

Effects of Task Load on Automatic Change Detection: A Simultaneous ERP/fMRI Study

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INTRODUCTION

- The intriguing question of the fate of unattended auditory deviance has been the focus of numerous studies; yet the underlying neural mechanisms contributing to this phenomenon remain uncertain.
- In the auditory modality, an *automatic*, electrophysiological response, termed the mismatch negativity or MMN (Näätänen, 1992), is elicited following irregularities in otherwise a repetitive train of auditory stimuli while subjects' attention is directed elsewhere (i.e., a primary task).
- When the irregularity is large in magnitude or otherwise novel, the MMN is followed by a positive component, the P3a, which is thought to represent involuntary attention switching (Escera et al., 1998).
- The demands of the primary task have been shown to modulate automatic detection of deviance and attention switch (Harmony et al., 2000; Berti & Schröger, 2003).
- The current study employed simultaneous recordings of ERPs and fMRI signals to study the neural substrates of unattended auditory deviance.
- The difficulty of a primary task in a selective attention paradigm was varied, such that in the difficult task behavioral performance (RT, Accuracy) was poorer compared with the easy task.

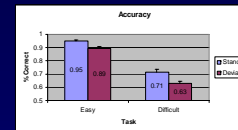
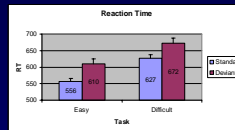
METHODS

- Subjects.** Twenty-one healthy, right handed. Eleven subjects had both fMRI and ERP data.
- Stimuli.**
- Short ($p = .50$) and long ($p = .50$) pure sine-wave tones of repetitive 1000 Hz in standard sequences, or with infrequent 1300 Hz deviants ($p_{\text{deviant}} = .22$) in deviant sequences.
 - Short tones were 50 ms in duration. Long tones were of either 100 ms (Easy task) or 60 ms (on average, Difficult task) duration.
- Paradigm.** Stimuli were presented every 1.4 s in a sequence of 9 stimuli during the 'quiet' periods between image acquisitions. Deviants occurred in positions 4 and 8 or 5 and 8.
- Task.** Participants performed a 2AFC Easy or Difficult duration discrimination task while ignoring deviance.
- fMRI Procedures.**
- GE Signa 1.5T scanner (GE Medical Systems, Milwaukee).
 - Functional data: T2*-weighted, gradient-echo, echo-planar images (TE = 40 ms, flip angle = 90, NEX = 1). TR = 15.5 sec, acquisition time = 2.4 sec. 22 axial slices, 3.75 x 3.75 x 4 mm3 voxels.
 - Anatomical data: 3-D spoiled gradient-echo sequence. Whole brain, 0.94 x 0.94 x 1.2 mm3 voxels.
 - Image analysis used AFNI software package (Cox, 1996). FWHM = 6 mm. Random effects analysis.
 - Unilateral masks were created to include the superior temporal and the transverse temporal gyri (BA 41) using the Talairach Daemon database for AFNI.
 - Cluster size threshold (956 μ , $p < .05$ corrected) was applied to the masked group t -maps.
- ERP Procedures.**
- 30-channel fMRI-compatible Optilink and Quik-Cap (Neuroscan Inc., TX). Continuous acquisition, 0.3-70 Hz, sampling rate = 500 Hz.
 - Nose reference, bipolar vertical eye channel and ECG channel.
 - Ballistocardiogram artifact removal.
 - Epochs -100 to 800 ms, filtered 1-20 Hz, artifact rejection ($\pm 100 \mu$ V).
 - ANOVA conducted on average voltage amplitude of the difference scores in window ± 25 ms around peak with task (easy, difficult) and electrode site (fronto-central) as the repeated measures factors.

RESULTS

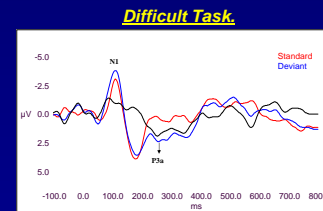
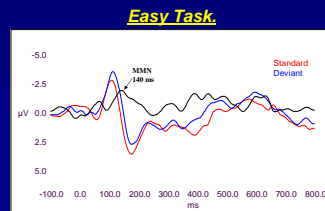
Behavioral Performance

- ANOVAs revealed main effects of task (easy, difficult) and stimulus type (standard, deviant) for both RT and accuracy. No interactions.
- RT was significantly greater in the Difficult task (651.38 ms) than in the Easy task (579.75 ms), and greater for deviants (640.75 ms) than for standards (590.38 ms).
 - Accuracy was significantly greater in the Easy task (.92) than in the Difficult task (.67), and greater for standards (.83) than for deviants (.76).

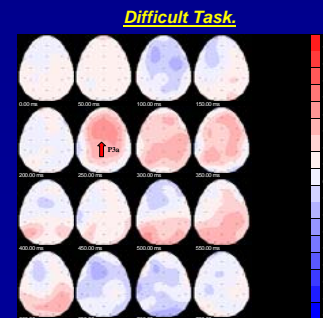
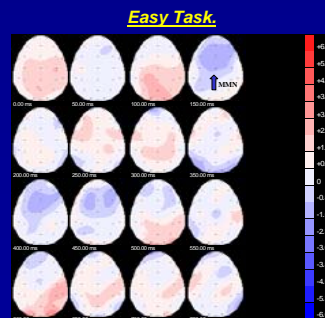


ERPs

- The MMN as measured in the FZ windowed time average (easy: -1.4 μ V, 118-168 ms; difficult: -.5 μ V, 150-200 ms) was significantly different from zero ($p < .05$) only in the Easy task.
- The P3a as measured in the FZ windowed time average (easy: 0.1 μ V, 222-272 ms; difficult: 1.6 μ V, 230-280 ms) was significantly different from zero ($p < .05$) only in the Difficult task.



Scalp Topography

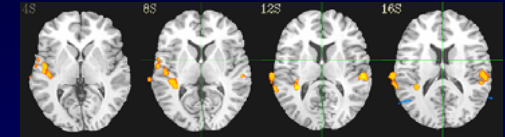


fMRI

DEVIANTS (S+D) > STANDARDS (S)

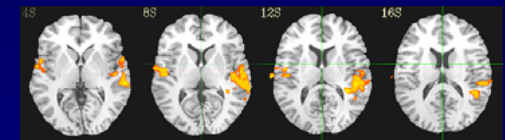
Easy Task.

S+D compared with S produced activations that were confined to the superior temporal plane, in the right planum temporale (PT), and the left Heschl's gyrus.



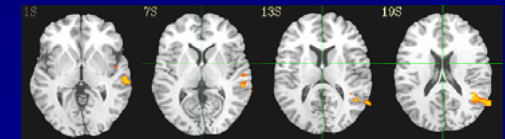
Difficult Task.

S+D compared with S produced activations in the right Heschl's gyrus and the right PT extending ventrally to right superior temporal gyrus (STG). Similar activations, however smaller, was observed in the left Heschl's gyrus and left anterior STG.



DIFFICULT > EASY

This contrast produced activation ventrally on the right STG/STS. No suprathreshold clusters were found on the left side.



DISCUSSION

- Both the MMN and the P3a were modulated by primary task difficulty.
- In accordance with previous studies (Woldorff et al., 1991; Trejo et al., 1995; Alain & Woods, 1997), the MMN was larger in the *easy* task, demonstrating its susceptibility to attentional modulations.
- Interestingly, P3a was larger in the *difficult* task, suggesting an involuntary switch of attention or conscious registration of the frequency deviance when attention was highly focused on the auditory stream.
- Consistent with previous neuroimaging studies (e.g., Müller et al., 2002; Opitz et al., 2002; Liebenthal et al., 2003; Sabri et al., 2003), the BOLD maps implicate areas in STG, predominantly in the right hemisphere, in the detection of unattended frequency deviance.
- Difficult > Easy contrast revealed activation *ventrally* on the right STG/STS, suggesting this region's involvement in switching attention towards an unattended, infrequent stimuli (P3a). Conversely, automatic deviance detection (MMN), which occurs earlier, was associated with more *dorsal* activation, suggesting hierarchy in auditory deviance processing.