

Age-dependent changes of auditory evoked potentials—Effect of task difficulty

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Abstract

The goal of this study was to evaluate the patterns of age-dependent changes of P3 components of auditory event-related potentials exploring the effects of task difficulty. The participants (age span: 19–68 years, $n = 55$, divided into five age groups) took part in an easy and in a difficult two-tone oddball frequency discrimination task with speed or accuracy instructions, and in a novelty oddball task. The latency of the P3 components increased with aging. While in the easy task a linear P3b latency increase could be seen, in the difficult tasks (difficult frequency discrimination or distracting novel stimuli) an accelerated latency increase was observed for the P3b and P3a. In the two-tone oddball paradigm age had no effect on P3b amplitude, but in the novelty oddball task the amplitude of P3 potentials decreased with age. These results indicate that distracting stimuli increase task demands, and in difficult tasks decay can be observed more easily due to the accumulation of various processing mechanisms characterizing aging.

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1. Introduction

According to one of the most influential theories (Bashore, 1990; Salthouse, 2000) cognitive aging is due to the slowing of central nervous system functions, and consequently the slowing of mental processing. The reduced processing speed may probably be caused by the limited time available for the simultaneous operations, leading eventually to a decline of performance (Salthouse, 1996).

A considerable body of data show impairments of inhibitory processes in elderly (Hasher and Zacks, 1988). These effects can mostly be related to structural and functional changes of the frontal structures which involve the shrinkage of cortical neurons (Haug and Eggers, 1991), the reduction of the number of synapses (Huttenlocher, 1979), the decrease of the number of cholinergic receptors, and that of the amount of various neurotransmitters (Adolfsson et al., 1979; Goldman-Rakic and Brown, 1981).

In the present study the process of cognitive aging was investigated by analyzing P300 potentials evoked in a “two-tone” and a “novelty oddball” paradigm. Typically, in the two-tone oddball task two different stimuli are presented, and the participant has to discriminate the standard tone from the target for example by a button press. In the novelty oddball paradigm additional “novel” stimuli, to which no response is required, are also presented.

The P3 complex is a positive component of the event-related potentials (ERPs) of about 300 ms latency, and consists of several subcomponents. The P3a wave is elicited by “novel” stimuli evoking orienting reaction, representing stimulus driven disruption of frontal attentional engagement (Polich and Criado, 2006). The P3a is probably of frontal origin (Knight, 1990), but other structures (inferior parietal lobe, cingulate gyrus) can also be involved in its generation (Bledowski et al., 2004; Linden, 2005). The P3b, having a longer latency than the P3a, is elicited by the target stimuli. It is associated with working memory (WM) functions with widespread generators of which the hippocampus and/or the temporo-parietal cortical regions are probably the most important (Molnar, 1994; Wood et al., 1984). According to one of the most widely known interpretations of the P3b with respect to information processing, P3b amplitude is related to the updating process

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of the mental model of the stimulus environment (Donchin and Coles, 1988). The latency of the P3b component reflects stimulus classification speed and is relatively independent of the demands of response selection and execution (Duncan-Johnson and Donchin, 1982). Higher task complexity causes the increase of P3b latency (McCarthy and Donchin, 1983; McCarthy and Donchin, 1981), while the amplitude of the P3b can be used for the assessment of processing resources since it is related to perceptual and attentional capacity (Donchin et al., 1986).

Considering the various mechanisms involved, it seems hardly surprising that both the P3a and the P3b components will be affected by aging. In elderly people the amplitude of P3a is smaller and/or its latency increases (Maurits et al., 2005; Gaeta et al., 2001; Friedman et al., 1998).

A reduction of P3b amplitude with advancing age is a rather common finding (Anderer et al., 1996; Brown et al., 1983; Fjell and Walhovd, 2001). The topography of the P3b component is altered in the elderly: a more equipotential scalp distribution can be seen with increasing age (Friedman et al., 1997; Picton et al., 1984; Anderer et al., 1996; Iragui et al., 1993).

Altogether, scalp topography with aging generally shows a gradual shift in activation from posterior to anterior sites (Fjell and Walhovd, 2001; Friedman et al., 1997; Anderer et al., 1996). The reason for this can be a kind of compensation: while for young adults a minimal exposure is enough for developing the appropriate representation and response, the elderly people need longer experience to form and preserve adequate representation, and an extended prefrontal recruitment to maintain good levels of performance (Friedman, 2003).

The amplitude of the P3 components is related to the available mental capacity engaged in the actual task (Donchin and Coles, 1988; Wickens et al., 1983). If this capacity declines in the elderly, this effect can be expected to be manifested in the decrease of the amplitude of both the P3a and P3b components. This change for the P3b would be more pronounced in the eldest subjects, especially if the speed of task execution becomes a critical factor introducing a certain time–pressure and/or the task is more difficult. We can also hypothesize that the P3a is even more sensitive to aging than the P3b, as suggested by the frontal theory of aging. The role of the frontal areas in the generation of the P3a component was verified by several studies (Daffner et al., 2000; Knight, 1997, 1984), showing that following frontal lobe lesion the P3a component elicited by novel stimuli was abolished, while the P3b was unaffected. In the present study the influence of age on both the P3b and the P3a components was studied in a novelty oddball condition. An easy frequency discrimination task was used, which, however, was made more complex by presenting three different kinds of stimuli.

In most of the studies using auditory ERPs the P3b latency was found to increase with advancing age and this slowing was found to be linearly related to age (Polich, 1996; Iragui et al., 1993; Patterson et al., 1988). However, in some studies a positively accelerated increase of P3b latency was found after the age of 45 years (Anderer et al., 1996; Brown et al., 1983). Although it is hard to compare the level of task difficulty

applied in these experiments, it seems likely that in those studies where a curvilinear relationship was found between P3b latency and age, the task seemed to be rather a difficult one. It is reasonable to suppose that the aging effect is not restricted to a single mechanism and these will not be involved in this process to the same extent. Several phenomena, such as slowing of processing or impaired inhibition are likely to contribute to the age-dependent latency increase, and if their impact becomes stronger with increasing age this may result in a nonlinear relationship. This cumulative effect may become manifested only at increased levels of task demand when the reserve capacity of the nervous system that could be used to compensate for such a higher demand may not be available.

In the present study the age-related change of the P3b latency was investigated in tasks of different difficulties. Subjects participated in an easy and in a difficult auditory oddball task (frequency discrimination) with an instruction requiring either a fast or an accurate response. It seemed reasonable to suppose that the “fast-difficult” task was the most demanding and the “accurate-easy” one was the easiest to perform. In addition to an expected increase (higher with advancing age and task difficulty) of reaction time, it was hypothesized that age-dependent changes in P3b latency would be more apparent in the “fast-difficult” condition compared to the “accurate-easy” condition. Similarly to the issue of accelerating cumulative effects caused by aging, it seems likely to propose that the mechanisms that play a role in the control of executive functions will be negatively influenced by these changes which will be manifested in the latency change of the P3b component. Consequently, it is to be expected that the latency of the P3b will increase in the more demanding “fast-difficult” task indicating the reduced available capacity for its regulation. Although the effect of “accuracy” versus “speed” instruction is rather well known as exerting an influence on the P3b (Verleger, 1997; Pfefferbaum et al., 1983; Kutas et al., 1977), no data were found in the literature in which the combination of increased demand on response accuracy and on response speed was studied, especially with respect to aging.

2. Methods

2.1. Participants

Sixty-five persons (42 women, 23 men) participated in the study 10 of who were excluded because of the excess amount of artifacts in the EEG. The following five age groups were defined: 18–29 years (group I); 30–39 years (group II); 40–49 years (group III); 50–59 years (group IV); 60–67 years (group V). The subjects, who were paid for participation, had no history of any kind of neurological or psychiatric disease. Their hearing level was tested by pure tone audiometry (0.25–8 kHz) performed before the EEG recording which revealed no more than 30 dB mean hearing loss at 0.25, 0.5, 1 and 2 kHz. There were no significant differences in their formal education ($\chi^2 = 7.098$, $p = 0.526$) or between sexes ($\chi^2 = 2.177$, $p = 0.703$). According to the Raven APM test the participants were within the normal range of their age-scores as shown in Table 2.

The protocol was approved by the Ethics Committee of the Institute for Psychology of the Hungarian Academy of Sciences and an informed consent was obtained from all subjects.

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