Early object-based top-down modulation in an attention and working memory task

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Introduction

- There is ample evidence regarding the ability of attention to bias neural processing at the level of distinct objects. Furthermore, there is much to corroborate a "biased competition" model of attention, in which objects in the visual field compete for cortical representation with limited neural resources, with the bias favoring the behaviorally relevant stimulus[1].
- Attentional modulation of the early N1/N170 component (~170 ms) has been shown to occur across a wide variety of attention paradigms (spatial-[2], feature-[3], object-based[4]).
- While modulation of the early P1 component (~100 ms) has been observed for location-based[2], feature-based[3], and some low-level object-based attentional tasks[5], it has never been reported in an object-based task utilizing complex, real-world stimuli such as faces and scenes.
- While it has been shown that attention to objects such as faces can modulate neural processing as early as 170 ms[4], it is a subject of controversy whether object-based attention can modulate earlier markers of processing.

EEG Methods

Participants

20 healthy right-handed individuals (mean--23.25 years, range--18-34 years, 10 males) are considered in the behavioral data. 17 of these subjects are included in the neural results (mean - 23.53 years, range - 18-34 years, 9 males)

Stimuli

The stimuli consisted of grayscale images of faces and natural scenes. The face stimuli consisted of a variety of neutral-expression male and female faces. Hair and ears were removed digitally as to remove any potential non-face-specific cues. For three of the five conditions, one face and one scene image were randomly paired, made transparent, and digitally overlapped using Adobe Photoshop CS2 such that both the face and scene were equally visible.

EEG Recording

Neural data was recorded with a BioSemi ActiveTwo 64-channel EEG acquisition system in conjunction with BioSemi ActiView software (CortechSolutions, LLC). Signals were amplified and digitized at 1024 Hz with 16-bit resolution. All electrode offsets were below 25kΩ. Markers of stimulus presentation were acquired by a photodiode.

Data Analysis

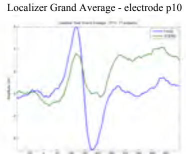
Pre-processing was conducted through Analyzer software (Brain Vision, LLC). Off-line, the raw EEG-data were referenced to an average reference, eye-movements and artifacts were removed through an independent component analysis and a voltage threshold of +/-50uV, and artifact-free data epochs were signal-averaged by trial. Stimulus-locked event related potentials (ERPs) were extracted during the analysis procedures. Epochs from correct trials in each condition were separately segmented and averaged. ERPs from each of the five conditions included a mean of 104 averaged epochs (range 70-120). ERP peak latencies and amplitudes were chosen using the same time windows used in the localizer analysis (see below).

Localizer Task

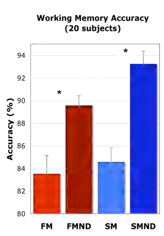
A separate localizer task was used to define electrodes of interest (EOIs) in each subject[7]. The task consisted of a classic 1-back design in which subjects attended to intermixed blocks of faces and scenes. Face and scene trials were then separately segmented and averaged.

- *P1 component*
  the first positive deflection appearing between 50 and 150 ms after stimulus onset at posterior sites.
- *N170 component*
  the maximal negative peak between 120 and 220 ms after stimulus onset at posterior sites.
- The lateral posterior electrode that showed the largest P1 and N170 amplitude difference between faces and scenes was chosen as that subject's P1 EOI and N170 EOI respectively.

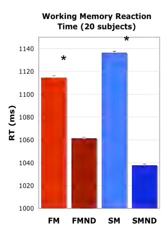
Localizer Grand Average - electrode p10



Behavioral Data



- Measures of working memory accuracy revealed a significant decrease in overlap conditions relative to the no-distractor conditions.
- The WM impairment was also evident in the corresponding increase in response time for overlap conditions.
- Mean accuracy in the PV condition was 99.3%, mean RT was 610 ms. (not shown).



Experimental Paradigm

- Face Memory, No Distractor (FMND condition)

The Encode-1 and Encode-2 faces are remembered. There is no distracting information. Subjects indicate whether or not the Probe is a match.

- Face Memory (FM condition)

The Encode-1 and Encode-2 faces are remembered while the scenes are ignored. Subjects indicate whether the face Probe is a match.

- Passive View (PV condition)

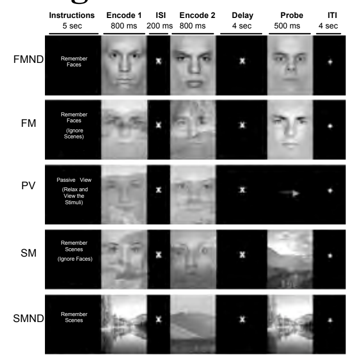
The Encode-1 and Encode-2 scenes are viewed passively, without trying to remember them. Subjects indicate whether the arrow points left or right.

- Scene Memory (SM condition)

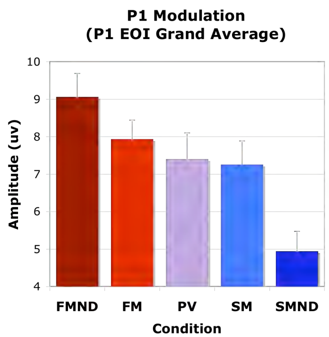
The Encode-1 and Encode-2 scenes are remembered while the faces are ignored. Subjects indicate whether the scene Probe is a match.

- Scene Memory, No Distractor (SMND condition)

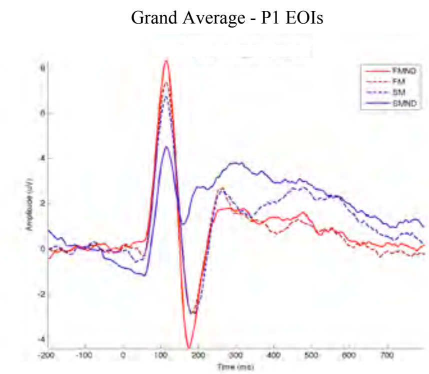
The Encode-1 and Encode-2 scenes are remembered. There is no distracting information. Subjects indicate whether or not the Probe is a match.



ERP Neural Data



Grand Average - P1 EOIs



Top-down Modulation of P1 amplitude

Although the FM and SM conditions were composed of the same *bottom-up* information (an overlapped face and scene), amplitude of the P1 in the FM condition was significantly modulated closer to that of the FMND condition, while amplitude of the SM condition was significantly modulated closer to that of the SMND condition. (Amplitude of the PV condition was not significantly different than FM or SM). Surprisingly, N170 amplitude did not show any significant modulatory effects.

Average EOI amplitude
FMND - 9.06 μV
FM - 7.93 μV
SM - 7.25 μV
SMND - 4.94 μV

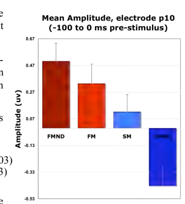
all p-values < 0.02

Anticipation

- The data show a trend indicating that before presentation of the stimuli, modulation might already be occurring.
- Epochs from each condition were baselined at -200 to -100 ms relative to stimulus onset. Mean amplitudes from -100 to 0 ms were then examined.
- FM is modulated closer to FMND while SM is modulated closer to SMND.

FMND vs. SMND (p<0.001) FM vs. SMND (p<0.003)
FM vs. SM (p=0.20) SM vs. FMND (p<0.03)

- The PV condition is again found in the middle (0.19 uV), although it is not significantly different than the FM or SM condition.

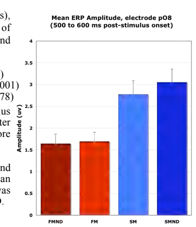


Late ERP

- Later in the processing stream (500-600 ms), neural representation (in lateral electrodes) of FM and SM approach that of FMND and SMND respectively.

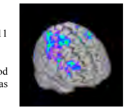
SM vs FM (p<0.002) FM vs SM (p<0.002)
SM vs.FMND (p<0.006) FM vs.SMND (p<0.001)
SM vs SMND (p=0.13) FM vs FMND (p=0.78)

- This suggests that late in the stimulus presentation period, subjects are able to filter out the irrelevant object while focusing more exclusively on the relevant object.
- This finding is not true for all preceding and successive 100 ms increments. Also, PV mean amplitude fell in the middle (1.52 uv), but was not significantly different than FM or FMND.



fMRI data

Methods



Participants

22 healthy right-handed individuals (mean--27.6 years, range--23-35 years, 11 females) with normal or corrected to normal vision took part.

Experimental Procedure

Blocks were similar to those in the EEG experiment, except both the Delay period and ITI were extended from 4 seconds to 8 seconds. A similar Localizer task was used to define stimulus-specific regions of interest such as the PPA.

Data Acquisition

Data were acquired on a Siemens 3T Trio Scanner using a 1.75 x 1.75 x 3.5 mm voxel size, TR of 2 seconds, and 33 slices.

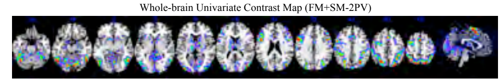
Data Analysis

Raw EPIs were corrected for slice-timing, motion-corrected, and smoothed using SPM. Images used for whole-brain analysis were normalized into MNI space prior to smoothing while images for ROI analysis were conducted in subject-native space. Data was modeled using a general linear model in SPM. ROI extraction/analysis was conducted using an ANOVA with multiple-corrections in MATLAB.

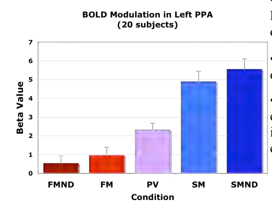
Results

- As in the EEG experiment, working memory accuracy showed a significant decrease and response time showed a significant increase in overlap conditions relative to no-distractor conditions. (Data not shown).

Whole-brain Univariate Contrast Map (FM+SM-2PV)



- Functional Regions of Interest (ROIs) were created using a localizer task similar to the EEG portion of the experiment. Anatomically restrained ROIs were composed of the 35 contiguous voxels that maximally responded to either faces or scenes.



- BOLD activity in the Parahippocampal Place Area (PPA) serves as a neural marker of scene processing.
- There is significant top-down modulation of the left PPA in overlap conditions.
- Although the FM and SM conditions consisted of the same bottom-up information, PPA activities in these conditions were significantly

FM vs FMND (p=0.93)
FM vs PV (p<0.01)
FM vs SM (p<0.001)
FM vs SMND (p<0.001)
SM vs SMND (p=0.41)
SM vs PV (p<0.001)
SM vs FMND (p<0.001)

- Theories of top-down modulation postulate that activity changes in posterior visual association cortex (VAC) is mediated by control areas of the prefrontal cortex[8]. Whole brain univariate activity maps (above: FM+SM-2PV) suggest the involvement of prefrontal and parietal networks in the modulatory processes.

Summary

- In sum, the present study shows top-down modulation of very early neural markers in an object-based attention paradigm.
- To rule out any indirect influences from spatial attention we utilized overlapping transparent images of faces and scenes, with either the face or the scene relevant and the other irrelevant. In this way, subjects were obliged to concurrently attend to one object while ignoring the other, independent of any spatial clues.
- *Bottom-up* information was held constant in a spatially-overlapped image of a transparent face and scene, while task goals were manipulated. Neural processing of these objects was modulated by task goals (as early as 111-118 ms).

Conclusions

- **We present the first evidence of top-down modulation of the P1 component in an object-based attention paradigm using complex, real-world stimuli such as human faces and natural scenes.**
- **These ERP data add important information about the time course of object-selective processing in posterior sensory cortices that is not possible using methods such as fMRI with low temporal resolution.**
- **When the same paradigm was performed in an fMRI experiment, BOLD measures revealed a similar pattern of top-down modulation in visual association cortices. This modulation is presumably mediated by networks with prefrontal control regions.**

References

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