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Research Report

Involuntary attentional capture by speech and non-speech deviations: A combined behavioral–event-related potential study

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ABSTRACT

This study applied an auditory distraction paradigm to investigate involuntary attention effects of unexpected deviations in speech and non-speech sounds on behavior (increase in response time and error rate) and event-related brain potentials (ΔN1/MMN and P3a). Our aim was to systematically compare identical speech sounds with physical vs. linguistic deviations and identical deviations (pitch) with speech vs. non-speech sounds in the same set of healthy volunteers. Sine tones and bi-syllabic pseudo-words were presented in a 2-alternative forced-choice paradigm with occasional phoneme deviants in pseudo-words, pitch deviants in pseudo-words, or pitch deviants in tones. Deviance-related ERP components were elicited in all conditions. Deviance-related negativities (ΔN1/MMN) differed in scalp distribution between phoneme and pitch deviants within phonemes, indicating that auditory deviance-detection partly operates in a deviance-specific manner. P3a as an indicator of attentional orienting was similar in all conditions, and was accompanied by behavioral indicators of distraction. Yet smaller behavioral effects and prolonged relative MMN-P3a latency were observed for pitch deviants within phonemes relative to the other two conditions. This suggests that the similarity and separability of task-relevant and task-irrelevant information is essential for the extent of attentional capture and distraction.

1. Introduction

Previous studies have demonstrated that unexpected, task-irrelevant sounds in our environment can involuntarily attract our attention and may thus impair the processing of task-relevant stimulus information (Escera et al., 1998; Grillon et al., 1990; Schröger and Wolff, 1998). This process, often referred to as auditory distraction, can result in specific behavioral and electrophysiological consequences such as performance deterioration and elicitation of certain components of the event-related brain potential (ERP). Involuntary attention has been previously associated with different cognitive subprocesses including change detection and attentional orienting. These processes are reflected in distinct ERP

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components. The Mismatch Negativity (MMN) is a negative deflection of the ERP with a peak latency of approximately 150 ms and a frontocentral scalp distribution that can be elicited by an irregular stimulus in a homogeneous series irrespective of whether the stimuli are attended or not (Näätänen et al., 1978) (for reviews, see e.g. Kujala et al. (2007), Näätänen et al. (2011)). MMN is assumed to reflect a mechanism that automatically detects unexpected stimulus characteristics by comparing a representation of the current stimulus with regular characteristics extracted from preceding stimuli (Winkler, 2007). In repetitive sound sequences, change detection can also be accomplished by more simple mechanisms based on differential adaptation to the frequently and the infrequently presented stimuli, indicated by an increase in the auditory N1 component (hereafter referred to as ΔN1) (see Horváth et al. (2008), for a detailed discussion). Another ERP component often observed within the context of auditory distraction is the P3a which peaks at around 300 ms and is elicited by large deviant or novel sounds (Squires et al., 1975). P3a is often interpreted as an indicator of an attention switch towards an unexpected stimulus (Escera et al., 2000, 2001; Snyder and Hillyard, 1976).

It has been argued that task-irrelevant information is more likely to interfere with the processing of task-relevant information when the two types of information are difficult to separate (Garner, 1974) than when they are parts of different stimulus streams or occur in different spatial locations. To obtain distractive effects on attention, task-irrelevant stimulus characteristics need to pass an attentional filter (Schröger, 1997) that depends on the type of task-relevant information. For a given amount of deviation, a distractor that is not part of the task-relevant object may fail to pass the attentional filter, while a distractor that is part of the task-relevant object would succeed. In other words, deviant stimuli are more likely to cause distraction if the channel separation between task-relevant and task-irrelevant information is minimized (Broadbent, 1971; Schröger and Wolff, 1998). Making use of this relation has led to the development of the auditory distraction paradigm by Schröger and Wolff (1998). In the original paradigm, subjects are asked to distinguish between long and short tones via button presses. Occasionally, these tones slightly change in frequency. Although the frequency change itself is irrelevant to the duration discrimination task, it can lead to reliable behavioral and electrophysiological distraction effects (Schröger et al., 2000), because task-relevant and task-irrelevant information are embedded into a single sound (object) and distracting information can thus not easily be ignored. Previous studies demonstrated that electrophysiological correlates of auditory distraction can also be elicited within speech stimuli (Grimm et al., 2008). However, no systematic comparison between speech and tonal material has been performed within an auditory distraction paradigm. Deviance detection mechanisms in speech processing are known to be different from those in tonal material. MMN for physical deviations in linguistic material has been reported to be diminished or

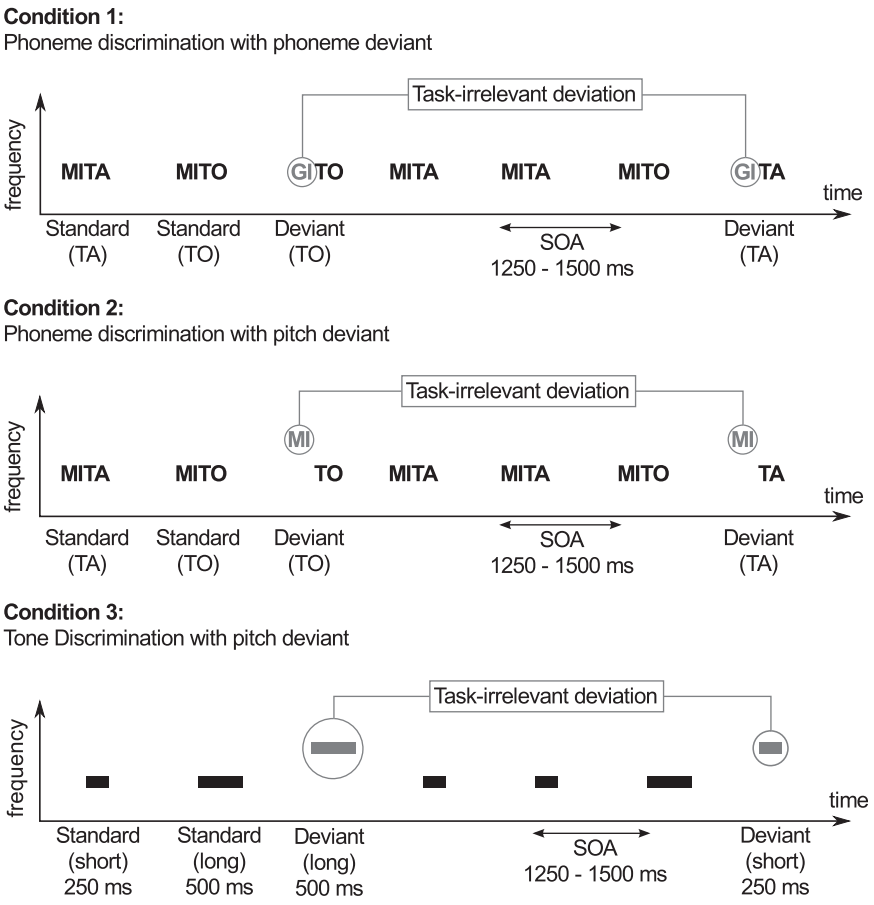

Fig. 1 – Experimental design for the three conditions.