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Research Report

Exploiting temporal predictability: Event-related potential correlates of task-supportive temporal cue processing in auditory distraction

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ABSTRACT

The human cognitive system has various functions to enhance performance in tasks requiring responses to stimuli. When potentially occurring stimuli are known, we can establish selective attention sets and ignore task-irrelevant events while attending task-relevant ones. When the stimulation is temporally structured, we can rely on constant temporal relationships between stimulus events to prepare for the task-relevant moments. Most distraction paradigms feature task-irrelevant events which are followed by task-relevant ones within a constant interval, and distraction is induced by randomly replacing some of the standard task-irrelevant events. The constant time interval transforms irrelevant events to task-supportive temporal cues, which are integrated into the task-behavior by the participants. The present study investigated whether distracters could be utilized as temporal cues to support task-related processing in a continuous auditory stimulation paradigm. A continuous tone featuring short and long gaps, and pitch glides was presented. Participants performed a gap duration discrimination task, while ignoring glides. Glides could be presented frequently or rarely. In the informative condition, 80% of the glides predicted the presentation time of the forthcoming gap (400 ms), while in the uninformative condition, the occurrence of gaps and glides was independent. Rare glides elicited an enhanced N1, mismatch negativity, and P3 event-related potentials in both informative and uninformative conditions. In informative conditions glides were followed by a contingent negative variation; and rare informative glides elicited an N2b, suggesting that despite triggering distraction-related processes, distracters could be integrated into the task-behavior, and could be utilized as task-supportive cues.

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1. Introduction

When performing tasks requiring overt or covert reactions to stimulation events, the predictability of the stimulation can often be exploited to streamline processing. If we know what types of stimulus events may occur, we can establish *selective attention sets*, which makes it possible to prepare for task-relevant sensory events while ignoring task-irrelevant ones (e.g. Parmentier, 2014). We can also make use of cues that predict when task-relevant events can occur, and prepare for their processing at a given moment in time (Holender and Bertelson, 1975). Numerous studies have shown that selective attention sets can be disrupted by rare, unpredictably occurring, or conspicuous stimulus events (distracters). In the present study, using the method of event-related potentials (ERPs), we investigated whether such distracters can nonetheless be utilized as temporal cues to support task-related processing in a continuous auditory stimulation paradigm.

Variants of the oddball paradigm especially suitable for investigating distraction-related processing have been introduced by Schröger and Wolff (1998b) and Escera et al. (1998). In these *distraction paradigms*, a discrete stimulus sequence is presented, and participants perform a discrimination task related to one aspect of the stimulation. Distraction is induced by infrequently, unpredictably changing a task-irrelevant aspect of the stimulation. In the paradigm introduced by Schröger and Wolff (1998b), participants perform a duration discrimination task in a sequence of short and long tones, in which (the task-irrelevant) tone pitch is occasionally changed (distracter trials). In the paradigm introduced by Escera et al. (1998), participants perform odd/even discrimination for visually presented numbers. Each number is preceded by a task-irrelevant sound, and distraction is induced by occasionally replacing the (task-irrelevant) sound with a different sound. The rationale of these arrangements is that behavioral and ERP response-differences between distracter and non-distracter trials reflect processes related solely to distraction because participants perform the same task on both types of trials.

Variations of these initial paradigms (see e.g. Berti and Schröger, 2003; Escera et al., 1998, 2000, 2001; Polo et al., 2003; Roeber et al., 2003a, 2003b; Schröger and Wolff, 1998a, 1998b) showed a consistent pattern of results. Response times in distracter trials were longer than in non-distracter trials, and more mistakes were made. In the ERPs (Escera et al., 2000; Escera and Corral, 2007) the distracter-minus-non-distracter difference waveforms showed an enhanced N1 and mismatch negativity (MMN) between 100 and 250 ms following the onset of the distracting stimulus event, followed by a P3a in the 250–400 ms interval; and finally a negative waveform termed reorienting negativity (RON) could be observed between 400 and 600 ms. These ERPs are usually described in a three-stage model of distraction. The deviant-related N1 enhancement and MMN are generally thought to reflect processes related to auditory change detection (e.g. Näätänen, 1982; Näätänen et al., 2007). P3a is thought to reflect an involuntary selective attention set change, that is, distraction (Friedman et al., 2001; Polich, 2007). Finally, RON may reflect processes involved in the restoration of the task-optimal attention set after the distracting event (Berti, 2008; Schröger and Wolff, 1998a; Sussman et al., 2003).

To better understand information processing in these paradigms, it is useful to point out that all of these paradigms feature two types of *stimulation events* which differ in terms of their task-relevancy: 1) One type of event is task-relevant in the sense that the occurrence of the event provides the information necessary to select the correct response. For example, in the paradigm introduced by Escera et al. (1998), the onset of the number is the task-relevant event. In the paradigm introduced by Schröger and Wolff (1998b), the task-relevant event occurs at the time point of the short tone offset, at which the tone either stops or continues. 2) The second type of event is task-irrelevant in the sense that it does not convey information regarding the response to be given, but nonetheless, it is a well-detectable transient change in the stimulation which allows the temporal structuring of the stimulation. In the Schröger and Wolff (1998b) paradigm, this event is the tone onset, whereas in the paradigm introduced by Escera et al. (1998) such events are the tone-onsets and -offsets.

These task-irrelevant events may play an important role in distraction paradigms, because these events can be used as *temporal cues* to predict the onset of the task-relevant events, especially if they precede the task-irrelevant events by a constant interval (foreperiod effect, see e.g. Capizzi et al., 2013; Holender and Bertelson, 1975; Leynes et al., 1998). Indeed, this is the case for all the studies referred to above: in these studies, irrelevant and relevant events were presented with constant temporal separation, typically in the range of 100–200 ms (e.g. Wetzel, Widmann and Schröger, 2012; Berti and Schröger, 2001; Schröger and Wolff, 1998a, 1998b), but even as high as 600 ms in some experiments (Ruhnau et al., 2010). Because of this, it seems reasonable to assume that task-irrelevant events play a "supportive" role in performing the task by allowing temporal preparation for the forthcoming task-relevant event.

There is substantial evidence for the supportive, temporal cueing function of the irrelevant events in these paradigms. In some arrangements, task-irrelevant events cannot be disregarded at all: in a duration discrimination task (Schröger and Wolff, 1998b) the stimulus onset is a crucial reference point, and therefore even small deviations – for example, otherwise hardly noticeable (1%) pitch changes – occurring at the onset result in robust distraction effects (Berti et al., 2004). Recent behavioral studies, in which the separation of task-relevant and – irrelevant events was manipulated, as well as whether the irrelevant event was followed by a relevant one on each trial, showed that the distraction-related response time delay was reduced when the foreperiod was not constant and the irrelevant event was unreliable (50% or less) in signaling the forthcoming task-relevant event (Berti, 2013; Jankowiak and Berti, 2007; Li et al., 2013; Parmentier, 2014; Parmentier et al., 2010; Wetzel et al., 2012). These results suggest that in distraction paradigms, participants actually use the "task-irrelevant" events as temporal cues to enhance their task performance, that is,