Cognition 109 (2008) 345–362

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

# Towards a cognitive model of distraction by auditory novelty: The role of involuntary attention capture and semantic processing

Fabrice B.R. Parmentier *

*Department of Psychology, University of the Balearic Islands, Spain*
*School of Psychology, University of Plymouth, Drake Circus, Plymouth PL4 8AA, UK*
*Department of Psychology, University of Western Australia, Australia*

ARTICLE INFO

*Article history:*
Received 13 May 2008
Revised 26 September 2008
Accepted 29 September 2008

*Keywords:*
Novelty detection
Attention capture
Oddball detection
Distraction
MMN
P3a
Re-orientation negativity

ABSTRACT

Unexpected auditory stimuli are potent distractors, able to break through selective attention and disrupt performance in an unrelated visual task. This study examined the processing fate of novel sounds by examining the extent to which their semantic content is analyzed and whether the outcome of this processing can impact on subsequent behavior. This issue was investigated across five laboratory experiments in which participants categorized visual left and right arrows while instructed to ignore irrelevant sounds. The results showed that auditory novels that were incongruent with the visual target (e.g., word "left" presented before a right arrow) disrupted performance over and above congruent novels (semantic effect) while both types of novels delayed responses in the visual task compared to a standard sound (novelty effect). No semantic effect was observed for congruent and incongruent standards, suggesting that novelty detection is necessary for involuntary semantic processing to unravel. While the novelty effect augmented as the difference between novels and the standard increased, the semantic effect was immune to this variation. Furthermore, the novelty effect decreased across the task while the semantic effect did not. A general cognitive framework is proposed encompassing these new findings and previous work in an attempt to account for the behavioral impact of irrelevant auditory novels on primary task performance.



## 1. Introduction

Efficient cognitive functioning often requires selective attention, that is, the ability to filter out task-irrelevant stimuli in order to concentrate on the task at hand. While resisting distraction can be desirable in many circumstances, possessing brain mechanisms able to break through selective attention and detect unexpected but potentially important stimuli is crucial from an adaptive perspective. To the early hominidaes, the brisk sound of a bush's moving leaves may have indicated the location of potential food or that of a predator. To us, the sound of screeching tyres might signify an imminent danger that one would want to be able to detect even if deeply concentrated reading our preferred journal. A trade-off between selective attention and auditory novelty detection is therefore advantageous. The interplay of these two phenomena can be studied in the laboratory and has primarily been investigated from an electrophysiological perspective. The cognitive analysis of the mechanisms involved in cross-modal attention capture remains, in comparison, largely unexplored. A recent study showed that rare auditory stimuli (referred to as *novels*) among otherwise repeated sounds (referred to as *standard*) distract performance in an unrelated visual task not through the disturbance of target processing but as a result of dynamic shifts of attention to and from the novel sound (Parmentier, Elford, Escera,

* Address: School of Psychology, University of Plymouth, Drake Circus, Plymouth PL4 8AA, UK. Tel.: +44 (0) 1752 233806; fax: +44 (0) 1752 233362.
*E-mail address:* fparmentier@plymouth.ac.uk

0010-0277/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.cognition.2008.09.005

Andrés, & San Miguel, 2008). This study seeks to extend this cognitive examination and address an important, yet little researched, issue: what is the fate of the novel sounds once oriented to? More specifically, the results of five experiments examine whether novel sounds are semantically processed outside one's voluntary control and whether such processing can impact on one's subsequent behavior. Finally, a theoretical framework will be proposed, aiming to fathom the *cognitive* mechanisms underpinning the cross-modal distraction induced by auditory oddballs.

First, I begin with a brief review of research on the involuntary detection of novel and deviant sounds and the resulting attention capture and orientation response (Sokolov, 1966).

### 1.1. The involuntary detection of novel sounds

Numerous studies have established that one's attention can be involuntarily captured by sudden changes (*oddball*, *novel*, or *deviant*) in a train of otherwise repeated sounds (*standard*). This type of attention capture has mostly been studied from an electrophysiological perspective and is characterized by a pattern of three specific brain responses (Schröger, 1997; Schröger & Wolff, 1998a, 1998b): mismatch negativity (MMN) and an enhanced N1 when the distractor deviates a great deal from the repetitive background (Alho et al., 1998), P3a (sometimes referred to as novelty P3; see Friedman, Cycowicz, and Gaeta (2001) for a review) and re-orientation negativity (RON; e.g., Schröger & Wolff, 1998b).

The MMN response reflects the pre-attentive detection of an unexpected change (or even the illusion of a change, see Stekelenburg, Vroomen, and de Gelder (2004)) in the auditory context, and follows from the comparison between a memory trace for past acoustic stimuli and the current auditory signal (Cowan, Winkler, Teder, & Näätänen, 1993; Näätänen & Winkler, 1999; Picton, Alain, Otten, Ritter, & Achim, 2000; Winkler & Cowan, 2005). The P3a response represents the involuntary orientation of attention towards the novel sound (Friedman et al., 2001; Grillon, Courchesne, Ameli, Geyer, & Braff, 1990; Woods, 1992) and is thought to result from an attentional interruption involving frontal areas (Opitz, Rinne, Mecklinger, von Cramon, & Schröger, 2002). A re-orientation negativity is also observed when participants are performing a primary task and must redirect their attention towards that task (Berti, Roeber, & Schröger, 2004; Berti & Schröger, 2001; Escera, Yago, & Alho, 2001; Schröger & Wolff, 1998a).

Behaviorally, responses in a primary task are delayed following the presentation of a task-irrelevant novel sound. For example, MMN-eliciting deviants presented among standards to an unattended ear delay participants' response to auditory targets in the other ear (Schröger, 1996). Schröger and Wolff (1998a, 1998b) reported similar findings in a task in which participants had to discriminate between long and short sounds irrespective of their frequency. Even though frequency was irrelevant to the participants' discrimination task, response latencies in the primary task were significantly longer for rare frequency deviants relative to standards (see also Berti and Schröger (2003) and Roeber, Berti, and Schröger (2003)). Such studies used the so-called one-channel paradigm in which targets and deviants are presented auditorily, usually as distinct features of the same auditory object (e.g., frequency and duration). Remarkably, however, target and irrelevant stimuli need not be presented at the same time or in the same sensory modality for distraction to occur, highlighting the a-modal nature of the attention capture phenomenon. Indeed, performance in a *visual* discrimination task is also affected by *auditory* deviants or novels (two-channel paradigm), as demonstrated in studies using the cross-modal oddball task (e.g., Andrés, Parmentier, & Escera, 2006; Barceló, Escera, Corral, & Perianez, 2006; Escera, Alho, Winkler, & Näätänen, 1998; Escera, Corral, & Yago, 2002; showed that, In this task, participants categorize visual digits, presented in sequence, as odd or even. Each digit is preceded by a task-irrelevant sound that participants are instructed to ignore. In most trials (e.g., 80% of trials), this sound is repeated (standard) while in the remaining trials it is replaced by a deviant or a novel sound. Behavioral distraction consists in the lengthening of response latencies in the visual task, following deviants or novels compared to standards.

In studies using the cross-modal oddball task, the primary interest is typically in the electrophysiological responses to the novel sound while behavioral distraction is secondary and usually not discussed in great depth. From a cognitive point of view, however, one may wonder exactly why hearing a task-irrelevant novel sound should disrupt the subsequent categorization of a visual digit. To answer this question, Parmentier et al. (2008) reported experiments designed to pinpoint the cognitive locus of distraction in the cross-modal oddball task. Their hypothesis was that if distraction was due to a reduction in the amount of attentional resources available to process the visual digits, then making this processing more demanding should amplify distraction. However, neither the visual degradation of the digits nor the use of more difficult categorization instructions affected distraction (as measured by the difference in response latency between novel and standard trials), despite sizable main effects of these manipulations. The authors suggested that distraction was therefore not the result of a slower processing of the visual targets. Instead they argued that it reflected a delay in initiating their processing that resulted from time penalties associated with involuntary shifts of attention to and from the novel sound. In line with this interpretation, the results of their Experiment 3 showed that distraction in the cross-modal oddball task could be eliminated by forcedly re-capturing attention after a novel sound by presenting a task-irrelevant visual distractor (characterized by an abrupt visual and motion onset) prior to the appearance of the visual target.

The distractive effect of deviants on behavioral performance in an unrelated task is not specific to the cross-modal oddball task. For example, Hughes, Vachon, and Jones (2005) reported that serial recall performance for visual verbal stimuli was reduced when an auditory temporal deviant was introduced among a sequence of irrelevant sounds presented concurrently with the sequence of to-be-remembered visual stimuli (see also Lange (2005)). Inter-