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Research Report

Evidence for the auditory P3a reflecting an automatic process: Elicitation during highly-focused continuous visual attention

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ABSTRACT

The P3a is an event-related potential (ERP) component believed to reflect an attention-switch to task-irrelevant stimuli or stimulus information. The present study concerns the automaticity of the processes underlying the auditory P3a. More specifically, we investigated whether the auditory P3a is an attention-independent component, that is, whether it can still be elicited under highly-focused selective attention to a different (visual) channel. Furthermore, we examined whether the auditory P3a can be modulated by the demands of the visual diversion task. Subjects performed a continuous visual tracking task that varied in difficulty, based on the number of objects to-be-tracked. Task-irrelevant auditory stimuli were presented at very rapid and random rates concurrently to the visual task. The auditory sequence included rare increments (+10 dB) and decrements (−20 dB) in intensity relative to the frequently-presented standard stimulus. Importantly, the auditory deviant stimuli elicited a significant P3a during the most difficult visual task, when conditions were optimised to prevent attentional slippage to the auditory channel. This finding suggests that the elicitation of the auditory P3a does not require available central capacity, and confirms the automatic nature of the processes underlying this ERP component. Moreover, the difficulty of the visual task did not modulate either the mismatch negativity (MMN) or the P3a but did have an effect on a late (350–400 ms) negativity, an ERP deflection perhaps related to a subsequent evaluation of the auditory change. Together, these results imply that the auditory P3a could reflect a strongly-automatic process, one that does not require and is not modulated by attention.

1. Introduction

Certain potentially-relevant auditory stimuli occurring outside the focus of attention can trigger an attention switch from the task-at-hand to the distracting auditory event. This process is called “passive” or “involuntary” attention (James, 1890) and may result in the evaluation and conscious perception of task-irrelevant stimuli. Näätänen (1990) has proposed different mechanisms by which a task-irrelevant auditory stimulus may be consciously perceived. In his model, a potentially-relevant stimulus is one that signals acoustic novelty or change. It is purported that the likelihood that such a potentially-relevant stimulus captures attention depends on the locus and strength of the listener’s attentional focus. For example, if attention is directed to the auditory stimulation, even a small task-irrelevant auditory change may cause

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distraction. In contrast, if attention is engaged in a visual task, an identical auditory stimulus may not trigger an attention switch, particularly if the visual task is difficult.

The purpose of the present study is to assess the automaticity of the attention-switching mechanism. A defining criterion of an automatic (versus a controlled) process is that it operates without being allocated attentional capacity. The main question in the present research pertains to whether the attention-switching mechanism can be deactivated when attention is strongly focused away from the task-irrelevant stimuli. In order to address this question, a task condition is required that will prevent attentional slippage to the task-irrelevant channel. An automatic process is however not necessarily immune to interference and attentional influences. According to Kahneman and Treisman's (1984) levels of automaticity, a weakly-automatic process is one that, while not requiring attention for its occurrence, is modulated by attention. By contrast, a strongly-automatic process neither requires nor is influenced by attention. A separate but related question in the present research concerns the effect of an attention manipulation on the operation of the attention-switching mechanism. In order to address this question, two task conditions are required that vary in the extent to which they allow attentional slippage to the task-irrelevant channel.

The study of automaticity in information-processing is facilitated by the recording of ERPs, as they provide a means of determining the extent to which to-be-ignored stimuli are processed. Of particular interest to the present study is the P3a, an ERP component believed to index the occurrence of an attentional capture (for a review, see Escera et al., 2000). Within the context of distraction, the P3a is elicited by task-irrelevant stimuli or stimulus information occurring in an easily distinguished channel compared to task-relevant stimuli. The processing of the distractor may come at a cost for task performance because attention is switched from the task-relevant to the-irrelevant channel. This is particularly the case when the temporal proximity between the occurrence of distractor and the task-relevant information is short (Schröger, 1996). The P3a follows a deviant stimulus that also elicits an earlier additional negativity, composed of an enhanced N1 and/or a mismatch negativity (MMN) component. N1 is enhanced when the deviant stimulus represents a frequency or locus change, or an intensity or duration (for brief stimuli) increment; whereas MMN is elicited by a violation in the predictability of a stimulus sequence (Näätänen and Picton, 1987). The strength (amplitude) of the N1 and MMN signals are a determining factor in the generation and size of the P3a (Berti et al., 2004; Yago et al., 2001). The N1 and MMN reflect automatic processes, in as much as these components are still generated when attention is effectively withdrawn from the eliciting stimuli (Näätänen and Picton, 1987; Woldorff et al., 1998). The processes underlying N1 and MMN thus do not require attention for their occurrence; however, they may be attenuated or enhanced based on the availability of attentional capacity (N1 effect, see Hillyard et al., 1973; for a recent review on MMN and attention, see Muller-Gass et al., 2006). They can thus be conceived, at least under some circumstances, as weakly-automatic processes. Hackley (1993) suggests that the transition from strong to weak automaticity in auditory information processing may occur as early as 15 ms. There are however ERP components (e.g. PN, N2b) prior to the time of P3a that are attention-dependent and reflect controlled processing.

1.1. *Are the processes underlying the auditory P3a of automatic or controlled nature?*

The primary aim of the present study is to examine whether the P3a is automatically generated; that is, whether the processes underlying the generation of the P3a operate without attention (i.e. an automatic process), or whether these processes can potentially be abolished by the withdrawal of attention (i.e. a controlled process). In order to test this, it is necessary to employ a task that requires highly-focused attention, thereby ensuring that the P3a-eliciting stimuli consistently occur outside of the focus of attention. Otherwise, P3a generation may be attributed to a brief covert attentional shift toward or co-monitoring of the channel in which the eliciting stimuli are presented (see attentional slippage hypothesis, Lachter et al., 2004; Näätänen, 1990). A few authors have in fact obtained an auditory P3a during relatively demanding visual tasks (Harmony et al., 2000; Muller-Gass et al., 2006; Munka and Berti, 2006; Yucel et al., 2005) but, in these studies, it might have been possible for subjects to nevertheless have also attended to the auditory channel even though they were instructed to ignore it. This is because these studies used discrete visual tasks (Harmony et al., 2000; Muller-Gass et al., 2006; Munka and Berti, 2006) or a slow rate of auditory stimulus presentation (Harmony et al., 2000; Munka and Berti, 2006; Yucel et al., 2005). When discrete visual stimuli are presented, subjects have greater opportunity to switch to the processing of the auditory information. A slow rate of auditory stimulus presentation is also not conducive to the selective focusing of attention to the visual domain because these stimuli are more likely to cause involuntary attention shifts toward the to-be-ignored auditory channel (Hansen and Hillyard, 1984; Woldorff and Hillyard, 1990). The present study optimised the experimental conditions in order to maximise the need and capability to highly focus attention on the visual task. The need was established by using a difficult continuous tracking task, which promotes the selective processing of task-relevant visual information. This task required subjects to track and respond to target objects and ignore identical non-target objects, as they moved randomly around a rectangular space (Pylyshyn and Storm, 1998). Furthermore, in order to allow the subject to more readily ignore the auditory sequence, we employed a very rapid (on average every 244 ms) and random auditory presentation rate. We also maximised the likelihood of obtaining a P3a by using deviant stimuli (a small intensity increment and a large intensity decrement) that are known to elicit a large P3a (Muller-Gass et al., 2006; Rinne et al., 2006). If the P3a is elicited under these stringent conditions, then the processes underlying the P3a are automatic, not reliant on centralised capacity, as this capacity is consumed by the demands of the difficult continuous visual task (Arnell and Jolicoeur, 1999).

1.2. *Are the processes underlying the auditory P3a affected by primary task demands?*

Whereas the study of automaticity requires a condition which prevents attentional slippage, the study of task effects on P3a requires two comparison task conditions that significantly differ