

# The impact of attended and unattended distractors on working memory maintenance



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## Introduction

There is evidence that distraction plays a role in disrupting working memory (WM) performance (Sakai 2003; Sakai & Passingham 2004; Yoon, Curtis et al. 2006; Sreenivasan & Jha 2007). There are two types of distracting influences on WM;

- 1) Attended distraction that demands the re-activation of information (e.g. being distracted by a phone call while on the way to do something), reliant on the medial temporal lobe (Sakai, Rowe et al. 2002; Sakai & Passingham 2004)
- 2) Suppression of irrelevant information (e.g. being distracting by noise in another room) which is believed to be dependent on filtering by the pre-frontal cortex (PFC) (Chao & Knight 1995; Chao & Knight 1998).

These two types of distraction have not yet been investigated within the same experiment. In this experiment we manipulated the relevance of the distractor to study the impact of different distractions on neural WM measures. We recorded electroencephalography (EEG) while subjects performed the task to investigate the temporal dynamics of the neural changes in top-down modulation.

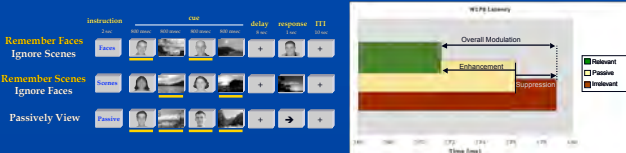
To test for differences between conditions, we looked at two well characterized event-related potential (ERP) components associated with memory, attention, and perception:

• **P100**: An early and robust component thought to signify early visual processing.

• **N170**: A face selective component occurring approximately 170ms after stimulus onset. Our recent study demonstrated that the latency of this component is modulated for relevant vs. irrelevant stimuli in younger adults (Gazzaley et al., 2005).

**EXPERIMENTAL GOAL: Utilize EEG to elucidate the neural underpinnings of working memory maintenance in the face of relevant and irrelevant distraction.**

## Past Results



In a previous study it was shown that when relevant and irrelevant information is presented somewhat quickly and in a randomized order, young healthy participants can enhance activity in visual areas when attending to relevant information and can suppress activity when viewing irrelevant information. **Enhancement is defined as the difference between Relevant and Passive and suppression is defined as the difference between Passive and Irrelevant.**

(Gazzaley et al. JCON, 2005; Gazzaley et al. In Submission)

## Methods

The design consists of four distinct tasks organized in an event-related manner and presented in blocks. The task is a delayed matching to sample task in which the subject views and stores a face and holds it in mind over a delay. In some conditions, a distracting face was presented during the delay. There were 4 conditions: No Distractor (ND), Ignore-Distractor (ID), subjects knew beforehand that the distractor was irrelevant. Attend-Distractor (AD), subjects made a judgment about the distractor and Passively View (PV, no encoding). All trials in the memory conditions were followed by a response period in which they report whether the probe stimulus matches one of the encoding stimuli. All data will be presented from the distractor stage.

### Participants

20 healthy younger individuals, ages 18-30 (avg=23.3 years).

### Stimuli

The stimuli were a set of grayscale images of face stimuli consisting of a variety of neutral-expression male and female faces across a large age range. Hair and ears were removed digitally as to remove any potential non-face-specific cues.

### EEG Recording

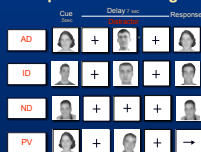
Neural data was recorded with a BioSemi ActiTwo 64-channel EEG acquisition system in conjunction with BioSemi ActiView software (CortecoSolutions, LLC). All electrode offsets were below 25kΩ. Signals were amplified and digitized at 1024 Hz with a 16-bit resolution. Markers of stimulus presentation were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

### Data Analysis

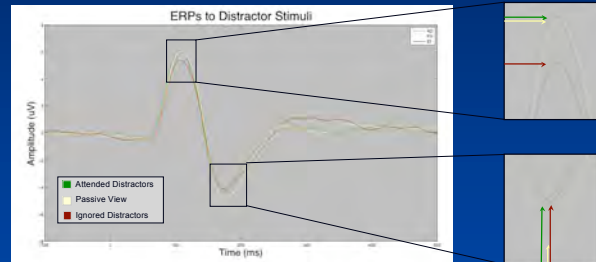
Pre-processing was conducted through Analyzer software (Brain Vision, LLC). Off-line, the raw EEG-data were referenced to an average reference, eye-movements and artifacts were removed through an independent component analysis and a voltage threshold of +/-50uV, and artifact-free data epochs were signal-averaged 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 four conditions included a mean of 76 averaged epochs (range: 70-80).

**Components of interest:** The P100 and N170 components occur predominantly in occipital-temporal electrodes. The data presented here are the peak latency and/or amplitude values at each subjects' electrode of interest. This electrode was selected as the electrode that showed the largest amplitude to all face stimuli (i.e. averaged over all conditions).

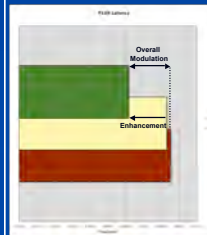
### Experimental Design



## ERP Data

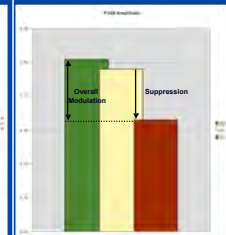


### P100 Latency



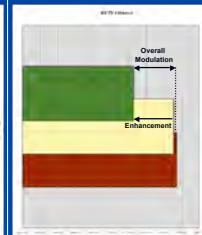
P100 latencies were earliest to the attended distractors and were significantly different than the ignored distractors (overall modulation,  $p < 0.01$ ). Additionally, the attended distractors had earlier P100 latencies than the passively viewed distractors (enhancement,  $p < 0.05$ ).

### P100 Amplitude



P100 amplitudes were biggest to the attended distractors and were significantly bigger than the ignored distractor (overall modulation,  $p < 0.01$ ). Ignored distractors were significantly smaller than the passively viewed distractors (suppression) ( $p = 0.01$ ).

### N170 Latency

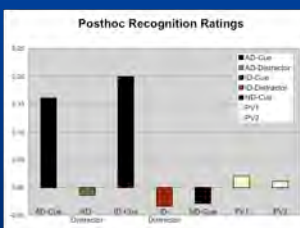


N170 latencies were longest to the ignored distractors and were significantly different than the attended distractors (overall modulation,  $p < 0.001$ ). Additionally, the attended distractors had earlier N170 latencies than the passively viewed distractors (enhancement,  $p = 0.001$ ).

## Behavioral Data

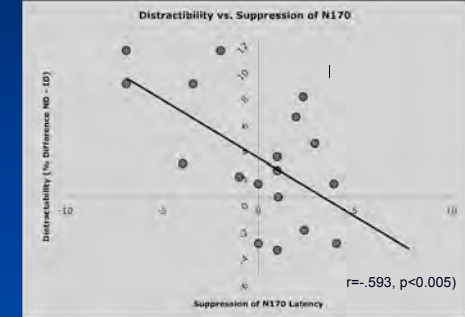


Behavioral results reveal that subjects perform with high accuracy when no distraction is present (96%). When an irrelevant distraction is presented (ID) accuracies drop significantly compared to when there is no distractor (ND) present (93%,  $p < 0.01$ ). When the subjects attend to the distraction (AD) their performance drops significantly (decrease in accuracy) from both the ND and ID conditions (89%,  $p < 0.01$ ).



A surprise post-experiment test was given to test for incidental long-term memory (LTM) recognition. Subjects viewed novel stimuli as well as stimuli they had previously seen (distributed evenly across conditions). This test revealed that subjects were better able to remember stimuli that were encoded in the distractor conditions (AD and ID,  $p < 0.05$ ) than those encoded in the no distractor condition (ND).

## Neural-Behavioral Correlation



Subsequent analyses revealed that the suppression of irrelevant information (as measured by N170 latency differences in ID from passive view) was correlated with distractibility (as measured by the difference between ND and ID working memory performance, i.e. a bigger difference = more distractible). This finding suggests that those individuals who do not neurally suppress distracting information have poorer working memory performance in the conditions containing distraction.

## Summary

- The P100 and N170 analyses show that latencies (and amplitudes of P100) reflect how much attention subjects are paying to stimuli. The more relevant stimuli have earlier and larger neural responses (supporting our past results).
- Behaviorally, subjects performance dropped as distraction was introduced, particularly when they were instructed to attend to the distractor.
- Subjects' ability to successfully ignore cue distraction (ID condition) correlated with their neural suppression of distracting information.
- Stimuli that were encoded before distraction were later remembered in a surprise post-experiment test better than those stimuli that were encoded in the no distractor condition.

While this study revealed functional markers of attention to distracting stimuli and the differential impact of two types of distraction on memory performance, it serves as the first in a series of experiments to evaluate the role of the PFC and hippocampus in distraction and memory performance (using TMS and fMRI), as well as the impact of distraction on aging.

## Conclusions

- P100 amplitude and latency as well as N170 latency are modulated depending on whether information is relevant or irrelevant. These components represent clear physiological markers of attention and top-down modulation.
- The most distractible participants showed the weakest neural suppression of irrelevant information.
- While there is a negative influence by the presence of distraction on working memory performance, there is an improvement in incidental long-term memory recognition ability, revealing a double dissociation between WM and long-term memory. This suggests that when subjects know they will face distraction while maintaining information in WM, they consolidate this information differently than when no distraction is present (possibly involving the medial temporal lobe).

## References

Chao, L. L. and R. T. Knight (1995). "Human prefrontal lesions increase distractibility to irrelevant sensory inputs." *NeuroReport* 6(12): 1605-10.  
 Chen, C. and R. T. Knight (1998). "Contribution of human prefrontal cortex to delay performance." *Cortex* 34(1): 17-27.  
 Gazzaley, A., Cooney, J.W., McEvoy, K., Knight, R.T., D'Esposito, M. (2005). "Attentional selection and suppression of the magnitude and speed of neural activity." *J. Cognitive Neuroscience*, 20(5), 17-3, 507-517.  
 Gazzaley, A., Cooney, J.W., McEvoy, K., Knight, R.T., D'Esposito, M. "Age-related top-down suppression deficit in the early stages of cortical visual memory processing." In submission.  
 Sakai, K. J. & Rowe, D. B. (2002). "Parietotemporal reactivation signal at retrieval after interruption of rehearsal." *Attention* 22(15): 6315-30.  
 Sakai, K. (2003). "Reactivation of memory: role of medial temporal lobe and prefrontal cortex." *Brain* 126(14): 241-52.  
 Sakai, K. and R. E. Passingham (2004). "Prefrontal selection and medial temporal lobe reactivation in retrieval of short-term verbal information." *Cereb. Cortex* 14(8): 914-21.  
 Sreenivasan, K. K. and A. P. Jha (2007). "Selective attention supports working memory maintenance by modulating perceptual processing of distractors." *Cereb. Cortex* 19(1): 32-41.