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# Preventing distraction: Assessing stimulus-specific and general effects of the predictive cueing of deviant auditory events

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ABSTRACT

Rare irregular sounds (deviants) embedded into a regular sound sequence have large potential to draw attention to themselves (distraction). It has been previously shown that distraction, as manifested by behavioral response delay, and the P3a and reorienting negativity (RON) event-related potentials, could be reduced when the forthcoming deviant was signaled by visual cues preceding the sounds. In the present study, we investigated the type of information used in the prevention of distraction by manipulating the information content of the visual cues preceding the sounds. Cues could signal the specific variant of the forthcoming deviant, or they could just signal that the next tone was a deviant. We found that stimulus-specific cue information was used in reducing distraction. The results also suggest that early P3a and RON index processes related to the specific deviating stimulus feature, whereas late P3a reflects a general distraction-related process.



## 1. Introduction

Human information processing capacity is limited. In sensory information processing tasks, prioritizing the processing of task-relevant sensory information (*selective attention*) is of high importance, because failure to suppress task-irrelevant information (*distraction*) may lead to brief decrease in performance necessitating the engagement of compensatory processes. On the other hand, being distracted may provide an opportunity to re-evaluate a situation and re-assess goal priorities. For example, it is well worth being distracted by the fire alarm even if the paper we read is highly interesting. Under normal circumstances, there is a balance between maintaining the selective attentional set and processing distracting stimuli. This balance can be affected in many ways: for example, by information signaling forthcoming distracting events. In a previous study Sussman et al. (2003) showed that such predictive cues are utilized by the brain to prevent or reduce the effects of potentially distracting stimuli. Here we report the results of experiments investigating how predictive cues strengthen the maintenance of the selective attention set, thus guarding against distraction by task-irrelevant auditory events.

Distraction-related processing can be described in the framework of a three-stage model (see e.g., Escera and Corral, 2007; Horváth et al., 2008). According to this model, incoming stimuli are processed by a sensory filter (*first stage*), which "flags" infrequent, unpredictable sensory events as being potentially informative, and initiates their attentional processing. That is, such events may trigger an involuntary attention switch (*second stage*). Following attention switching, a number of processes take place (*third stage*). As a result of the evaluation of the distracting event, task or goal priorities may change. If not, that is, performing the current task is continued, then the task-optimal attention set is restored (re-orientation).

This three-stage model is largely based on studies presenting oddball sequences and measuring event-related brain potentials (ERPs). In the oddball paradigm, infrequent, unpredictably occurring stimuli (*deviants*) are embedded in a regular stimulus sequence (items of which are termed *standards*). Differences in behavioral or physiological responses to deviants and standards are assumed to reflect processes described in the three-stage model. ERP responses associated with the first stage of the model comprise of 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 reg-

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ularities extracted from the previous stimulation. The latter is indexed by the mismatch negativity (MMN), peaking 100–200 ms after deviance onset (Näätänen et al., 1978; for a process-oriented review, see Winkler, 2007). Either one of these processes may initiate an involuntary attention switch assumed to be reflected by the modality-independent, fronto-central P3a (or novelty P3, see Friedman et al., 2001; Polich, 2007). When participants attend the stimuli, both target and non target deviants also often elicit a central negativity (N2b; Näätänen and Gaillard, 1983; for a review, see Folstein and van Petten, 2008). N2b is assumed to reflect the controlled registration of the infrequent task-relevant event (Ritter et al., 1992). For the third stage of the model, the correspondence between cognitive functions and ERP components is less well studied. Restoration of the task-optimal attentional set is thought to be reflected, at least in part, by the modality-independent, reorienting negativity (RON), which peaks fronto-centrally, 400–600 ms after the onset of change/deviation (Berti and Schröger, 2001; Schröger et al., 2000; Schröger and Wolff, 1998b). However, RON may also reflect some adjustments to response- and decision-related aspects of goal-directed behavior (Berti, 2008a,b; Escera et al., 2001). Finally, the P3b component, which typically peaks parietally, probably 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).

Sussman, et al. (2003, see also Wetzel and Schröger, 2007) showed that some of the distraction-related processes delineated above can be influenced by information predicting a forthcoming deviant. On each trial, participants discriminated short and long sounds presented with 50% probability, each. Deviants presented 10% of the time differed from the standard sounds in the task-irrelevant pitch feature. In this paradigm (Schröger and Wolff, 1998a), behavioral and physiological response differences between deviants and standards are assumed to reflect processes related to distraction. Sussman et al. (2003) presented a visual cue – one of two possible stimuli – before each auditory stimulus, and manipulated the predictive value of the cue across conditions. In the Predictable condition, there was a one-to-one correspondence between the two visual cue stimuli and the two sound pitches so that the visual stimulus signaled the type of the next sound. In the Unpredictable condition, the two visual stimuli and the two pitches were presented independently of each other so that the visual stimulus was not predictive with respect to the type of sound. In the Predictable condition, no significant P3a or RON ERP components were elicited by deviants, and no significant behavioral distraction-related response delays were observed, in contrast with the Unpredictable condition, in which both P3a and RON, and a response delay were observed. However, the ERP responses linked with first-stage processes (N1 and MMN) were not affected. Thus, whereas sound change and acoustic deviation was detected irrespective of the predictive value of the visual cue, information about the timing and quality of the infrequent task-irrelevant event reduced the distraction caused by this event. Assuming the above-described interpretation of P3a and RON, predictive information reduced the tendency for switching attention to the task-irrelevant deviant sound-feature and, possibly as a consequence, reorientation was less often needed.

Whereas the Sussman et al. (2003) study showed which stages can be influenced by the information provided by predictive cues, it did not clarify what aspect of the cue information was utilized in preventing/reducing distraction. There are at least two ways in which information about a forthcoming distractor may provide a means to prevent distraction.

(1) Information regarding the probability of the forthcoming stimulus (i.e., whether or not a tone will carry a rare task-irrelevant feature) may be used to enhance focusing on the set of task-relevant stimulus-features, thereby *generally* impacting the processing of any incoming task-irrelevant information. Indeed, it has been suggested that signals originating from the first stage may have to reach a variable threshold before they can trigger an involuntary attention shift (Schröger, 1997). The existence of such a threshold is supported by the fact that measures of distraction seem to correlate with the magnitude of unexpected sensory change. That is, more salient changes result in higher measures of distraction in oddball paradigms (see e.g. Berti et al., 2004; Escera et al., 2001; Yago et al., 2001; but see Horváth et al., 2008 for constraints on this correlation). It has been suggested that distractors appearing within the focus of attention may be more effective than those outside the focus (Schröger and Wolff, 1998a), and voluntary allocation of attention may be the primary way to influence this threshold.

(2) *Stimulus-specific* information about the distractor stimulus (e.g., its pitch) may be used to prevent distraction. Such information may be used for example, to inhibit the processing of the specific information or to adapt the selective attentional set to accommodate the predicted stimulus; for example, set up a response association for a high tone of short duration.

The aim of the current study was to specify whether in preventing/reducing distraction, the brain utilizes the general or specific information (as defined above) provided by the predictive cue. To this end, in two experiments, we manipulated whether the visual cue conveyed information only regarding the probability (*general* information) or also the *specific* make-up of the forthcoming stimulus. Similarly to Sussman et al.'s (2003) study, in both experiments, a visual cue was presented before each sound, and the predictive value of the visual cue was manipulated across the conditions. In the Fully Predictable conditions, there was a one-to-one correspondence between the visual cue stimuli and the possible pitches which the forthcoming sound could assume. In the Predictable Sound Probability conditions, the cue signaled only whether the forthcoming sound was a deviant or a standard, but it did not specify the pitch of the deviant. In the Unpredictable conditions, there was no correspondence between the visual cue stimuli and the pitch of the subsequent sound. In order to separate the general and the stimulus-specific cueing effects, in addition to the Single deviant conditions, which replicated Sussman et al.'s (2003) conditions, we also presented Multiple Deviants conditions in which cues could be uninformative regarding the forthcoming tone (Unpredictable condition) or could signal either only the probability of the subsequent sound (Predictable Sound Probability condition) or also the specific pitch of the subsequent sound (Fully Predictable condition). Experiment 2 was designed to separate alternative explanations accounting for the results of Experiment 1. We start with the details of Experiment 1, and then provide the rationale and hypotheses of Experiment 2 in the Discussion of the results of Experiment 1.

In addition to replicating the results of Sussman et al. (2003) (presented in detail as Supplementary Material), we tested the following hypotheses in Experiment 1.

The *stimulus-specific cue information hypothesis* suggests that the specific information about the forthcoming deviant sound is utilized. Thus it should provide a more efficient way of preventing distraction than a general cue can. Therefore, distraction measures should be smaller in the Fully Predictable than in the Predictable Sound Probability condition. It is also possible that the cue carrying only sound-probability information is not useful at all for preventing distraction. In this case, distraction-related measures should not differ from each other between the Predictable Sound Probability and the Unpredictable—Multiple Deviants condition. In contrast, if only foreknowledge regarding deviancy itself is utilized in preventing distraction, then distraction measures should not differ from each other between the Predictable Sound Probability and Fully predictable conditions.