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Research Report

Attentional load of the primary task influences the frontal but not the temporal generators of mismatch negativity

Domenico Restuccia [a,b,*], Giacomo Della Marca [a], Camillo Marra [a], Marco Rubino [a], Massimiliano Valeriani [c]

[a]Department of Neurosciences, Catholic University, Policlinico A. Gemelli, L.go A. Gemelli 8, 00168 Rome, Italy
[b]Scientific Institute "E. Medea"—Regional Scientific Research Center of San Vito al Tagliamento and Pasian di Prato, Italy
[c]Division of Neurology, Pediatric Hospital "Bambino Gesù", IRCCS, Rome, Italy

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Abstract

According to the model hypothesized by Näätänen and Michie (Biol Psychol 1979; 8: 81–136), the generation of the mismatch negativity (MMN) requires a mismatch detection, taking place in temporal areas, followed by the activation of frontal generators, underlying attention switching toward the deviant stimulus. We aimed at verifying whether the activation of temporal and frontal regions is dependent on the amount of attentional resources allocable toward the deviant stimulus. We recorded event-related potentials (ERPs) in nine healthy subjects while reading and during a demanding visual task (Multiple Features Target Cancellation, MFTC). Raw data were further evaluated by Brain Electrical Source Analysis (BESA). During the Reading condition, distraction toward the unattended auditory stimuli was reflected by the enhancement of the N1 response to frequent stimuli and by the elicitation of a P3a response to deviant ones. The MMN distribution was explained by bilateral temporal dipoles. During the MFTC condition, no P3a was detected, while source analysis showed the activation of a right frontal generator. Temporal dipoles showed no change between the two conditions: we thus conclude that the earlier mismatch detection is independent on the attentional load. By contrast, the activation of a right frontal subcomponent occurred only during the high-load task, independently on any actual attention shift reflected by the P3a component. We thus discuss the hypothesis whether the right frontal MMN generator, rather than subserving a simple attention switching toward the deviant stimulus, plays a role in modulating the auditory change detection system ("contrast enhancement" model).

Theme: Sensory systems
Topic: Auditory systems, central physiology

Keywords: Mismatch negativity; P3a; Distraction; Frontal cortex

1. Introduction

When physically deviant sounds are interspersed within a sequence of repetitive acoustic stimuli but subjects are instructed to pay no attention to the acoustic stimulation, deviants can elicit a series of scalp responses, labeled, according to their polarity on centro-frontal scalp regions, as mismatch negativity (MMN), N2b and P3a components. The characteristics of the abovementioned components have been extensively studied in previous literature (see [21] for a review). In particular, the P3a component, elicited in the 250–350 ms latency range, is evoked with higher amplitude by very intrusive deviants ("novel" stimuli) and is thought to reflect a shift of attention toward the deviant stimulus [6,15,43]. Although less extensively studied, also, the preceding negative response (N2b) is possibly linked to involuntary attention shift [23,25]. By contrast, the earlier

* Corresponding author. Department of Neurosciences, Catholic University, Policlinico A. Gemelli, L.go A. Gemelli 8, 00168 Rome, Italy. Fax: +39 0635501909.
E-mail address: drestuccia@rm.unicatt.it (D. Restuccia).

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MMN component, elicited in the 120–180 ms latency range, is thought to reflect the preattentive detection of deviants [13,19,22]. It has been debated for a time whether the MMN component is fully independent from attention. This question has been more often addressed by exploring MMN changes during dichotic listening paradigms. Despite some contrasting results in earlier studies [20,24,41,42], it seems now ascertained that the MMN reduction in the unattended sound channel is probably due to the competition for deviance detection between deviants with similar physical features [37], so confirming that attention per se does not affect the MMN. Seen in this view, the independence of MMN on overt attention is consistent with its presumed role in triggering passive attention [34]. In the earlier interpretation of Näätänen and Michie [22], MMN-generating mechanisms require two successive steps, i.e., the mismatch detection, taking place in temporal lobes, and the initiation of the attention switching toward the unattended stimulus, involving frontal areas. The contribution of frontal sources to the building of MMN has been further demonstrated by other studies [2,3,8,12,17,18,30,38]. The aims of our study are: (1) to investigate whether frontal activity is always necessary in MMN building or it is involved only when most attention resources are allocated elsewhere and (2) to define the topographic characteristics of the frontal MMN source. During standard MMN elicitation, the subject is usually distracted from the acoustic stimulus by means of a simple visual task such as reading. Therefore, we decided to compare ERPs recorded in two conditions characterized by a different visual attentional load, i.e., a standard non-target condition (subjects read a novel) and the execution of a demanding visual task. Moreover, we evaluated the cerebral generators activated in the 80–200 ms latency range by means of Brain Electrical Source Analysis (BESA), which proved useful in distinguishing the respective contribution of cerebral sources to acoustic ERPs [12].

ERPs were therefore recorded from nine healthy volunteers, while they read a novel and while they performed Multiple Features Targets Cancellation (MFTC) task [7]. MFTC requires the simultaneous consideration of a few features and the selection of the appropriate targets from an array of distractors (see Fig. 1). In general, target cancellation tasks are commonly utilized to explore deficits of visuo-spatial attention (for instance, see [39]); because of its high attentional load, MFTC has been proven useful in demonstrating attentional deficits in Alzheimer patients [7].

2. Materials and methods

2.1. Subjects

Subjects (four men, five women) were volunteer staff ranging in age between 24 and 48 years. All subjects were normal hearing, and none of them had a history of neurological illness.

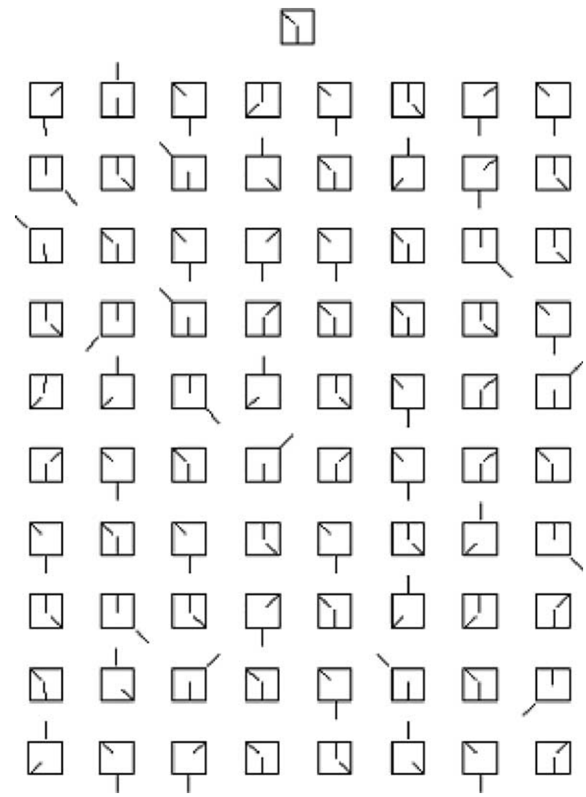

Fig. 1. Multiple Features Target Cancellation (MFTC) task. The subject is asked to cancel as quickly as possible all the 13 items identical to the model placed above the array.

2.2. Recording procedure

Auditory stimuli were presented during the execution of the tasks, but subjects were instructed to not pay attention to the acoustic stimulation. Auditory stimuli were sinusoidal tones (85 ms duration, 1 ms rise and 1 ms fall time, 85 dB SPL of intensity), presented binaurally via headphones. Frequent 800 Hz tones and deviant 500 Hz tones were presented with a probability of 85% and 15% respectively, with an interstimulus interval (ISI) of 1 s. Participants underwent four successive blocks of about 500 acoustic stimuli. In particular, the two blocks corresponding to the Reading condition were always of 500 stimuli each, whereas the two blocks corresponding to the MFTC condition varied according to the duration of the task since stimulation was stopped when the subject filled all 15 sheets (see below). Since subjects employed about 16 min to perform the task, this corresponded to an average of 480 stimuli per block. Each couple of blocks which corresponded to one of the two tasks was superimposed to verify their reproducibility and then further averaged.

ERPs were recorded in two different conditions, which were presented in a different order from one subject to another. During each condition, subjects were instructed to not pay attention to tones. (1) Reading. Subjects read a novel. The subject was informed that he had to summarize the novel in a short briefing following the stimulation. (2)