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Age-related differences in distraction and reorientation in an auditory task

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Abstract

Behavioral and event-related potential measures of distraction and reorientation were obtained from children (6 years), young (19–24 years) and elderly adults (62–82 years) in an auditory distraction-paradigm. Participants performed a go/nogo duration discrimination task on a sequence of short and long (50–50%) tones. In children, reaction times were longer and discrimination (d') scores were lower than in adults. Occasionally (15%), the pitch of the presented tones was changed. The task-irrelevant feature variation resulted in longer reaction times and lower d' scores with no significant differences between the three groups. Task-irrelevant changes affected the N1 amplitude and elicited the mismatch negativity, N2b, P3 and reorienting negativity (RON) sequence of event-related brain potentials. In children, the P3 latency was the same as in young adults. However the RON component was delayed by about 100 ms. In the elderly, P3 and RON were uniformly delayed by about 80 ms compared to young adults. This pattern of results provides evidence that distraction influences different processing stages in the three groups. Restoration of the task-optimal attention set was delayed in children, whereas in the elderly, the triggering of involuntary attention-switching required longer time.

Keywords: Attention; Distraction; Orienting response; Children; Aging; Event-related potential (ERP); Mismatch negativity (MMN); P3; Reorienting negativity (RON)

1. Introduction

In many everyday situations, maintaining high-level performance in a given task requires focusing on the task-relevant aspects of the environment while disregarding the irrelevant ones. Although goal-directed behavior is primarily governed by top-down control, infrequent unpredictable events are automatically detected (Näätänen, 1992) and can trigger an orienting response (Sokolov, 1963; Schröger, 1997). Orienting towards unexpected task-irrelevant stimuli is advantageous in an evolutionary sense, because these may carry information that is crucial for survival. However, distraction from one's current task usually leads to temporary deterioration of performance in that task (Escera et al., 2000).

Normal functioning of the cognitive system is characterized by a good balance between maintenance of goal-directed behavior and involuntary orientation (passive attention, James, 1890; Escera et al., 2000). The balance, however, shifts during maturation and aging. Children and elderly adults are more susceptible to distraction than young adults, a fact often attributed to weaker inhibition efficiency related to immature or deteriorated frontal lobe functions (Van der Molen, 2000; Hasher et al., 2007). However, several processes participate in the distraction-orientation-refocusing cycle and, therefore, changes occurring in the course of human life may affect different functions involved in the interplay between voluntary and passive attention.

In the present study, we investigated processes contributing to goal-directed and orienting-related activities in three age-groups (early school-age children, young and elderly

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adults) with the goal to assess the effects of development and aging on the various processes.

1.1. A three-stage model of distraction

Current understanding of the interplay between distraction caused by unexpected events and control processes governing goal-directed behavior can be described in the framework of a *three-stage model of distraction* (Escera et al., 2000; Friedman et al., 2001; Näätänen, 1990, 1992; Polich and Criado, 2006; Schröger, 1997; Schröger and Wolff, 1998b).

The *first* stage of the model features processes, which continuously monitor and "model" the temporal aspects of the sensory environment without the involvement of voluntary control processes (Schröger, 1997; Näätänen, 1990; Winkler, in press). Modeling the environment is mainly based on the extraction of regularities from recent stimulation, whereas monitoring is based on the detection of discrepancies between the predictions of the model and incoming stimuli (Winkler, in press; Winkler et al., 1996). Regularity extraction and deviance-detection is an economic solution to the monitoring problem, as it minimizes the demand on capacity-limited control processes in relatively stable environmental stimulus configurations. Small deviations from the detected regularities usually lead to model-updates, which can be handled within the first processing stage (Näätänen and Winkler, 1999; Winkler, in press; Winkler et al., 1996). In contrast, major deviations can trigger higher-order processes leading to an involuntary change in the allocation of attention (Näätänen, 1990; Schröger, 1997; Escera et al., 1998). That is, gradual changes in the environment occurring over a longer period of time may go unnoticed, whereas the same change occurring rapidly may catch one's attention.

The processes of involuntary attention-switching constitute the *second stage* of the distraction model. Distraction is understood as a transition from a selective attention set which is optimal with respect to performing a given task, to a different, probably suboptimal set (with respect to performing the original task), which might allow for more efficient processing of the distracting task-irrelevant event (Escera et al., 2000; Polich, 2003; Schröger et al., 2000).

Processes at the *third stage* of the model are responsible for restoring the optimal attention-set for the task at hand (reorientation), that is, they directly subserve the voluntary re-establishing of the selective attention set appropriate for the primary task (Munka and Berti, 2006). These processes probably take place only if the task is still relevant at the point when the distracting event has been evaluated. Response execution based on task-relevant information may take place before as well as after the optimal attention-set has been restored.

In summary, the first stage can be described as filtering the task-irrelevant stimulation with automatic identification of events that violate the detected sensory regularities. Such events may trigger the involuntary attention-switching mechanisms of the second stage. The third stage encompasses mechanisms that compensate the effects of involuntary orientation to task-irrelevant aspects of the environment by restoring the task-optimal attention-set.

1.2. ERP correlates of the three processing stages

The three-stage model receives important support from the analysis of event-related potentials (ERPs) elicited in the *oddball* paradigms. In the oddball paradigm, occasional irregular stimuli are presented within the sequence of a repeating stimulus. The repeating stimulus is termed the *standard*, whereas the stimuli violating the repetition are termed *deviants*. The ERPs elicited in the oddball paradigm reflect many of the processes taking place during the three stages of the distraction-orientation-refocusing cycle. Some of the ERP components are elicited whether or not attention is directed towards the oddball stimulus sequence (corresponding to automatic/involuntary stimulus processing), other ERP components are elicited mainly when participants perform a task related to the oddball sequence. We start our description of the distraction-related ERP components with the ERP components elicited irrespective of the direction of focused attention, which are typically studied in the passive task conditon in which participants perform a task that is not related to the oddball sequence.

In the *passive* oddball paradigm, deviants elicit the modality-specific (auditory, visual and somatosensory) mismatch negativity (MMN), peaking 100–200 ms after the onset of deviance (Czigler et al., 2002; Näätänen et al., 1978; Shinozaki et al., 1998). As MMN can be elicited even if participants do not attend the stimuli, it is assumed to reflect a pre-attentive deviance detection process (Näätänen, 1990; Sussman et al., 2003b). In terms of the three-stage model, MMN reflects an important process in the first stage, one which detects irregular unattended stimuli.

In paradigms utilizing easily discriminable, salient deviants, MMN is often followed by the P3a, a fronto-central positivity peaking at about 300 ms (Friedman et al., 2001) from deviation onset. However, P3a-like activity can also be elicited without a preceding MMN (Rinne et al., 2006), e.g., by rare salient stimuli. P3a is assumed to reflect the activation of an attention-switching mechanism, which is an important step of involuntary orienting of attention (Escera et al., 2000; Friedman et al., 2001; Knight and Scabini, 1998; Schröger, 1996). Thus P3a would index processes in the second stage of the distraction model. However, there is no general consensus on the precise role of the P3a *within* the second processing stage (see Dien et al., 2004).

In *active* oddball paradigms (in which participants perform a task related to the stimulus sequence) a number of additional components can be observed.

When the oddball sequence is attended, MMN is overlapped/followed by the N2b component peaking around 200 ms (Näätänen and Gaillard, 1983; Ritter and Ruchkin, 1992). N2b probably reflects a modality-aspecific process: the controlled registration of the occurrence of an infrequent