Effects Of Attentional Load On Mismatch Negativity

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INTRODUCTION

Task-irrelevant novel and salient stimuli, such as changes in visual position or auditory pitch, can capture attention involuntarily, away from task-relevant information[1]. The cortical information processing to task-irrelevant auditory stimuli has been studied by means of the mismatch negativity (MMN), a frontocentral negative component of the event-related potential (ERP)[2-5]. The MMN is elicited by rare, deviant auditory stimuli embedded within sequences of homogeneous auditory stimuli . Previous electrophysiological studies showed that MMN is of pre-attentive nature because it does not depend on whether the subject is engaged in an easy or more demanding visual task[3,6]. In contrast, Woldorff and his colleagues[7,8] have demonstrated that the brain's detection of deviant stimuli is not automatic but rather can be suppressed when attention is focused elsewhere, suggesting a "gating" mechanism operating on unattended stimuli. Using ERP study, we examined whether the involuntary attention shifts were modulated by the availability of attentional resources allocated to a primary task.

METHODS

Subjects

❖ The ERP subjects were 17 right-handed young adult university students (age range 19-28 years, 9 females) and received course credit. The data of 4 ERP subjects were discarded because of excessive artifacts or technical problems. All subjects reported normal hearing and (corrected-to) normal visual acuity, reported no serious neurological or psychiatric problems. All gave written consent to participate in the study approved by the Institutional Review Board of Duke University Medical Center.

ERP Task and Procedure

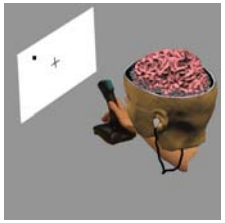

Fig. 1 ERP Task

❖ Subjects performed a visual tracking task at each of two levels of tracking difficulty while simultaneously hearing tones that they were asked to ignore. A first order (1st-Order) (velocity) tracking was implemented for the lower difficulty level, and a second order (2nd-Order) (acceleration) tracking dynamic was implemented for the more complex and demanding task. The tasks were created using Visual Basic software. Auditory stimuli were generated using MATLAB software, (MathWorks, Natick, MA) including 10-ms rise/fall times.

❖ Simultaneous with the visual tracking task, subjects were presented with task-irrelevant auditory pure tones binaurally at 75dB SPL through headphone, consisting of frequent "standard" (600 Hz, ~92%) and infrequent "deviant" tones (780 Hz, ~8%) of 200 ms duration. Inter-tone interval (ITI) was 1.5 sec, and inter-deviant interval (IDI) was 12-21 sec. During the ERP study, subjects performed the 1st-Order tracking task during 8 runs, and the 2nd-Order tracking task during 8 runs of ~ 3.4 min. each, accompanied by 125 standard and 10 deviant tones per run.

❖ Subjects were comfortably seated in a chair in a dimly lit, electrically shielded and sound-attenuated chamber. They did the visual tracking task The visual tracking task was presented on a computer screen with a gray background placed 75-80cm from the subject.

ERP Recording

❖ Brain electrical activity was recorded from 31 scalp locations using tin electrodes attached to electrode caps (Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, Ft7, FC3, FCz, FC4, FT8, T3, C3, Cz, C4, T4, Tp7, Cp3, Cpz, CP4, TP8, T5, P3, Pz, P4, T6, O1, Oz, and O2) according to the 10–20 system (Electro-Cap International, Inc., Eaton, OH). The electro-oculogram (EOG) was monitored by two electrodes placed at the outer canthi and below of the right eye. Electrode impedances were kept below 5 kΩ. All sites were referenced to the chin electrode. The EEG was amplified (band pass, 0.01–100 Hz), digitized (250 Hz per channel) and digitally stored in a PC for off-line analysis. Off-line low-pass digital filtering 15Hz (Butterworth, order 8) was applied to the averaged data and epochs of 100 ms pre-stimulus and 600 ms post-stimulus periods were separately averaged for the standard and for deviant stimuli in each task difficulty. During the averaging procedure, epochs contaminated by EOG artifacts were eliminated using root mean square EOG values as criteria. The mean voltage of the 100 ms pre-stimulus period served as a baseline for amplitude measurement.

THE RESULTS

1. ERP Behavioral Data

❖ In the ERP behavioral data analyses, we compared the tracking error rate scores within a 3 s-windows preceding and following the auditory deviant tone. A significant Task main effect was found (ANOVA (Task x Time) F1,12 = 115.649, p<0.0001). No significant Time and interaction effects were obtained (F1,12 =1.052, p>0.1, F1,12 =2.272, p>0.1, respectively).

2. Frontocentral Mismatch Negativity Difference Waveforms

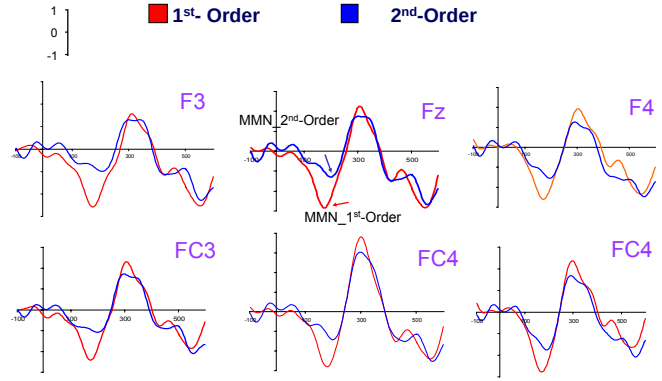

Fig. 2 Grand average difference waveforms (13 subjects)

❖ The differences in MMN mean amplitudes to deviant tones for the 2nd-order tracking task significantly differed from zero at the frontocentral electrode locations in the intervals 120 to 250 ms (Fz: t_{12} = -2.16, p =0.026, F3: t_{12} = -2.35, p = 0.02 , F4: t_{12} = -2.01, p = 0.03, FCz: t_{12} = -1.98, p = 0.04, FC3: t_{12} = -2.28 p = 0.02, FC4: t_{12} = -1.99, p = 0.03, one-tailed).

❖ The peak amplitude latency did not differ significantly between the two tracking tasks.

❖ Repeated-measures ANOVA (laterality (F3, Fz, F4) x task (1st-order, 2nd-order) on the MMN mean amplitude showed a significant main effect of task (F1,12 = 4.803, p = 0.05). Neither laterality nor interaction factors were significant.

3. Scalp Distribution of the MMN wave

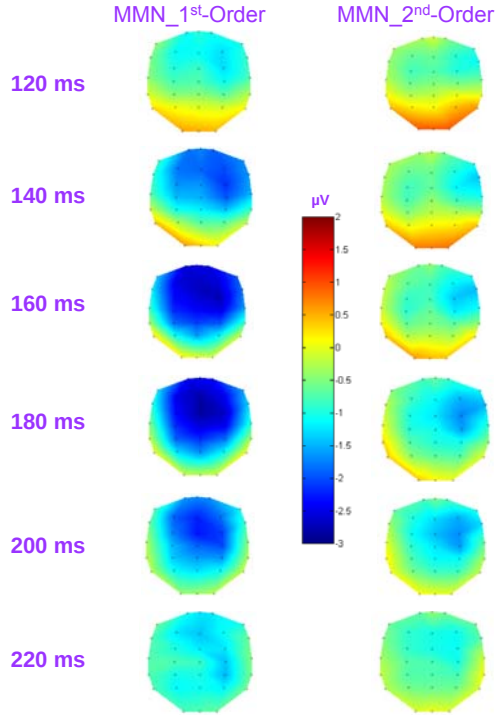

Fig. 3 MMN scalp distributions over consecutive 20ms measuring windows

CONCLUSION

❖ ERP data reported here provide direct evidence for the modulation of involuntary attention to task-irrelevant auditory stimuli by the availability of attentional resources allocated to the primary task

❖ The present findings of smaller MMN mean amplitudes at the frontocentral electrode locations during more demanding visual tasks argues against the hypothesis that the detection of deviant auditory stimuli is automatic and resources-independent.

❖ The results of the study demonstrate that when the task complexity is increased—the portion of capacity used by that process rises—there is a corresponding decrease in activation to task-irrelevant auditory tones in frontocentral regions.

❖ This study extends the findings of Woldorff et al.[7,8] showing modulation of the intensity-MMN, by demonstrating that the demands of a primary task also modulate the pitch-MMN generators recorded from frontocentral electrode locations.

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