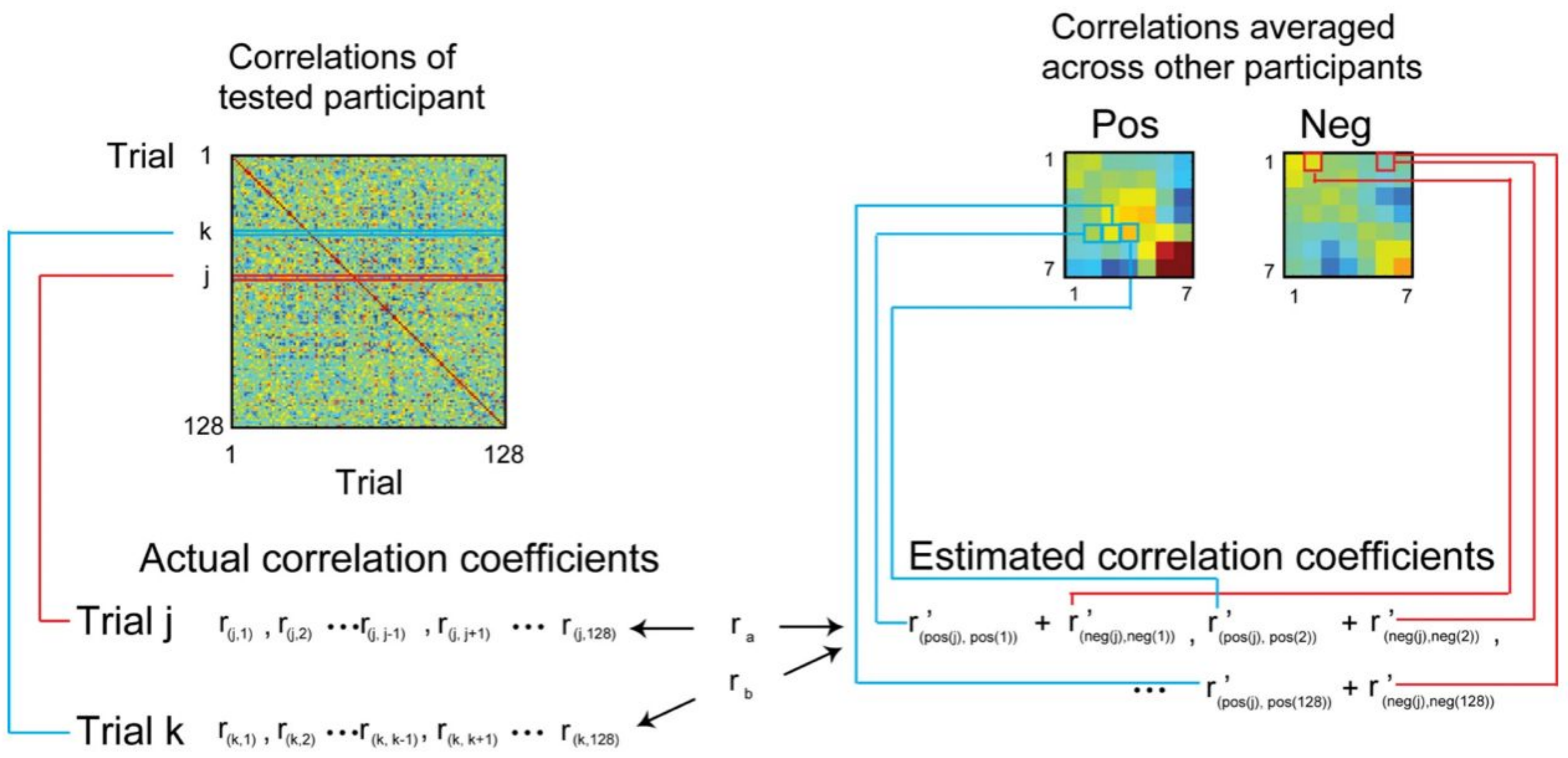
Universal (Cross-subject)?

7.1 Item Classification

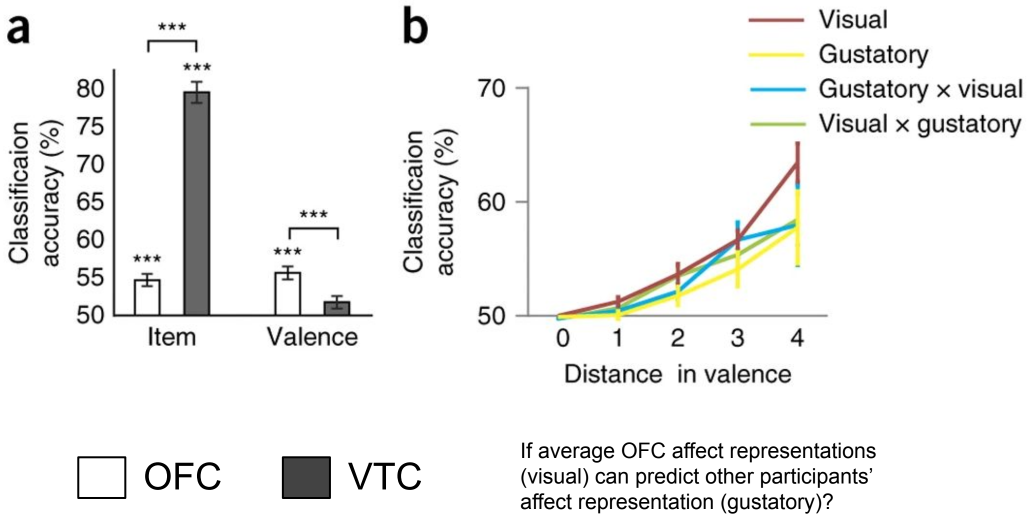


If $r_a > r_b$, it is taken as correctly classified.

7.2 Valence Classification



7.3 Classification of affect brain states across participants



If average OFC affect representations (visual) can predict other participants' affect representation (gustatory)?

Takeaways:

(1) Item-specific information is more robustly translatable across participants in VTC compared with the OFC; valence-specific information shows the pattern the other way around.

(2) Even without an overlap in modality, the OFC supported classification of the affect experience across individuals.

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    Neural population vector in a region may represent the affective coloring of experience, whether between objects, modalities, or people.

Reference

Chikazoe J., Lee D.H., Kriegeskorte N., Anderson A.K. (2014). Population coding of affect across stimuli, modalities and individuals. Nature Neuroscience, 17(8), 1114-1122

Russell, J.A. A circumplex model of affect. *J. Pers. Soc. Psychol.* 39, 1161–1178 (1980).

Shenhav, A., Barrett, L.F. & Bar, M. Affective value and associative processing share a cortical substrate. *Cogn. Affect.* Behav. Neurosci. 13, 46–59 (2013).

Wang S. et al. (2017). The human amygdala parametrically encodes the intensity of specific facial emotions and their categorical ambiguity. Nature Communication 8, 14821.