Neural Mechanisms of Attention to Objects

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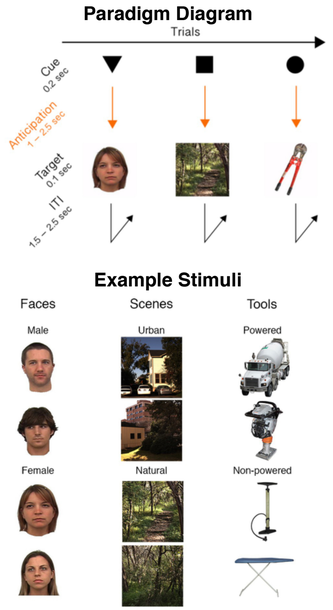
Introduction

- Alpha band (8-12 Hz) oscillatory neural activity may reflect functional inhibition (Jensen and Mazaheri, 2010), and may be part of neural mechanisms of attention.
- Anticipatory visual attention to different spatial hemifields is associated with contralateral decreases in alpha band EEG power (Worden et al., 2000).
- An analogous modulation of alpha-band EEG activity has been observed in brain areas associated with color and motion in a visual feature-based attention experiment (Snyder and Foxe, 2010), suggesting a common visual attentional mechanism.
- If top-down visual attention operates on the cortical areas associated with target visual information by the same mechanism throughout the visual system, we would expect to observe alpha-band modulation in forms of attention targeting higher-level visual features, such as objects (including faces, places, tools, etc.)
- **Hypothesis: Different patterns of alpha-band EEG scalp topography accompany anticipatory attention to different categories of objects.**

Experiment 1 – Methods



Object-based attention paradigm

Participants were instructed:

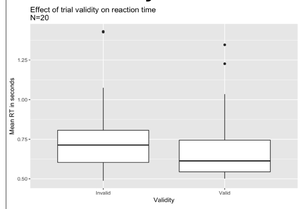
- **Triangle** cue indicates upcoming **face**
- **Square** cue indicates upcoming **place**
- **Circle** cue indicates upcoming **tool**
- Use cue to prepare for upcoming target
- Press Button 1 (button box, index finger) for **male** face, **nature** scene, or **powered** tool
- Press Button 2 (button box, middle finger) for **female** face, **urban** scene, or **unpowered** tool
- All stimuli presented at center fixation
- 80% cue validity, to measure behavioral difference between validly cued and invalidly cued trials
- 20 undergraduate volunteer participants
- 420 trials for each participant

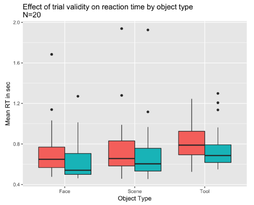
Electroencephalogram (EEG) recording and pre-processing details

- 64 active scalp electrodes (no electrooculogram)
- Average referenced offline
- Less than 5% of trials rejected by manual inspection for noise and muscle artifacts
- Eye blink artifacts removed by independent component analysis

Experiment 1 – Results

Reaction time difference between Invalid and Valid trials reflects object-based attention

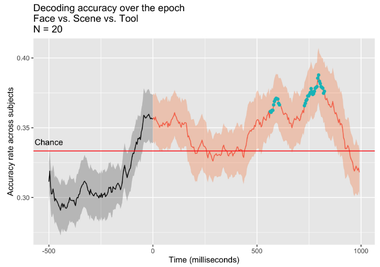




Generalized linear mixed model results (see Lo and Andrews, 2015)

- Random effect of Subject
- Gamma-distributed RT model
- Significant effect of Validity ($p < 0.001$)
- Significant effect of Object ($p < 0.001$)

SVM decoding reveals time course of significant differences between alpha power scalp distributions



- To assess whether alpha topography contained information about the attended object category, we utilized a support vector machine (SVM) learner to decode the attention condition at every sample point across the epoch.
- For a given time point, decoding accuracy significantly above chance indicates that alpha topography is significantly different between attention conditions.

Details of decoding procedure

- One vs. one error-correcting output codes (ECOC) classification with SVM learner
- 10 iterations of 6-fold cross validation
- Performed within-subject, at every sample point (250 Hz)
- Decoding software from Matlab Deep Learning Toolbox

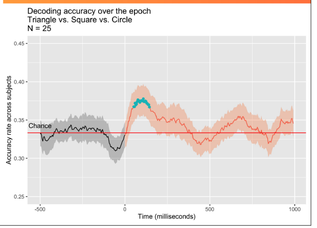
Details of statistical significance assessment

- At each time point, we performed a one-tailed *t* test of decoding accuracy across all participants against chance (one third).
- We constructed a null distribution of the summed *t* values (*t* masses) of h=1 clusters across 1000 iterations of simulated decoding results using random sampling with replacement.
- We determined the α=0.05 critical *t* mass from this null distribution.

Experiment 2 – Methods

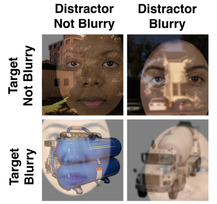
- Paradigm identical to that of Experiment 1, except that cue shape was not predictive of subsequent object category (cue validity set to 33%)
- Participants instructed that cue shape is not meaningful, but not explicitly instructed to ignore the cue shape
- All environment and EEG acquisition variables equated to those of Experiment 1
- 25 undergraduate volunteer participants
- All EEG preprocessing and analysis methods identical to those of Experiment 1

Experiment 2 – Results

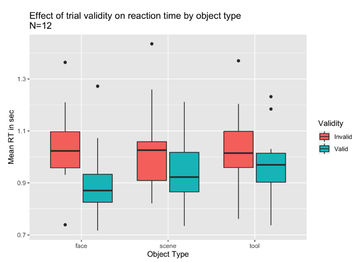


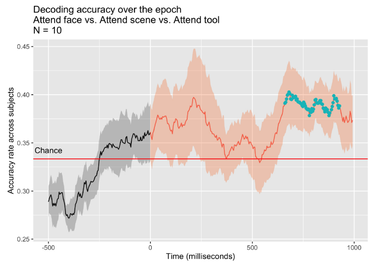
Experiment 3 – Methods

- General structure of paradigm similar to that of Experiment 1, but task was equated across all object category conditions: press Button 1 if cued object image is blurry, press Button 2 if cued object image is in-focus.
- For valid trials (75% of trials), target stimuli were image blends comprising a cued object image and an uncued, distractor image.
- For invalid trials, stimuli were image blends comprising a checkerboard mask and an uncued object image.
- 10 undergraduate volunteer participants
- All EEG preprocessing and analysis methods same as those of Experiment 1



Experiment 3 – Results





Conclusions

- Cue-directed anticipation of different object categories produces behavioral attention effects as conventionally operationalized.
- Anticipatory attention to different categories of objects produces different patterns of alpha band EEG power at the scalp, suggesting different alpha generators in the brain.
- Scalp-distributed alpha band power is significantly different between attention to faces, places, and tools in the range 500 – 900 msec.
- This finding was replicated using a category-neutral behavioral task (Experiment 3), suggesting that task set or motor preparation differences are not driving the effect.
- Stimulus-evoked sensory activity could only be decoded up to 200 msec after cue onset (Experiment 2), suggesting that decoding results in the 500 – 900 msec range cannot be attributed to physical properties of cue shapes.

References & Acknowledgements

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Decoding procedure adapted from: Bae, G. Y., & Luck, S. J. (2018). Dissociable Decoding of Working Memory and Spatial Attention from EEG Oscillations and Sustained Potentials. The Journal of Neuroscience, 38, 409-422.

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