Neurobiology of Aging 34 (2013) 1952–1962

Contents lists available at SciVerse ScienceDirect

Neurobiology of Aging

journal homepage: www.elsevier.com/locate/neuaging

Does age increase auditory distraction? Electrophysiological correlates of high and low performance in seniors

Stephan Getzmann*, Patrick D. Gajewski, Michael Falkenstein

Leibniz Research Centre for Working Environment and Human Factors at the Technical University of Dortmund (IfADo), Dortmund, Germany

ARTICLE INFO

Article history:
Received 13 September 2012
Received in revised form 13 February 2013
Accepted 17 February 2013
Available online 21 March 2013

Keywords:
Aging
Sensory processing
Auditory perception
Event-related potentials
MMN
P3a
Healthy elderly

ABSTRACT

Aging usually affects the ability to focus attention on a given task and to ignore distractors. However, aging is also associated with increased between-subject variability, and it is unclear in which features of processing older high-performing and low-performing human beings may differ in goal-directed behavior. To study involuntary shifts in attention to task-irrelevant deviant stimuli and subsequent reorientation, we used an auditory distraction task and analyzed event-related potential measures (mismatch negativity), P3a and reorienting negativity) of 35 younger, 32 older high-performing, and 32 older low-performing participants. Although both high and low performing elderly individuals showed a delayed reorienting to the primary stimulus feature, relative to young participants, poor performance of the elderly participants in processing of deviant stimuli was associated with strong involuntary attention capture by task-irrelevant features. In contrast, high performance of the elderly group was associated with intensified attentional shifting toward the target features. Thus, it appears that performance deficits in aging are due to higher distractibility in combination with deficits in the orienting–reorienting mechanisms.

1. Introduction

Healthy aging is associated with declines in various cognitive functions such as working memory capacity, processing speed, and inhibitory control (Van der Linden et al., 1999). In particular, elderly individuals often encounter difficulties in complex task settings where various concurring stimuli are present, and where top-down attentional control is needed to focus attention on a relevant event and to ignore irrelevant events to achieve efficient behavioral control (Duncan, 2006). As older adults are typically more readily distracted by task-irrelevant stimuli than are younger adults, goal-directed behavior of elderly persons could suffer from deficits in selectively promoting relevant stimuli and inhibiting irrelevant stimuli (reviewed by Kramer and Madden, 2008).

The interplay of goal-directed and orientation-related cognitive processes in complex scenarios has been described within a three-stage model of distraction (Polich and Criado, 2006; Escera et al., 2000; Schröger and Wolff, 1998): At the first stage of *regularity extraction* and *deviance detection* task-relevant information is filtered out of a stream of ongoing stimulation, and task-irrelevant information is automatically detected in terms of violations of regularities in sensory memory buffers. At the second stage of *involuntary attention-switching* the deviant information may lead to involuntary attention shifts that are, in a final stage of *reorientation*, to be compensated for by mechanisms restoring the optimal attention-set relevant for a given task.

This distraction–orientation–refocusing cycle has experimentally been operationalized within an auditory distraction paradigm in which a sequence of repeating tones is intermixed with occasional irregular tones violating the repetition. Subjects have to respond to the *standard* tones, while ignoring *deviant* tone features (Schröger et al., 2000). The basic processes taking place during the three stages can be distinguished by analysis of the event-related potentials (ERPs): Deviant stimuli typically evoke the fronto-central mismatch negativity (MMN) (Näätänen et al., 1978) that is thought to be a physiological correlate of pre-attentive deviance detection (Näätänen, 1990; Sussman et al., 2003). The MMN is usually followed by the fronto-central P3a (Friedman et al., 2001), a correlate of an involuntary attention-switching mechanism (Escera et al., 2000; Friedman et al., 2001; Knight and Scabini, 1998; Schröger, 1996). Finally, a late fronto-central negativity, so-called reorienting negativity (RON) (Schröger et al., 2000; Schröger and Wolff, 1998), is assumed to reflect re-allocation of attention to the relevant task after distraction by the deviant features (empirical evidence in Berti, 2008a; Hölig and Berti, 2010). In contrast to the deviants, standard stimuli usually produce a fronto-central N1-P2 complex that is followed by the parietal P3b (reviewed by Polich

* Corresponding author at: Leibniz Research Centre for Working Environment and Human Factors, Ardeystraße 67, D-44139 Dortmund, Germany. Tel.: +49 231 1084 338; fax: +49 231 1084 401.
E-mail address: stephan.getzmann@rub.de (S. Getzmann).

0197-4580/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.neurobiolaging.2013.02.014

and Criado, 2006). Although the N1 reflects an automatic processing of sensory input, the P2 has been related to attention allocation (Potts, 2004), and the P3b to the allocation of working memory and processing resources (Polich, 2007).

Previous studies have shown that the interplay of deviance detection, involuntary attention shifts, and top-down attentional control mechanisms change with increasing age (Mager et al., 2005; Cooper et al., 2006; Horváth et al., 2009; Ruzzoli et al., 2012), indicating an increased susceptibility to distracting stimuli. However, different cognitive subprocesses involved in the distraction–orientation–refocusing cycle may play a role: On the one hand, an age-related reduction of MMN relative to younger adults suggests specific deficits in encoding or retention of sensory information (Alain and Woods, 1999; Bertoli et al., 2002; Cooper et al., 2006; Czigler et al., 1992; Karayanidis et al., 1995; Pekkonen et al., 1993; Ruzzoli et al., 2012). On the other hand, age-related changes in P3a (Czigler et al., 2006; Gaeta et al., 2001; Mager et al., 2005; Horváth et al., 2009) and RON (Mager et al., 2005; Horváth et al., 2009) suggest attentional orienting and reorienting to contribute to deficits observed in elderly persons.

Beside this deficit view, it has been hypothesized that older adults may compensate for increased distractibility by stronger focusing of attention on the task-relevant stimuli (Horváth et al., 2009). In line with the decline-compensation hypothesis, elderly adults invest more effort than young adults to achieve the same level of performance (reviewed by Dennis and Cabeza, 2008). Neurophysiological studies thus demonstrated that especially high-performing older adults recruit extra cognitive resources, relative to their low-performing counterparts (Cabeza et al., 2002). In speech comprehension, for example, high-performing older adults efficiently counteracted age-related neural declines through increased allocation of attentional resources that were associated with additional activation of frontal brain areas (Getzmann and Falkenstein, 2011; Getzmann, 2012). According to the effortfulness hypothesis (Wingfield et al., 2005), this extra effort requires and inflates cognitive resources. In sum, age-related declines in performance in the auditory distraction paradigm could be based on (1) specific deficits in the distraction–orientation–refocusing cycle, and (2) insufficient cognitive resources to completely compensate for these deficits.

The present study investigated auditory distraction in younger and older adults, focusing on the question in which features of processing older high-performing and low-performing adults may differ in goal-directed behavior. Specifically, given the strong interindividual variability in cognitive performance in elderly (Hultsch et al., 2002), we asked whether high performance of older participants was associated with preservation of processing capacities (enabling the distraction-orientation-refocusing cycle to be performed as efficient as the young) or compensation of actual deficits. To answer this question, a total of 129 older and 35 younger adults performed an auditory distraction task well suited to examine the different processes underlying the 3-stage model introduced above (Mager et al., 2005; Horváth et al., 2009; Getzmann et al., 2013). Participants had to discriminate the duration of short and long tones that were either of high-probability standard frequency or of low-probability deviant frequencies (Schröger and Wolff, 1998). Thus, the participants had to attend to the task-relevant tone feature (i.e., its duration), while ignoring the distracting task-irrelevant tone feature (i.e., its pitch). To clarify the sources of performance differences within the older group, a high-performing (Old-High) and low-performing (Old-Low) subgroup was taken from the entire group of older participants, and ERPs on standard and deviant stimuli were analyzed for both older groups and the younger group.

Significant differences in ERPs between the Old-High and Old-Low group, in combination with minor differences between the Old-High and Young group, would suggest preservation of processing capacities as a crucial factor. In this case, specific deficits of the Old-Low group in cognitive subprocesses involved in the distraction-orientation-refocusing cycle should become manifest by selective analyses of N1, MMN, P3a, and RON: differences in N1 and MMN would suggest deficits in sensory encoding and deviance detection, respectively, while differences in P3a and RON would suggest deficits in attentional orienting and re-orienting. Significant ERP differences between the Old-High and Young group, possibly in combination with increased frontal activation in the Old-High group relative to the Old-Low group, would suggest compensatory mechanisms to be at work, according to the decline-compensation hypothesis.

2. Methods

2.1. Participants

A group of 164 healthy volunteers took part in the study, consisting of 35 younger (19 female; mean age 25.2 years; range 19–33 years) and 129 older adults (86 female; mean age 70.2 years; range 63–88 years). The younger participants were recruited from local colleges, whereas the older participants were recruited through a number of newspaper advertisements and flyers distributed in the city of Dortmund (Germany). The data for the older participants were gathered as part of a training study with a pre- and a post-measure (detailed in Gajewski and Falkenstein, 2012), with only the pre-measure data being reported here. The older participants were included in this study after meeting the following criteria: They should be at least 65 years of age, physically and mentally fit, living independently and self-paced, and having sufficient or corrected visual and auditory acuity. Exclusion criterions were history of cardiovascular, psychiatric, neurological, motor, or oncologic disease, and psychopharmacologic or hormonal therapy. The older participants also underwent a neuropsychological assessment (described in section 2.5). The participants were explained the scope of the study and gave written informed consent before any study protocol was commenced. The study conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki) and was approved by the local Ethical Committee of the Leibniz association. The data for 4 older participants were excluded from further analyses because of poor quality of electro-encephalography (EEG) data: One data set showed high alpha activity, and in 3 data sets electro-oculography (EOG) channels were flawed.

2.2. Stimuli, task, and procedure

The auditory stimuli were sine waves composed of base frequencies of either 500 Hz, 1000 Hz, or 2000 Hz. The stimuli were generated digitally using CoolEdit 2000 (Syntrillium Software Co, Phoenix, AZ), and were presented binaurally using stereo headphones (AKG, K271 Studio) at the intensity of 70 dB(A). The auditory stimuli were short (200 ms) and long (400 ms) tones (both including 5-ms rise and 5-ms fall times) presented with equal probability. 80% of these long and short tones were frequent standard stimuli (1000 Hz), and 20% were rare deviant stimuli (either 500 Hz or 2000 Hz, each 10%). The sequence of standard and deviant stimuli was pseudo-randomized. During testing, the participants sat on a comfortable chair in a dimly lit and quite room. Using a 2-alternative forced-choice duration discrimination task, the participants had to discriminate the duration of the tones. They had to press 1 response button for short and another for long tones irrespective of the pitch of the tone. The response buttons were held in the subject's hands. The duration–hand contingency was counterbalanced between participants. Participants