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Distraction in a continuous-stimulation detection task

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ABSTRACT

Event-related potential (ERP) correlates of distraction are usually investigated in the oddball paradigm following a *discrete*, *trial-by-trial* stimulation protocol. In this design, participants perform a *discrimination* task while oddball stimuli deviate in a task-irrelevant stimulus feature. In our experiment, participants detected gaps in a *continuous* tone while infrequent frequency glides served as distracting events.

Glides preceding a gap by 150 ms delayed the response to the gap and elicited the ERP sequence of N1, probably MMN, P3a, and reorienting negativity, suggesting that these responses reflect distraction-related processes which are neither task- nor stimulation-specific.

When participants watched a silent movie and the auditory stimulation was task-irrelevant, glides preceding a gap by 150 ms enhanced the amplitude of the gap-elicited N1. However, when the auditory stimulation was task-relevant, the gap-elicited N1 was attenuated. These results show that the glides drew attention away from the ongoing task, both from watching the silent movie and from detecting gaps.

1. Introduction

Distraction is an involuntary attentional change triggered by events which are irrelevant with respect to the current behavior. Whereas distraction has often adverse effects on the immediate task performance, it may be crucial in many situations where behavioral goals have to be changed to adaptively follow situational changes. For example, breaking your phone conversation to jump out of the way of a honking car might serve you better than continuing the conversation without noticing the danger. An experimental model for the study of distraction is the oddball paradigm. Here, stimuli of a regular, predictable stimulus sequence (standards) are occasionally replaced by irregular stimuli (deviants) in an unpredictable manner. Some of the differences observed in behavioral and event-related potential (ERP) responses to deviants and standards have been interpreted as being directly related to distraction.

One variant of the oddball paradigm, the auditory distraction paradigm, introduced by Schröger and Wolff (1998a), was found to be especially suited for the investigation of distraction. In this paradigm, on each trial, participants perform a two-alternative forced choice (2AFC) discrimination-task based on one (task-relevant) property of the stimuli (for example, they have to press one button for short tones and another one for long tones). The two types of stimuli differing in the task-relevant property are presented equiprobably. A different (task-irrelevant) property of the stimuli (e.g., tone pitch) changes on some (deviant) trials, usually unpredictably. Because the same task has to be performed on both deviant and standard trials, some of the behavioral and ERP response differences between deviants and standards can be attributed to distraction-related processing. Whereas the distraction paradigm has proven to be a useful research tool, it is important to assess the generality of the phenomena observed in this paradigm, because distraction obviously occurs in many different situations. One characteristic that is common to all variants of the auditory distraction paradigm is stimulus discrimination and categorization. More and more evidence suggests that some of the distraction-related responses may reflect working memory and task-related processes. For example, Escera et al. (2001) found that the distraction-related ERP waveform contained at least one subcomponent time-locked to the task-relevant aspect of the stimulation. Roeber et al. (2005) found that response change/repetition modulated distraction-related behavioral and ERP responses (see also Roeber et al., 2009).

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Thus task-related processes interact with distraction. Furthermore, Berti (2008a) suggested that some of the distraction-related ERP components actually reflect working memory operations, such as switching between objects manipulated in working memory (Berti, 2008b). In light of these studies, a different, non-discrimination-based task may help to distinguish task-specific from genuine distraction-related effects. The aim of the present study was to test the effects of distraction in a detection task and compare them with the results usually obtained in the prototypical auditory distraction paradigm (Schröger and Wolff, 1998a). To this end we developed a novel continuous-stimulation distraction paradigm.

The typical results obtained in the original distraction paradigm and their interpretations can be described in a three-stage model of distraction (for recent summaries, see Escera and Corral, 2007; Horváth et al., 2008c). Processes in the first stage form a sensory information filter, which reduces the processing load on capacity-limited processing resources by absorbing predictable sensory events. Two of these processes are reflected in the ERPs: a first-order change detection process, which is reflected by the modulation of the modality-specific N1 component (peaking around 100 ms after change onset; for a review, see Näätänen and Picton, 1987); and a deviance-detection process working on the basis of regularities extracted from the previous stimulation, indexed by the mismatch negativity (MMN, peaking 100–200 ms after deviance onset; Näätänen et al., 1978; for a recent summary on the interpretation of the MMN component see Winkler, 2007).

The processes reflected by N1 and MMN can trigger an involuntary attention switch (e.g., a shift towards the unpredictable change; Näätänen, 1990), thus initiating the second stage of the distraction model. Some processes playing a role in this attention-change are thought to be reflected by the modality-independent, fronto-central P3a (or novelty P3, see Friedman et al., 2001), which probably takes both sensory and cognitive aspects of the information carried by the given stimulus into account (relation to goals, conceptual context, subjective importance, etc., see, e.g., Barcelo et al., 2006; Friedman et al., 2003). However, the link between the processes underlying the ERP components of the first stage (N1 and MMN) and those generating the P3a have been recently questioned (Horváth et al., 2008c; Rinne et al., 2006). When various complex sounds (often termed as novel sounds) are occasionally presented within a sequence predominantly made up of a regularly repeating simple tone, an early P3a subcomponent can be observed in the novel-minus-standard ERP difference waveform (Escera et al., 2000). The early P3a is probably generated in auditory cortex (Alho et al., 1998). It is, however, not known, whether this subcomponent is related to attention switching, or it reflects acoustic deviation. In active versions of the auditory oddball paradigm (i.e., when participants perform a task related to the stimuli), a central negativity, the N2b (Näätänen and Gaillard, 1983) is also often elicited by both target and non-target deviants. N2b is generally thought to reflect the controlled registration of the infrequent task-relevant event (Ritter et al., 1992).

Processes taking place after the attention switch constitute the third stage of the model. The functions of these processes seem to be manifold, and there is no consensus yet regarding the correspondence between cognitive functions and the observable ERP components. If task priorities do not change as a result of the evaluation of the distracting event (i.e., the task should be carried on), the task-optimal attention has to be restored: this function is thought to be reflected, at least in part, by the modality-independent, reorienting negativity (RON), which peaks 400–600 ms after the onset of change/deviation (Berti and Schröger, 2001; Schröger et al., 2000; Schröger and Wolff, 1998b). RON usually shows a frontal (e.g., Berti and Schröger, 2001), fronto-central (e.g., Roeber et al., 2003), or central (e.g., Horváth et al., 2008c) scalp maximum. Performing the task optimally after distraction may also require adjustments to response- and decision-related aspects of task-related processing (Berti, 2008a; Escera et al., 2001; Horváth et al., 2008a), which may also be partly reflected by RON, or by the modulation of the parietal P3b component, which is typically elicited by targets requiring a response. The P3b probably also reflects the maintenance of the task-related stimulus context information in working memory, or decision-related processes regarding stimulus–response associations (Donchin and Coles, 1988; Polich, 2007; but see Verleger, 1988, 2008).

Several studies employing the 2AFC auditory distraction paradigm found the succession of N1/MMN, N2b, P3a, RON components on deviant trials (e.g., Jankowiak and Berti, 2007; Roeber et al., 2003; Wetzel et al., 2006). These studies also found slower behavioral responses and usually more errors on deviant than on standard trials. The go/no-go variant of the auditory distraction paradigm produced the same pattern of ERPs as the 2AFC task (see, e.g., Sussman et al., 2003), although the P3a and RON component amplitudes were found to differ between short (go) and long (no-go) trials (Horváth et al., 2009).

In the original version of the auditory distraction paradigm (tone duration discrimination task with pitch as task-irrelevant property, see Fig. 1), there are two moments within each trial where important stimulus information can be discovered: the onset of a tone, and the latency at which the short tone ends. Stimulus onset informs the participant about the beginning of the trial (probably facilitating preparation for the occurrence of the task-relevant information) and about the (task-irrelevant) standard/deviant status of the stimulus. At the latency at which the short tone ends the information governing the discriminative response becomes available in the form of the presence or absence of an offset of the tone. In the present study we reduced (see below) cueing information by presenting a continuous tone instead of discrete tones (continuous-stimulation paradigm, see Fig. 1). The target event was a short gap occasionally inserted into the continuous tone. Participants were required to respond to the gaps (the detection condition). The task-irrelevant distractor was an infrequent frequency glide, which is known to elicit N1 (Noda et al., 1999) and MMN whether embedded in a continuous tone

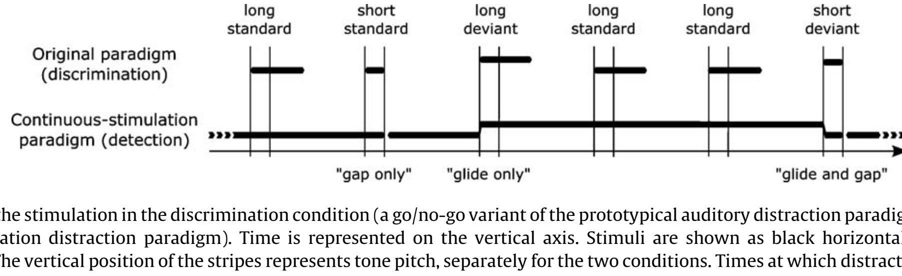

Fig. 1. Schematic diagram of the stimulation in the discrimination condition (a go/no-go variant of the prototypical auditory distraction paradigm) and the detection condition (the new continuous-stimulation distraction paradigm). Time is represented on the vertical axis. Stimuli are shown as black horizontal black lines with their length representing tone duration. The vertical position of the stripes represents tone pitch, separately for the two conditions. Times at which distracting (tone/glide onset) and task-relevant information (the offset of the short tone/gap) can be discovered are marked with grey vertical lines.