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Article *in* Experimental Psychology · April 2013

DOI: 10.1027/1618-3169/a000196 · Source: PubMed

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Research Article

Behavioral Distraction by Auditory Deviance Is Mediated by the Sound's Informational Value

Evidence From an Auditory Discrimination Task

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Abstract. Sounds deviating from an otherwise repetitive background in some task-irrelevant respect (deviant sounds among standard sounds) capture attention in an obligatory fashion and result in behavioral distraction in an ongoing task. Traditionally, such distraction has been considered as the ineluctable consequence of the deviant sound's low probability of occurrence relative to that of the standard. Recent evidence from a cross-modal oddball task challenged this idea by showing that deviant sounds only yield distraction in a visual task when auditory distractors (standards and deviants) announce with certainty the imminent presentation of a target stimulus (event information), regardless of whether they predict the target's temporal onset (temporal information). The present study sought to test for the first time whether this finding may be generalized to a purely auditory oddball task in which distractor and target information form part of the same perceptual stimulus. Participants were asked to judge whether a sound starting from a central location moved left or right while ignoring rare and unpredictable changes in the sound's identity. By manipulating the temporal and probabilistic relationship between sound onset and movement onset, we disentangled the roles of event and temporal information and found that, as in the auditory-visual oddball task, deviance distraction is mediated by the extent to which distractor information harbingers the presentation of the target information (event information). This finding suggests that the provision of event information by auditory distractors is a fundamental prerequisite of behavioral deviance distraction.

Keywords: distraction, oddball, novelty

Efficient cognitive functioning requires a finely tuned balance between two key abilities: (1) that of focusing attention on a task while ignoring task-irrelevant distractors (selective attention); and (2) that of detecting unexpected changes in our immediate environment that may have potential relevance outside the scope of the current task (e.g., detection of a fire alarm while engaged in an office task). One drawback of the latter is distractibility, that is, the reduction of behavioral performance following the involuntary capture of attention by distractors.

Previous work demonstrates that an unexpected change in a stream of otherwise repetitive auditory stimuli distracts participants (e.g., Schröger, 1996; Escera, Alho, Winkler, & Näätänen, 1998). This type of distraction can be studied in the laboratory using variations of the so-called oddball task. In its purely auditory form, this task requires participants to attend and respond to a specific feature of sequentially presented stimuli (e.g., discriminating the duration of tones) while ignoring rare and unpredictable changes in a task-irrelevant feature (e.g., pitch). In its cross-modal form, the task typically involves the successive presentation of an auditory distractor followed by a visual target. Conventionally, the distractor or irrelevant feature repeated on most trials is referred to as the *standard* while that presented on rare and unpredictable occasions is termed *deviant.* The presentation of a deviant sound, relative to that of a standard, results in a significant lengthening of response times (RTs) in the primary task, hereafter referred to as *deviance distraction.*

Deviance distraction results from the time penalty associated with the orientation of attention to and from the deviant stimulus (Parmentier, Elford, Escera, Andrés, & SanMiguel, 2008), and can be exacerbated by a conflict between the involuntary processing of the deviant sound's content and the voluntary processing of the target stimulus (Parmentier, 2008; Parmentier & Turner, 2013; Parmentier, Turner, & Elsley, 2011; Parmentier, Turner, & Perez, 2013). This distraction effect is observed across different sensory channels, whether distractor and target information are both presented in the auditory modality (e.g., Berti, 2008; Berti &

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DOI: 10.1027/1618-3169/a000196

Schröger, 2003; Horváth & Winkler, 2010; Roeber, Widmann, & Schröger, 2003; Schröger, 1996), the visual modality (Berti & Schröger, 2004; Boll & Berti, 2009), or in different modalities, such as in the auditory-visual (Andrés, Parmentier, & Escera; 2006; Ljungberg & Parmentier, 2012a; Munka & Berti, 2006; Parmentier & Andres, 2010; Parmentier, Maybery, & Elsley, 2010; SanMiguel, Linden, & Escera, 2010) or tactile-visual cross-modal oddball tasks (Ljungberg & Parmentier, 2012b; Parmentier, Ljungberg, Elsley, & Lindkvist, 2011). Hence the evidence clearly indicates that deviance distraction is not limited to a specific modality or combination of modalities.

The Role of the Distractor's Informational Value

Deviance has been implicitly considered as a sufficient condition for the obligatory emergence of behavioral distraction (e.g., Escera et al., 1998). This view was challenged by Ljungberg, Parmentier, Leiva, and Vega, 2012 (see also Parmentier, Elsley, & Ljungberg, 2010; Wetzel, Widmann, & Schröger, 2012) who noted that auditory distractors in past cross-modal studies invariably announced a target stimulus (event information) after a fixed temporal interval (temporal information), thereby fulfilling the role of unspecific warning (e.g., Hackley, 2009; Niemi & Näätänen, 1981). Ljungberg et al. reported the results of an auditory-visual cross-modal oddball in which the event and temporal information was manipulated orthogonally by varying the probability distractors were followed by targets (.5 vs. 1) and the temporal interval between the two (100, 200, or 300 ms). Comparing the effects of deviant sounds in four conditions differing in terms of the type of information conveyed by the auditory distractors (Event + Temporal, Event, Temporal, Uninformative), they found deviance distraction whenever event information was present and not when it was absent. These results suggest that unexpected changes in a stream of sounds yield behavioral distraction as long as they carry relevant goal-directed information, specifically, the likelihood of occurrence of a target. Temporal information, in contrast, did not affect distraction, at least for temporal intervals of the typically size used in the cross-modal oddball task.

Generalizing the Effect of Informational Value on Deviance Distraction

The question at stake here is whether the mediation of deviance distraction by the distractor's informational value can be generalized from the cross-modal oddball task to an auditory task (e.g., Berti & Schröger, 2003; Schröger, 1996) and, hence, potentially constitute a general principle of behavioral deviance distraction. From an informational point of view, we would like to argue that distractor and target information in auditory oddball tasks maintain a relationship that can be described as conveying event and, in some studies, temporal information. Let us consider the task used in the vast majority of the auditory oddball tasks: the duration judgment task. In that task, participants judge whether sounds are short or long irrespective of rare changes in pitch. The pitch information is available from the onset of the sound, and the point in time at which the sound can either stop (short) or continue (long) always follows the sound's onset by a fixed interval. Distractors therefore provide temporal information about the target feature (duration). Furthermore, because sounds necessarily always contain both pitch and duration information, the presentation of pitch information always announces the upcoming occurrence of the target feature (in this case the point in time when short and long sounds can be discriminated). Distractor sounds therefore also provide event information in this task.

A review of past studies including auditory oddball tasks in which participants attend to one feature of auditory stimuli while instructed to ignore another, and in which behavioral performance was measured, reveals that 22/30 used the duration discrimination task discussed above (see Table 1). In the remaining studies, the distractor stimulus or feature always preceded the target, typically within the same auditory object (Grimm et al., 2008; Hölig & Berti, 2010; Horváth, Roeber, Bendixen, & Schröger, 2008; Roeber, Berti, Müller, Widman, & Schröger, 2009; Schröger, 1996; Wetzel, Berti, Widmann, & Schröger, 2004; Wetzel, Widmann, & Schröger, 2009), with one exception (Rinne, Särkkä, Degerman, Schröger, & Alho, 2006, where distractor and target occurred simultaneously). In all studies, the presentation of the distractor was perfectly correlated with that of the target.

In summary, past studies measuring behavioral deviance distraction in purely auditory oddball tasks involved stimuli that can be regarded as conveying event information and, for several, temporal information, similar to what has been observed in auditory-visual oddball tasks. This begs an important question: Is deviance distraction in auditory oddball tasks mediated by the distractor's informational value (as is observed in the cross-modal oddball task)? To address this issue, we carried out an experiment in which participants categorized the lateral movement of a sound while ignoring rare and unexpected changes of its identity. We compared deviance distraction as a function of the type of information provided by auditory distractors about the targets (event, temporal, both, or none). If behavioral distraction obeys the same principles in auditory and auditory-visual cross-modal tasks, distraction should be observed when sounds convey event information and not otherwise.

Methods

Participants

Eighty participants (63 females) from the Northeast Normal University of China took part in this experiment in

Table 1. Alphabetically ordered list of studies using an auditory oddball task in which behavioral distraction was measured and reported (studies using the so-called three-stimulus paradigm in which participants only respond to a rare target and not to standard and deviant stimuli are therefore excluded). The table displays their key methodological characteristics, including the modality in which stimuli were presented, their duration, the nature of the standard and deviant/novel manipulation, and the task participants were asked to perform. Behavioral distraction was observed in all studies

Study	Stimulus duration (ms)	Standard	Novel/deviant	Participant's task
Bendixen, Prinz, Horváth, Trujillo-Barreto, and Schröger (2008)	50 or 120	Tone	Tone (sequential pattern violation)	Duration judgment (2-AFC)
Bendixen et al. (2007)	200 or 400	Tone	Tone (sequential pattern violation)	Duration judgment (2-AFC)
Bendixen and Schröger (2008)	200 or 400	Tone	Tone (sequential pattern violation)	Duration judgment (2-AFC)
Berti (2008)	200 or 400	Tone	Tone (different pitch, loudness, or location)	Duration judgment (2-AFC)
Berti, Roeber, and Schröger (2004)	200 or 400	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Berti and Schröger (2001)	200 or 400	Tone or triangle	Tone (different pitch) or modified triangle (location or orientation)	Duration judgment (respond to long, not short)
Berti and Schröger (2003)	200 or 400	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Boll and Berti (2009)	200 or 400	Tone or triangle	Tone (different pitch) or modified triangle (location)	Duration judgment (respond to long, not short)
Grimm et al. (2008)	200	One of two consonant-vowel syllables	One of two consonant-vowel syllables (different pitch, location, or duration)	Phonemic discrimination task (2-AFC)
Hölig and Berti (2010)	200	Tone	Tone (different pitch)	Location judgment (central vs. lateral)
Horváth, Roeber, et al. (2008)	50 and 250 (pairs of tones)	Pair of tones	Spectral difference between first and second tone	Pitch change direction judgment
Horváth, Sussman, Winkler, and Schröger (2011)	100 or 200	Tone	Tone (different pitch)	Duration judgment (respond to long, not short)
Horváth and Winkler (2010)	Continuous sound	Tone	Pitch glide	Temporal gap detection
Jankowiak and Berti (2007)	200 or 400	Tone	Tone (different pitch, loudness, or location)	Duration judgment (2-AFC)
Mager et al. (2005)	200 or 400	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Muller-Gass and Schröger (2007)	100 or 400 190 or 310	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Rinne et al. (2006)	100		Harmoniccomplexes	Harmonic complexes (different intensity)
Pitch judgment (2-AFC)				
Roeber et al. (2009)	400	Four syllables	Four syllables (different pitch)	Syllable discrimination (2-AFC)
Roeber, Berti, and Schröger (2003)	200 or 400	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Roeber, Berti, Widmann, and Schröger (2005)	200 or 400	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Roeber et al. (2003)	200 or 400	Burst of white noise from central or left location	Burst of white noise (different location or different duration, depending on task)	Duration judgment (2-AFC) or location judgment (2-AFC)

(Continued on next page)

Table 1. (Continued)

Study	Stimulus duration (ms)	Standard	Novel/deviant	Participant's task
Sabri, Liebenthal, Waldron, Medler, and Binder (2006)	50 or 60	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Schröger (1996)	50 or 100 60	Tone	Tone (different pitch)	Intensity judgment (2-AFC) in left channel while ignoring tones in right channel (fixed SOA between channels)
Schröger, Giard, and Wolff (2000)	200 or 400	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Schröger and Wolff (1998)	100 or 200	Tone	Tone (different pitch, with small, medium, and large deviation)	Duration judgment (respond to long, not short)
Sussman, Winkler, and Schröger (2003)	100 or 200	Tone	Tone (different pitch)	Duration judgment (respond to long, not short)
Wetzel et al. (2004)	400	Animal sounds	Location	Sound discrimination (2-AFC)
Wetzel and Schröger (2007)	200 or 500	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Wetzel, Widmann, Berti, and Schröger (2006)	200 or 500	Tone	Tone (different pitch)	Duration judgment (2-AFC)
Wetzel et al. (2009)	500	Tone	Environmental sounds	Left/right categorization of sound movement

exchange for a small payment. All participants reported normal hearing and normal or corrected-to-normal vision. Participants were between 19 and 29 years old (M = 20.01, SD = 2.11). None of the participants reported any history of attention-related disorders. All participants were informed about the experimental procedure and were naïve to the purpose of the experiment. Twenty participants were randomly allocated to each of four experimental conditions (see below).

Materials

All auditory stimuli were created from two binaural normalized sounds, each 400 ms long. Both were low-pass filtered at 1,000 Hz using a static filter with a steepness of 10 dB per octave. One sound was that of a buzzing bee. The other was of a croaking frog. Fourteen sounds were used in the experiment. Two consisted of the sounds as described above (bee and frog sounds presented binaurally with identical sound intensity in the left and right channels). The remaining 12 sounds consisted of digitally edited versions of the bee and frog sounds in which a movement to the left or the right auditory channel started at one of three temporal positions (100, 200, and 300 ms after the sound's onset). The movement was simulated by linearly reducing sound intensity in one auditory channel (e.g., left) in order to reach minimum intensity by the end of the original sound duration while maintaining sound intensity unchanged in the other channel. Sounds were presented through headphones with a starting intensity of approximately 70 dB. The task was programmed in the E-Prime software (Psychology Software Tools, Pittsburgh, PA) and administered on a PC computer.

Design and Procedure

The participant's task consisted in discriminating the direction in which sounds presented through headphones moved by pressing corresponding keys on the computer keyboard using two fingers from their dominant hand (keys 1 and 2 on the numerical keypad for left and right movements, respectively). Each trial consisted in the presentation of a sound followed by a 2,000 ms interval during which participants were required to respond. The next trial was automatically presented at the end of that response period. In 80% of trials, the sound participants categorized was that of the bee (standard) while in the remaining 20% it was that of the frog (deviant). Participants were instructed to try to ignore the identity of the sound and to concentrate instead on the direction in which it moved. Instructions also emphasized the need for both speed and accuracy.

Four experimental conditions (*Event + Temporal, Event, Temporal,* and *Uninformative*, see below) were compared between participants, each involving standard and deviant sounds (within-participant factor). Each condition included 25 practice trials followed by 900 test trials separated in six blocks of 150 trials. Each block contained 30 deviant trials and 120 standard trials, randomly ordered with the constraint that two deviant trials were never presented in immediate succession. Left and right sounds occurred with equal probability and unpredictably in all experimental conditions. The between-subjects conditions differed with respect to the probability that the sound would move (1 or .5) and the time at which the movement would begin (100, 200, or 300 ms into the sound), allowing us to create conditions in which event and temporal information were manipulated orthogonally in a 2 (Event information: present, absent) × 2 (Temporal information: present, absent) design. In the *Event + Temporal Information* condition, all sounds included a movement and this movement began 200 ms after the sound's onset. As a result, the sound's onset always announced the upcoming presentation of the target information (movement) and its predicted temporal onset. In the *Event Information* condition, all trials included a movement but the onset of that movement varied equi-probably between three intervals (100, 200, and 300 ms), such that all sounds announced the presentation of the target (movement) but not its time of occurrence. In the *Temporal Information* condition, in contrast, movement could only be initiated 200 ms into the sound but the probability of a target (movement) occurring was .5 (when no movement was present, the sound intensity remained unchanged in the left and right auditory channels). Finally, in the *Uninformative* condition, neither event nor temporal information was provided. Sounds included a movement in only half the trials and when they did, the onset of that movement relative to the sound's onset varied equi-probably between three intervals (100, 200, 300 ms). Thus in this condition, the sound's onset did not announce whether the target information would be presented or when. The key trials shared by all information conditions and subjected to statistical analysis below were those involving a movement 200 ms after the sound's onset. All other trials served the function of fillers aiming to introduce event or temporal uncertainty in the task (as in Ljungberg et al., 2012; Parmentier, Elsley, et al., 2010). The Temporal and Uninformative conditions both involved 50% of trials without a target stimulus. Accordingly, in these trials, participants were required not to respond.

Participants were tested individually in a quiet testing room. They received performance feedback at the end of each block and were allowed a short break before initiating the next block. The whole experimental session took approximately an hour.

Results

Both response accuracy (proportion correct) and RTs (mean RTs, measured from the onset of the sound's movement) were measured for the trials of comparable temporal and probabilistic characteristics shared across all information conditions, namely, trials in which sounds involved a movement starting 200 ms from the sound's onset (as in Ljungberg et al., 2012; Parmentier, Elsley, et al., 2010). Trials with RTs greater than 1,000 ms (1.3% of the data) were considered outliers and excluded from the analyses below.

Accuracy

The proportion of correct responses was close to ceiling (M = .96, SD = .03). The proportion of correct responses was analyzed using a 2 (Distractor Type: standard vs. deviant, within-participant) × 2 (Temporal Information: present vs. absent, between-participants) × 2 (Event Information: present vs. absent, between-participants) mixed-design ANOVA. This analysis revealed no main effect of deviance, $F(1, 76) < 1$, MSE = .0005, η_p^2 = .005, p = .531, no main effect of temporal information, $F(1, 76)$ = 1.42, MSE = .0016, η_p^2 = .018, p = .237, and no main effect of event information, $F(1, 76) < 1$, MSE = .0016, $\eta_p^2 < .001$, p = .983. The Deviance × Event Information interaction was not significant $F(1, 76) < 1$, MSE = .0005, η_p^2 = .0003, p = .882. The Event × Temporal Information was not significant either, $F(1, 76) < 1$, MSE = .0016, η_p^2 = .006, p = .495. The Deviance × Temporal Information interaction just reached significance, $F(1, 76)$ = 3.93, MSE = .0005, η_p^2 = .049, p = .05, reflecting a small advantage (0.9% difference) of the deviant condition over the standard condition in the absence of temporal information, $F(1, 76)$ = 3.41, MSE = .0005, p = .069, and no difference in the presence of temporal information, $F(1, 76) < 1$, MSE = .0005, p = .342. Finally, the three-way interaction was not significant either, $F(1, 76) < 1$, MSE = .0005, η_p^2 = .0003, p = .882.

Response Times

A 2 (Distractor Type: standard vs. deviant) × 2 (Event Information: present vs. absent) × 2 (Temporal Information: present vs. absent) mixed-design ANOVA revealed a main effect of event information, $F(1, 76)$ = 18.007, MSE = 6,422, η_p^2 = .192, $p < .001$ (shorter RTs in the presence of event information than in its absence), and a main effect of deviance (longer RTs in the presence of a deviant relative to standard stimulus), $F(1, 76)$ = 15.955, MSE = 474, η_p^2 = .174, $p < .001$. The main effect of temporal information was not significant, $F(1, 76) < 1$, MSE = 6,422, η_p^2 = .003, p = .621, nor were any of the interactions involving temporal information: Deviance × Temporal Information, $F(1, 76)$ = 2.045, MSE = 474, η_p^2 = .026, p = .157, Event × Temporal Information, $F(1, 76)$ = 2.827, MSE = 6,422, η_p^2 = .036, p = .097, or three-way interaction, $F(1, 76) < 1$, MSE = 474, η_p^2 = .0008, p = .803. A significant Deviance × Event Information was observed however, $F(1, 76)$ = 7.292, MSE = 474, η_p^2 = .088, p = .009. This interaction reflected the significant deviance distraction in the presence of event information, $F(1, 76)$ = 22.410, MSE = 474.49, $p < .001$, and not in its absence, $F(1, 76) < 1$, MSE = 474.49, p = .363. In sum, as visible from Figure 1, deviance distraction was observed in the Event and Event + Temporal information conditions – in which deviance distraction was of similar amplitude, $F(1, 76)$ = 1.412, MSE = 474.494, p = .239 - but not in the Uninformative and Temporal conditions. Overall, the analysis of RTs shows that deviance distraction was

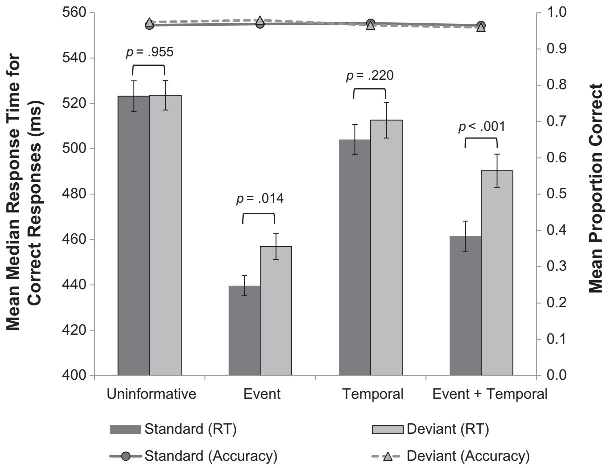

Figure 1. Performance in the Uninformative, Event, Temporal, and Event + Temporal conditions of the auditory oddball task. Bars represent the mean response latencies for correct responses. Lines represent the mean proportion of correct responses. Error bars correspond to one standard error of the mean (the size of the standard error for the accuracy data was too small to be visible on this graph). *P*-values correspond to contrasts measuring distraction (deviant vs. standard) in each information condition.

mediated by event information (distraction only observed when sounds predicted the presentation of the target information), not by temporal information. The same results were obtained when carrying out the ANOVA with accuracy as a covariate (see Appendix).

Discussion

Using a task in which participants judged the lateral movement of sounds, we found that the rare and unpredictable presentation of a deviant (frog) sound instead of the standard (bee) sound yielded significant behavioral distraction in conditions conveying event information, that is, in conditions in which the sound's onset predicted with certainty the occurrence of a movement. This was observed irrespective of whether the temporal onset of that movement varied or was held constant. In contrast, no deviance distraction was observed when half the sounds contained no movement, irrespective of the temporal information they conveyed. This pattern demonstrates for the first time that behavioral distraction in the auditory oddball task is mediated by the distractor's informational content, and more specifically, the predictability of the occurrence of the target stimulus (in this case the movement's sound). Finally, accuracy was overall slightly higher (0.9%) in conditions of temporal uncertainty, an unexpected finding that might possibly reflect an increase in alertness following deviant sounds (see SanMiguel, Linden, et al., 2010, for supporting evidence) and a small shift in the participant's response criteria. Importantly, however, this small effect did not undermine the more important finding from our study, namely, the mediation of deviance distraction by event information.

Event information impacted on performance in two ways: by speeding up responses overall and by mediating distraction. These findings fit with data highlighting the warning value of event information (e.g., Hackley, 2009). When every sound entailed the presentation of a target feature (movement), the introduction of rare and unexpected changes in sound identity resulted in longer RTs, suggesting that behavioral distraction is mediated by the extent to which the cognitive system covertly uses distractors to prepare for action. Interestingly, participants in go/no-go tasks have been shown to adopt a more cautious response strategy when they expect their responses may need to be withheld (Aron, 2011; Verbruggen & Logan, 2009). It may therefore be that the introduction of no-go trials in our Temporal and Uninformative conditions diverted cognitive resources away from the involuntary monitoring of auditory distractors as warning signals and directed them, instead, toward a higher level of task-set and/or strategic control.

Distraction by deviant sounds has long been examined from an electrophysiological perspective (e.g., Friedman, Cycowicz, & Gaeta, 2001; Schröger, 1996; Schröger, 1997), focusing on the involuntary capture of attention by deviant sounds as marked by a triumvirate of specific brain responses: MMN, P3a, and RON (e.g., Berti & Schröger, 2001; Horváth, Winkler, & Bendixen, 2008; Munka & Berti, 2006). Behavioral distraction has, in contrast, often been treated as a by-product and, until recently, not received much scrutiny (e.g., Parmentier et al., 2008; Wetzel et al., 2012). It is worth emphasizing that we focused on behavioral deviance distraction and that our conclusions cannot therefore be generalized to distraction as measured electrophysiologically. There is indeed growing evidence that behavioral and electrophysiological indexes of distraction are only partially correlated (e.g., SanMiguel, Morgan, Klein, Linden, & Escera, 2010), suggesting that behavioral distraction deserves further research in its own right. For example, recent work by Wetzel, Widmann, and Schröger (2011) indicates that while behavioral distraction is absent in the cross-modal oddball task when the auditory distractors are uninformative, the P3a response is insensitive to this manipulation and exhibit the same characteristics regardless of the sounds' informational content (see Horváth, Winkler, et al., 2008, for the suggestion that the occurrence of P3a "does not imply that more detailed stimulus evaluation should necessarily follow P3a elicitation," p. 145). In contrast, Berti (2012) recently reported P3a in response to deviant sounds but in the absence of behavioral distraction. One may tentatively suggest that electrophysiological indexes of change detection and attention capture may occur in an obligatory fashion but that behavioral distraction is subject to later processing and filtering. Such filtering may be influenced by the extent to which auditory distractors are of functional use for the participant's immediate goals, for example, to activate task sets and/or motor plans for the responses required in the task (e.g., Jentzsch, Leuthold, & Ridderinkhof, 2004; Rosenbaum & Kornblum, 1982).

The key implication from our study is that deviance is not a sufficient condition for sounds to yield behavioral distraction, just as it is not in the cross-modal oddball task either (Parmentier, Elsley, et al., 2010). Furthermore, our results show that the functional similarity between the auditory-visual cross-modal (Ljungberg, Parmentier, Leiva, et al., 2012) and the auditory version of the oddball task goes further: in both, event information appears to be pivotal. Together with recent work by Parmentier, Elsley, Andrés, and Barceló (2011) demonstrating that deviant sounds yield distraction because they violate the cognitive system's expectation of a standard sound rather than because of the deviant sound's low probability of occurrence (see also Bendixen, Roeber, & Schröger, 2007; Schröger, Bendixen, Trujillo-Barreto, & Roeber, 2007; van Zuijen, Simoens, Paavilainen, Näätänen, & Tervaniemi, 2006), our study suggests that behavioral distraction by deviant sounds should not simply be construed as the obligatory outcome of the presentation of rare auditory distractors but is sensitive to the extent to which sounds warn of and predict the occurrence of a target stimulus.

Finally, data from our Event and Event + Temporal conditions are in line with the idea that distraction does not only reflect the impact of the deviant stimuli but also the benefit from the presentation of a frequent, informative, and perceptual constant standard stimulus when this stimulus conveys useful warning information. Berti and Schröger (2006) found that participants process targets faster when the number of standard stimuli increases. In line with this finding, Jankowiak and Berti (2007) found that RTs to standard sounds (presented in a design involving three equiprobable types of deviant) decrease as the probability of that standard increases from .5, to .65, and to .75. Interestingly, distraction by deviants was only significant in the latter two cases, that is, in conditions in which standard sounds facilitated performance relative to the first condition. In the light of these findings, one may hypothesize that behavioral distraction in our task might only emerge when standard sounds benefit performance, which appears to occur when they are frequent and act as useful warning signals by conveying event information.

In conclusion, our study demonstrates that (1) assuming that deviant sounds' low base-rate probability is a sufficient condition to observe deviance distraction would be inaccurate; that (2) behavioral distraction as reported in past auditory oddball studies may relate to the perfect correlation between the presentation of distractor and target information; and that (3) the key mediation played by event information in deviance distraction can be generalized from the crossmodal oddball task to the auditory oddball task and therefore be, *pro tempore,* hailed as a potential general principle of behavioral deviance distraction. Considered in a more global theoretical context, our results fit with the emerging view of the brain as a predictive device (e.g., Bubic, von Cramon, Jacobsen, Schröger, & Schubotz, 2009) that uses stimulus contingencies to build forward models of the environment and that, when appropriate, capitalizes on such models to optimize behavior and prepare for action.

Acknowledgments

This work was carried out with The Fundamental Research Funds for the Central Universities (I0SSXTI I4) awarded to Biqin Li. Fabrice Parmentier was supported by a research grant (PSI-2009-08427) from the Spanish Ministry of Science and Innovation and by a research grant (31100730) from the National Natural Science Foundation of China awarded to Biqin Li.

References

Andrés, P., Parmentier, F. B. R., & Escera, C. (2006). The effect of age on the involuntary capture of attention by irrelevant sounds: A test of the frontal hypothesis of aging. *Neuropsychologia, 44*, 2564–2568.

Aron, A. R. (2011). From reactive to proactive and selective control: Developing a richer model for stopping inappropriate responses. *Biological Psychiatry, 69*, e55–e68.

Bendixen, A., Prinz, W., Horváth, J., Trujillo-Barreto, N. J., & Schröger, E. (2008). Rapid extraction of auditory feature contingencies. *Neuroimage, 41*, 1111–1119.

Bendixen, A., Roeber, U., & Schröger, E. (2007). Regularity extraction and application in dynamic auditory stimulus sequences. *Journal of Cognitive Neuroscience, 19*, 1664–1677.

Bendixen, A., & Schröger, E. (2008). Memory trace formation for abstract auditory features and its consequences in different attentional contexts. *Biological Psychology, 78*, 231–241.

Berti, S. (2008). Cognitive control after distraction: Event-related brain potentials (ERPs) dissociate between different processes of attentional allocation. *Psychophysiology, 45*, 608–620.

Berti, S. (2012). Automatic processing of rare versus novel auditory stimuli reveal different mechanisms of auditory change detection. *Neuroreport, 23*, 441–446.

Berti, S., Roeber, U., & Schröger, E. (2004). Bottom-up influences on working memory: Behavioral and electrophysiological distraction varies with distractor strength. *Experimental Psychology, 51*, 249–257.

Berti, S., & Schröger, E. (2001). A comparison of auditory and visual distraction: Behavioral and event-related indices. *Cognitive Brain Research, 10*, 265–273.

Berti, S., & Schröger, E. (2003). Working memory controls involuntary attention switching: Evidence from an auditory distraction paradigm. *European Journal of Neuroscience, 17*, 1119–1122.

Berti, S., & Schröger, E. (2004). Distraction effects in vision: Behavioral and event-related potential indices. *Neuroreport, 15*, 665–669.

Berti, S., & Schröger, E. (2006). Visual distraction: A behavioral and event-related brain potential study in humans. *Neuroreport, 17*, 151–155.

Boll, S., & Berti, S. (2009). Distraction of task-relevant information processing by irrelevant changes in auditory, visual, and bimodal stimulus features: A behavioral and event-related potential study. *Psychophysiology, 46*, 645–654.

Bubic, A., von Cramon, D. Y., Jacobsen, T., Schröger, E., & Schubotz, R. I. (2009). Violation of expectation: Neural correlates reflect bases of prediction. *Journal of Cognitive Neuroscience, 21*, 155–168.

Escera, C., Alho, K., Winkler, I., & Näätänen, R. (1998). Neural mechanisms of involuntary attention to acoustic novelty and change. *Journal of Cognitive Neuroscience, 10*, 590–604.

Friedman, D., Cycowicz, Y. M., & Gaeta, H. (2001). The novelty P3: An event-related brain potential (ERP) sign of the brain's evaluation of novelty. *Neuroscience & Biobehavioral Reviews, 25*, 355–373.

Grimm, S., Schröger, E., Bendixen, A., Bäß, P., Roye, A., & Deouell, L. Y. (2008). Optimizing the auditory distraction paradigm: Behavioral and event-related potential effects in a lateralized multi-deviant approach. *Clinical Neurophysiology, 119*, 934–947.

Hackley, S. A. (2009). The speeding of voluntary reaction by a warning signal. *Psychophysiology, 46*, 225–233.

Horváth, J., Roeber, U., Bendixen, A., & Schröger, E. (2008). Specific or general? The nature of attention set changes triggered by distracting auditory events. *Brain Research, 1229*, 193–203.

Horváth, J., Sussman, E., Winkler, I., & Schröger, E. (2011). Preventing distraction: Assessing stimulus-specific and general effects of the predictive cueing of deviant auditory events. *Biological Psychology, 87*, 35–48.

Horváth, J., & Winkler, I. (2010). Distraction in a continuous-stimulation detection task. *Biological Psychology, 83*, 229–238.

Horváth, J., Winkler, I., & Bendixen, A. (2008). Do NI/MMN, P3a, and RON form a strongly coupled chain reflecting the three stages of auditory distraction? *Biological Psychology, 79*, 139–147.

Hölig, C., & Berti, S. (2010). To switch or not to switch: Brain potential indices of attentional control after task-relevant and task-irrelevant changes of stimulus features. *Brain Research, 1345*, 164–175.

Jankowiak, S., & Berti, S. (2007). Behavioral and event-related potential distraction effects with regularly occurring auditory deviants. *Psychophysiology, 44*, 79–85.

Jentzsch, I., Leuthold, H., & Ridderinkhof, R. (2004). Beneficial effects of ambiguous precsues: Parallel motor preparation or reduced premotoric processing time? *Psychophysiology, 41*, 231–244.

Ljungberg, J. K., & Parmentier, F. B. R. (2012a). The impact of intonation and valence on objective and subjective attention capture by auditory alarms. *Human Factors, 54*, 826–837. doi: 10.1177/0018720812438613

Ljungberg, J. K., & Parmentier, F. B. R. (2012b). Cross-modal distraction by deviance: Functional similarities between the auditory and tactile modalities. *Experimental Psychology, 59*, 355–363. doi: 10.1027/1618-3169/a000164

Ljungberg, J. K., Parmentier, F. B. R., Leiva, A., & Vega, N. (2012). The informational constraints of behavioral distraction by unexpected sounds: The role of event information. *Journal of Experimental Psychology: Learning, Memory & Cognition, 38*, 1461–1468. doi: 10.1037/a0028149

Mager, R., Falkenstein, M., Störmer, R., Brand, S., Müller-Spahn, F., & Bullinger, A. H. (2005). Auditory distraction in young and middle-aged adults: A behavioural and event-related potential study. *Journal of Neural Transmission, 112*, 1165–1176.

Muller-Gass, A., & Schröger, E. (2007). Perceptual and cognitive task difficulty has differential effects on auditory distraction. *Brain Research, 1136*, 169–177.

Munka, L., & Berti, S. (2006). Examining task-dependencies of different attentional processes as reflected in the P3a and reorienting negativity components of the human event-related brain potential. *Neuroscience Letters, 396*, 177–181.

Niemi, P., & Näätänen, R. (1981). Foreperiod and simple reaction time. *Psychological Bulletin, 89*, 133–162.

Parmentier, F. B. R. (2008). Towards a cognitive model of distraction by auditory novels: The role of involuntary attention capture and semantic processing. *Cognition, 109*, 345–362.

Parmentier, F. B. R., & Andrés, P. (2010). The involuntary capture of attention by sound: Novelty and post-novelty distraction in young and older adults. *Experimental Psychology, 57*, 68–76.

Parmentier, F. B. R., Elford, G., Escera, C., Andres, P., & San Miguel, I. (2008). The cognitive locus of distraction by acoustic novelty in the cross-modal oddball task. *Cognition, 106*, 408–432.

Parmentier, F. B. R., Elsley, J. V., Andres, P., & Barceló, F. (2011). Why are auditory novels distracting? Contrasting the roles of novelty, violation of expectation and stimulus change. *Cognition, 119*, 374–380.

Parmentier, F. B. R., Elsley, J. V., & Ljungberg, J. K. (2010). Behavioral distraction by auditory novelty is not only about novelty: The role of the distracter's informational value. *Cognition, 115*, 504–511.

Parmentier, F. B. R., Ljungberg, J. K., Elsley, J. V., & Lindkvist, M. (2011). A behavioral study of distraction by vibrotactile novelty. *Journal of Experimental Psychology: Human Perception & Performance, 37*, 1134–1139.

Parmentier, F. B. R., Maybery, M. T., & Elsley, J. V. (2010). The involuntary capture of attention by novel feature pairings: A study of voice-location integration in auditory sensory memory. *Attention, Perception & Psychophysics, 72*, 279–284.

Parmentier, F. B. R., & Turner, J. (2013). Auditory distraction: A dual contribution to the involuntary semantic processing of unexpected spoken words. *Journal of Experimental Psychology: General*. Advance online publication. doi: 10.1037/a0031550

Parmentier, F. B. R., Turner, J., & Elsley, J. V. (2011). Distraction by auditory novelty: The course and aftermath of novelty and semantic effects. *Experimental Psychology, 58*, 92–101.

Parmentier, F. B. R., Turner, J., & Perez, L. (2013, January). A dual contribution to the involuntary semantic processing of unexpected spoken words. *Journal of Experimental Psychology: General*. Advance online publication. doi:10.1037/a0031550

Rinne, T., Särkka, A., Degerman, A., Schröger, E., & Alho, K. (2006). Two separate mechanisms underlie auditory change detection and involuntary control of attention. *Brain Research, 1077*, 135–143.

Roeber, U., Berti, S., Müller, D., Widmann, A., & Schröger, E. (2009). Disentangling effects of auditory distraction and of stimulus-response sequence. *Psychophysiology, 46*, 425–438.

Roeber, U., Berti, S., & Schröger, E. (2003). Auditory distraction with different presentation rates: An even-related potential and behavioral study. *Clinical Neurophysiology, 114*, 341–349.

Roeber, U., Berti, S., Widmann, A., & Schröger, E. (2005). Response repetition vs. response change modulates behavioral and electrophysiological effects of distraction. *Cognitive Brain Research, 22*, 451–456.

Roeber, U., Widmann, A., & Schröger, E. (2003). Auditory distraction by duration and location deviants: A behavioral and event-related potential study. *Brain Research. Cognitive Brain Research, 17*, 347–357.

Rosenbaum, D. A., & Kornblum, S. (1982). A priming method for investigating the selection of motor responses. *Acta Psychologica, 51*, 223–243.

Sabri, M., Liebenthal, E., Waldron, E. J., Medler, D. A., & Binder, J. R. (2006). Attentional modulation in the detection of irrelevant deviance: A simultaneous ERP/fMRI study. *Journal of Cognitive Neuroscience, 18*, 689–700.

SanMiguel, I., Linden, D., & Escera, C. (2010). Attention capture by novel sounds: Distraction versus facilitation. *European Journal of Cognitive Psychology, 22*, 481–515.

SanMiguel, I., Morgan, H. M., Klein, C., Linden, D., & Escera, C. (2010). On the functional significance of Novelty-P3: Facilitation by unexpected novel sounds. *Biological Psychology, 83*, 143–152.

Schröger, E. (1996). A neural mechanism for involuntary attention shifts to changes in auditory stimulation. *Journal of Cognitive Neuroscience, 8*, 527–539.

Schröger, E. (1997). On the detection of auditory deviations: A pre-attentive activation model. *Psychophysiology, 34*, 245–257.

Schröger, E., Bendixen, A., Trujillo-Barreto, N. J., & Roeber, U. (2007). Processing of abstract rule violations in audition. *PLoS One, 2*, e1131.

Schröger, E., Giard, M.-H., & Wolff, C. (2000). Auditory distraction: Event-related potential and behavioral indices. *Clinical Neuropsychology, 111*, 1450–1460.

Schröger, E., & Wolff, C. (1998). Behavioral and electrophysiological effects of task-irrelevant sound change: A new distraction paradigm. *Cognitive Brain Research, 7*, 71–87.

Sussman, E., Winkler, I., & Schröger, E. (2003). Top-down control over involuntary attention switching in the auditory modality. *Psychonomic Bulletin & Review, 10*, 630–637.

van Zuijen, T. L., Simoens, V. L., Paavilainen, P., Näätänen, R., & Tervaniemi, M. (2006). Implicit, intuitive and explicit knowledge of abstract regularities in a sound sequence: An event-related brain potential study. *Journal of Cognitive Neuroscience, 18*, 1292–1303.

Verbruggen, F., & Logan, G. D. (2009). Automaticity of cognitive control: Goal priming in response-inhibition paradigms. *Journal of Experimental Psychology: Learning, Memory & Cognition, 35*, 1381–1388.

Wetzel, N., Berti, S., Widmann, A., & Schröger, E. (2004). Distraction and reorientation in children: A behavioral and ERP study. *Neuroreport, 15*, 1355–1358.

Wetzel, N., & Schröger, E. (2007). Cognitive control of involuntary attention and distraction in children and adolescents. *Brain Research, 1155*, 134–146.

Wetzel, N., Widmann, A., Berti, S., & Schröger, E. (2006). The development of involuntary and voluntary attention from childhood to adulthood. A combined behavioral and event-related potential study. *Clinical Neurophysiology, 117*, 2191–2203.

Wetzel, N., Widmann, A., & Schröger, E. (2009). The cognitive control of distraction by novelty in children aged 7–8 and adults. *Psychophysiology, 46*, 607–616.

Wetzel, N., Widmann, A., & Schröger, E. (2011). *Attentional capture and distraction – uninformative novel sounds capture attention but do not necessarily impair performance.* Poster presented at International Conference on Cognitive Neuroscience XI (ICON), Palma de Mallorca, Spain, September, 2011.

Wetzel, N., Widmann, A., & Schröger, E. (2012). Distraction and facilitation – two faces of the same coin? *Journal of Experimental Psychology: Human Perception and Performance, 38*, 664–674. doi: 10.l037/a0025856

Received October 17, 2012
Revision received November 22, 2012
Accepted December 11, 2012
Published online April 30, 2013

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Appendix

The analysis of RTs with response accuracy as a covariate yielded the same results as the above analysis. The covariate had no significant effect, $F(1, 75) < 1$, $MSE = 479.44$, $p = .644$. The main effect of Event Information was significant, $F(l, 75) = 18.446$, $MSE = 6256.659$, $p < .00$ i, as was the main effect of deviance, $F(l, 75) = 15.444$, $MSE = 479.44$, $p < .001$, and the Event Information × Deviance interaction, $F(l, 75) = 7.172$, $MSE = 479.44$, $p < .01$. None of the remaining effects or interaction were significant: Temporal Information, $F(l, 75) < 1$, $MSE = 6256.659$, $p = .466$; Event × Temporal Information, $F(l, 75) = 3.364$, $MSE = 479.44$, $p = .070$; Temporal Information × Deviance, $F(l, 75) = 2.221$, $MSE = 479.44$, $p = .1\ 40$; three-way interaction, $F(l, 75) < l$, $MSE = 479.44$, $p = .798$.