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When compensation fails: Attentional deficits in healthy ageing caused by visual distraction

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ABSTRACT

Age related changes in frontal lobe functions are often related to attentional deficits that lead to increased distractibility by irrelevant stimuli. However, attentional functions have been reported not to decline in general with increasing age but simply be too slow to deal properly with distraction in time. Therefore older people might be able to compensate for distraction quite efficiently with sufficient processing time. Compensation, however, might fail when early perceptual processing is affected by distraction already. In the present study, a change in luminance or in orientation had to be detected in a sequence of two visual frames. Older participants showed reduced performance only when luminance and orientation changes were presented simultaneously at separate locations (perceptual conflict condition). Sensory ERP components were not overall altered with increasing age. Only in conflicting trials, a strong bias towards physically more salient information was observed. Additionally, older adults showed markedly delayed ERP-correlates of fronto-central control mechanisms in the conflict condition. The data indicate that processing deceleration cannot compensate for perceptual conflicts induced by mis-weighting of incoming information.

1. Introduction

With increasing age, attention, working memory, episodic memory and other cognitive functions change in efficiency (Craik & Salthouse, 2000). The most influential hypotheses about the origin of age-related cognitive alterations are the "processing speed hypothesis" in which a global decline in processing speed is assumed (=general slowing; Salthouse, 1996), and the "inhibitory deficit hypothesis" which proposes an inability to control interference from task-irrelevant information with increasing age as a core deficit affecting various cognitive abilities (Hasher & Zacks, 1988; Kane, Hasher, Stoltzfus, Zacks, & Conelly, 1994).

Although there is accumulating evidence that general slowing might not be as general as originally assumed, e.g., from studies that report differential slowing factors in different sets of tasks (Lima, Hale, & Myerson, 1991) or from findings of widely unaffected early components of the event-related potential of the EEG (=ERP) with increasing age (Yordanova, Kolev, Hohnsbein, & Falkenstein, 2004), some studies show substantial contribution of slowing to behavior (Bugg, DeLosh, Davalos, & Davis, 2007; Bugg, Zook, DeLosh, Davalos, & Davis, 2006).

In a recent study, Gazzaley et al. (2008) investigated possible interactions between general slowing and inhibitory deficits in a working memory task. They found evidence for a direct interaction between alterations in neural processing speed and the ability to suppress irrelevant information at an early processing stage. Control processes that occur later in the time course of information processing appear to be less affected by age-related decline. Thus, Gazzaley et al., 2008 claim that suppression ability is not abolished with normal aging, but rather delayed to a later processing stage (see also Andrés, Parmentier, & Escera, 2006).

Such a pattern of behavior can also be observed in attentional tasks. Slowing in the ability to allocate attention to a position where a non-informative cue was presented preceding the target stimulus, the so-called inhibition of return (=IOR; for a review see Klein, 2000; Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan, 1985), is delayed, but not abolished with increasing age (Castel, Chasteen, Scialfa, & Pratt, 2003; Wascher, Falkenstein, & Wild-Wall, 2011) although electrophysiological measures indicated qualitative changes in processing irrelevant information of the cue (Wascher et al., 2011). Thus, delayed responses in attentional tasks might be due to a relatively longer lasting capture of attentional resources with increasing age and not to functionally deficient attentional mechanisms in general (see also Lien, Gemperle, & Ruthruff, 2011). Hence, with increasing age, behavior might be slower but comparably as efficient with

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respect to accuracy as behavior of in young participants, as long as older adults have sufficient time to process. In fact, it has been reported that older people respond slower in order to be more accurate (Falkenstein, Hoormann, & Hohnsbein, 2001; Hoffmann & Falkenstein, 2011; Wild-Wall, Falkenstein, & Hohnsbein, 2008). This rather strategic approach can only succeed as long as the processing stream of incoming information is intact. Yet, this strategy should not be possible when signals arrive in fast succession or even simultaneously. Here distraction may be able to immediately distort the processing of relevant signals (Enns & Di Lollo, 2000). Such sensory distractibility might suffice to severely impair higher cognitive processing like working memory (Gazzaley et al., 2008).

Sensory distractibility with increasing age due to salient signals is a disputed issue. Pratt and Bellomo (1999), reported stronger attentional capture in older, compared to young adults. Phillips and Takeda (2010) demonstrated an increase of phase locking in the gamma band for older adults, indicating stronger susceptibility to bottom-up mechanisms. Additionally, older adults show severe deficits in visual masking (Kline & Birren, 1975) as well as in change blindness tasks (Rizzo et al., 2008). Opposed to these findings, some evidence for intact distracter inhibition abilities in older adults were reported (Lien et al., 2011; Wnuczko, Pratt, Hasher, & Walker, 2012). Salient distracters in a distributed display do not necessarily lead to deficits in selecting intentionally focused stimulus features, not even with abrupt onsets (Lien et al., 2011).

The source for this apparent contradiction might be the dynamic interplay between voluntary (top-down controlled) and stimulus driven (bottom-up) mechanisms in attentional selection. The biased competition account of selective attention (Desimone, 1998; Desimone & Duncan, 1995) proposes that incoming signals compete with each other in sensory processing and only the information that has been most amplified (bottom-up and/or top-down) wins and reaches consciousness. Within this system, the saliency of a particular stimulus, the amount of its intentional amplification and the neural sensitivity to its information determine whether it is selected for further processing or not (Beste, Wascher, Güntürkün, & Dinse, 2011; Kastner & Ungerleider, 2001; Reynolds & Desimone, 2003; Reynolds, Pasternak, & Desimone, 2000). Therefore, there are several possible sources for the impact an irrelevant distracter has on stimulus processing and not all appear to be impaired with increasing age.

In the present study, a change detection task was used to test the distractibility to salient stimuli with increasing age in the framework of the biased competition account. Participants had to detect a luminance or orientation change of a laterally presented bar that could be accompanied by a change of the other dimension at the opposite location (Wascher & Beste, 2010b). In case of such a competition of incoming signals, participants often fail to see the luminance change. Performance in this task highly depends on the perceptual sensitivity for intended information (Beste et al., 2011), attentional effort paid to the task (Sänger & Wascher, 2011) and the relative salience of relevant signals (Wascher and Beste, 2010b). Most importantly, it has been demonstrated that the outcome of early perceptual processing that initially weight the competing stimuli is highly predictive for successful selection (Schneider, Beste, & Wascher, 2012).

In order to uncover subtle age-related differences in processing of such types of stimuli, event-related potentials of the EEG (ERPs) were measured. By means of the ERPs, the studies that were mentioned above distinctively described cortical correlates of sub-processes assigned to initial sensory stimulus processing (posterior asymmetries over visual areas in the N1 range = N1pc[1]), the intention based selection of relevant information (N2pc) and executive control functions that are related to the evoked perceptual conflict (an anterior N2, most probably reflecting activation of the anterior cingulate cortex [ACC]).

Age-related deficits in the intentional control of irrelevant and relevant signals should be visible in the N1pc already. Reduced abilities of older adults to amplify intended information should lead to lower amplitudes when such information is presented. This should account for all conditions in which a relevant change (either luminance or orientation) is presented. Moreover, in those conditions slowed sensory processing should be visible in the latency of the N1. In conflict trials, when irrelevant stimuli compete with relevant information, increased susceptibility to bottom-up information, due to reduced distracter control, should not only lead to selectively increased error rates in this particular condition, but also to a bias of attention towards more salient information for early processing stages as reflected in the N1pc.

However, one might also hypothesize that the sensory portion of the attentional selection remains widely unaffected with increasing age. In accordance to previous findings of intact early sensory processing (Yordanova et al., 2004), the deficit might occur not earlier than in the selection of relevant information, indicated by unaltered components in the N1 range but reduced amplitudes for the N2pc, at least when conflicting information is presented.

However, due to the frontal decline with increasing age, a conflict induced by contradicting information in this task may be simply resolved less efficiently. In this particular task, we have reported that more salient distracters induce larger conflicts and larger amplitudes and shorter latencies of the fronto-central N2 in conflict trials (Wascher & Beste, 2010b). Given that older participant have problems in activating this frontal control instances, one would expect higher error rates accompanied by a decrease of amplitude of the N2 while no change would be expected in the N1 range.

All three hypothesized sources, distorted control of stimulus driven processes (bottom-up), impaired ability to intentionally reallocate attention and deficient conflict monitoring would fit into the concept of increased distractibility with increasing age. In all cases, behavioral effects in terms of reduced accuracy should be restricted to the conflict condition, since only in this condition relevant and irrelevant information have to be separated. Prolonged response times might occur in all conditions, since general slowing should also affect responses to singular events.

2. Materials and methods

2.1. Participants

Twelve older adults (6 female), aged between 53 and 63 years (mean age: 58.8 years, std: 2.9 years), and twelve young adults, between 19 and 27 years old (mean age: 22.4 years, std: 3.1 years) participated in the current experiment. All participants took part in return for a payment of € 8/h. Participants with a neurological or psychiatric disorder in the anamnesis were excluded from participation. All had normal or corrected to normal vision and all were right handed. Participants provided informed written consent prior to entering the experiment. The study was approved by the local ethic-committee.

2.2. Stimuli and procedure

The stimuli used consisted of two bars, presented 1.1° left and right from a fixation cross (see Fig. 1). The bars were about 1.35° long and 0.56° wide and oriented either vertically or horizontally. They were either darker or brighter than the background (30 cd/m^2) with a contrast of $\pm$5 cd/m^2 (low contrast) or $\pm$20 cd/m^2 (high contrast). This contrast variation was introduced to control for age-related differences in luminance sensitivity (Owsley, Sekuler, & Siemsen, 1983). The luminance and orientation of the two bars were randomly intermixed in any possible combination for the first frame. The contrast was always constant within one trial.

[1] "pc" denotes an increase in negativity "**c**"ontralateral to a given spatial event over "**p**"osterior electrodes.