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Research Report

The influence of strongly focused visual attention on the detection of change in an auditory pattern

*Lauren D. Sculthorpe**, *Charles A. Collin*, *Kenneth B. Campbell*

School of Psychology, University of Ottawa, Ontario, Canada K1N 6N5

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ABSTRACT

The mismatch negativity, an ERP that reflects the detection of change in the auditory environment, is considered to be a relatively automatic process. Its automaticity has by in large been studied using the oddball paradigm, in which a physical feature of a frequently presented standard stimulus is changed. In the present study, the automaticity of the MMN is tested using a MMN elicited by a violation of a more abstract auditory pattern. Fourteen subjects were presented with an alternating pattern of two tones (ABABAB) that was occasionally broken by deviant repetitions (e.g., ABABABBBAB). The alternating tones were separated by 1 or 6 semitones in different conditions. The subjects were engaged in a continuous multiple object tracking (MOT) task and thus ignored the auditory stimuli. Difficulty of the MOT task was manipulated by increasing the number of objects to be tracked. Subjects were also asked to read a text and ignore the auditory stimuli in another condition. A much larger MMN was elicited by pattern violations in the 6 than in the 1 semitone condition. The difficult visual task should have presumably required greater attentional focus than the easy task, and performance did deteriorate during the difficult MOT. The MMN, however, was not affected by the demands of the MOT task. This finding suggests that the MMN elicited by the violation of a pattern is not affected by the presumed attentional demands of a difficult continuous task such as multiple object tracking.

1. Introduction

The detection of acoustic change is critical for survival. This process of acoustic change detection is reflected by an event-related potential called the Mismatch Negativity (MMN). A large majority of studies record the “classic” MMN using the oddball task (see Näätänen et al., 2007 for a recent review). In the oddball task, the subject is presented with a sequence of discrete, homogeneous “standard” auditory stimuli. At rare and unpredictable times, a physical feature of the standard is changed producing a “deviant” stimulus. The standard elicits a complex known as the N1–P2 vertex potential. In addition to N1–P2, the deviant stimulus elicits the MMN. The MMN is best observed as a difference wave, computed by subtracting the standard from the deviant ERP. The subtraction process removes exogenous, sensory processing that is common to both the standard and the deviant, leaving only processing that is unique to the deviant (Näätänen et al., 1980).

The MMN peaks 100–250 ms after the onset of the deviant stimulus, with a larger extent of deviance eliciting a MMN with higher amplitude, and shorter latency (Näätänen et al., 1989). The MMN is maximal over frontocentral scalp cites, and inverts at the mastoids when the nose is used as reference (Näätänen et al., 1980). This scalp distribution has largely been

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* *Corresponding author*. Fax: +613 562 5147.
E-mail addresses: lscul087@uottawa.com (L.D. Sculthorpe), kcampbel@uottawa.ca (K.B. Campbell).

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explained by intra-cranial sources located in the supratemporal region of the auditory cortex (Alho, 1995). There may also be a contribution of a second source in the right frontal lobe, although it remains poorly understood (Giard et al., 1990; Rinne et al., 2000).

Almost any physical stimulus change will elicit the MMN, including tonal frequency (Näätänen et al., 1978; Sams et al., 1985), intensity (Näätänen et al., 1987), duration (Näätänen et al., 1989), and spatial location (Paavilainen et al., 1989). Complex deviants such as a change in speech sounds will also elicit the MMN (Winkler et al., 1999). The scalp distribution of the MMN varies depending on the type of deviant that is used (Alho, 1995).

The MMN occurs when the physical features of an incoming stimulus change from those that precede it. It can also be elicited by a violation of a complex regularity (Näätänen et al., 2001). The large majority of studies have employed a physical change to “first-order” standard stimulus features. In studies of the MMN to more complex and abstract changes, there may be no physically identical, repetitive standard stimuli. Rather, what is “standard” is a more abstract regularity that is shared by several physically different standard stimuli. For example, Tervaniemi et al. (1994) presented subjects with a sequence of continuously descending tones (each tone being lower in frequency than the preceding tone). Deviant stimuli either ascended, rather than descended, or repeated the same tone. Both types of deviants elicited the MMN.

The MMN has been elicited by violations of a variety of complex regularities (Paavilainen et al., 1999; Winkler and Schröger, 1995; Paavilainen et al., 2003; Tervaniemi et al., 1994; Sussman and Gumenyuk, 2005; Saarinen et al., 1992; Nordby et al., 1988; Zachau et al., 2005). Alain et al. (1994) employed a simple alternating pattern of two paired tones (ABABAB). Deviant stimuli in this paradigm were repetitions of either the A or the B tone (eg. ABAABA). The two tones in the pair were separated by 1, 6, or 12 semitones, and pattern violations produced a MMN that increased in amplitude with increasing tonal separation.

Because the detection of acoustic change is critical for survival, it needs to occur rapidly, and without the need for active attention being directed towards the auditory channel. In the Näätänen model of auditory perception, change detection is claimed to occur prior to awareness that change has occurred (i.e. at a pre-conscious level). The MMN was originally conceptualized to be strongly automatic: it did not benefit from attention, and was not dependent on it. A large number of studies have tested this claim using the oddball paradigm. Early studies described the MMN to be unaffected by attention, since deviants in both the unattended and attended channels of a dichotic listening task appeared to elicit MMNs of equal amplitude (Näätänen et al., 1978, 1980; Alho et al., 1989, 1994). Later dichotic listening studies, using more optimal paradigms, demonstrated a smaller MMN to unattended than attended deviants (Woldorff et al., 1991, 1998; Arnott and Alain, 2002; Trejo et al., 1995). There are, however, methodological problems with intramodal studies of selective attention. The active detection of the rare auditory deviant (or “target”) will elicit another negativity, the N2b, that peaks at about the same time and shares a similar frontocentral scalp topography with the MMN. Näätänen et al. (1993) have thus argued that the apparent enhancement of the MMN with attention directed to the auditory channel may, in fact, be a result of effects on the overlapping and summating N2b. The N2b does not invert in amplitude at the mastoids, whereas the MMN does, but this difference is quite subtle and is not always apparent in ERP recordings.

The problem of N2b overlap is overcome in many MMN studies by ensuring subjects do not attend to the auditory channel, and overtly detect the rarely-occurring deviant. Subjects are thus often engaged in an intermodal (visual–auditory) task, being asked to attend to a visual task and ignore the concurrent standard and deviant stimuli occurring in an incidental auditory channel. The ease of the visual task is often manipulated. The more difficult task is presumed to demand a greater focusing of attention. The underlying assumption in these studies is that the strong demands of a difficult visual task do not allow the subject to either rapidly switch or share resources between the visual task and task-irrelevant auditory stimuli. In contrast, it is assumed that during the easy visual task, subjects will have additional resources available for the processing of auditory stimuli. Most research using intermodal visual–auditory tasks have demonstrated the MMN to be unaffected by the visual task (Dyson et al., 2005; Dittmann-Balcar et al., 1999; Muller-Gass et al., 2006, 2007; Kathmann et al., 1999; Otten et al., 2000; Harmony et al., 2000; Alho et al., 1994; Sams et al., 1985, 1984). A small number of studies, particularly those in which a continuous visual task is employed, have reported effects of visual task difficulty on the MMN to a large frequency deviant in an oddball task (Kramer et al., 1995; Restuccia et al., 2005; Yucel et al., 2005; Zhang et al., 2006). The most recent model of auditory change detection (Näätänen et al., 2007) classifies the oddball MMN as a weakly automatic process: although the MMN is elicited independently of attention, attention may modulate its amplitude (see Hackley, 1993 for a discussion of this concept).

While the effects of attention on the MMN elicited by physical deviants in an oddball task have been widely studied, little is known about the effects of attention on the pattern MMN. Alain and Woods (1997) noted in a dichotic listening task that the pattern MMN was larger in the attended auditory channel than in the ignored channel. The problem of N2b overlap with the MMN during active attention, however, cannot be dismissed in these studies.

The present study employed an intermodal paradigm in which subjects were engaged in either an easy or a difficult visual task, and were asked to ignore concurrently-presented auditory pattern stimuli. The use of a discrete visual task is problematic for the study of the pattern MMN. This is because discretely-presented stimuli become integrated into the auditory sequence, thus disrupting the pattern in which the auditory stimuli are presented. To avoid disruption of the auditory pattern, a continuous visual multiple object tracking (MOT) task was employed (Pylyshyn and Storm, 1988).

The MOT task was modified from the original Pylyshyn and Storm (1988) design to produce a tracking period of sufficient length for auditory pattern presentation. Subjects tracked circular targets among identical non-targets as they moved randomly across the screen. Visual probes, in the form of a color change, required a response if they occurred in one of the target objects. The purpose of this study was to investigate the susceptibility of the pattern MMN to the demands of this