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Age-related changes in cognitive conflict processing: An event-related potential study

Ralph Mager [a,*], Alex H. Bullinger [a], Serge Brand [a], Maria Schmidlin [a], Heinz Schärli [a], Franz Müller-Spahn [a], Robert Störmer [a], Michael Falkenstein [b]

[a] *Center of Applied Technologies in Neuroscience-Basel, Psychiatric University Clinic of Basel, Wilhelm Klein-Strasse 27, 4025 Basel, Switzerland*

[b] *Leibniz Research Centre for Working Environment and Human Factors (IfADo), Dortmund, Germany*

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Abstract

Cognitive tasks involving conflicting stimuli and responses are associated with an early age-related decline in performance. Conflict and conflict-induced interference can be stimulus- or response-related. In classical stimulus-response compatibility tasks, such as the Stroop task, the event-related potential (ERP) usually reveals a greater negativity on incongruent versus congruent trials which has often been linked with conflict processing. However, it is unclear whether this negativity is related to stimulus- or response-related conflict, thus rendering the meaning of age-related changes inconclusive. In the present study, a modified Stroop task was used to focus on stimulus-related interference processes while excluding response-related interference. Since we intended to study work-relevant effects ERPs and performance were determined in young (about 30 years old) and middle-aged (about 50 years old) healthy subjects (total $n = 80$). In the ERP, a broad negativity developed after incongruent versus congruent stimuli between 350 and 650 ms. An age-related increase of the latency and amplitude of this negativity was observed. These results indicate age-related alterations in the processing of conflicting stimuli already in middle age.

Keywords: Normal ageing; ERPs; Interference; Conflict; Stroop task

1. Introduction

Numerous empirical data show a decrease in cognitive performance with advancing age [37]. Some researchers attribute this phenomenon to nonspecific factors, such as general slowing and decreasing resources [8]. However, it is well documented that not all cognitive abilities are equally affected by age. In some tasks stimulus processing and decision-making are not compromised in older subjects [50]. On the other hand, it is known that older people are less able to selectively inhibit irrelevant information [35]. These findings have contributed to the inhibitory deficit hypothesis that serves as an important model to study cognitive ageing [18]. The inhibitory deficit is thought to be caused by alterations of the prefrontal cortex (PFC) occurring during normal ageing [1,33]. More recent models of attention [3,7,34] suggest that inhibitory functions, such as those described by Hasher and Zacks [18], are mediated by an attentional control system which depends on a distributed attentional network within the brain, involving the anterior cingulate cortex, prefrontal cortex, parietal cortex, extrastriate cortex, and subcortical regions. The interaction of prefrontal and parietal cortex is generally modelled in the way that the PFC controls and modulates information processing in the parietal areas [10,38], and age-related changes have been reported [31]. The parietal cortex has been shown to play a particularly important

Abbreviations: ACC, anterior cingulate cortex; ANOVA, analyses of variance; DLPFC, dorsolateral prefrontal cortex; EEG, electroencephalogram; ERP, event-related potential; fMRI, functional magnetic resonance imaging; PET, positron emission tomography; PFC, prefrontal cortex; RRP, response-related potentials; RT, reaction time; SOA, stimulus onset asynchrony

* Corresponding author. Tel.: +41 61 3255242; fax: +41 61 3255492.
E-mail address: ram@coat-basel.com (R. Mager).

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role in networks underlying voluntary attentional control [17,48].

1.1. Test paradigms

Most studies have inferred inhibitory functioning from Go/Nogo tasks and from interference paradigms such as the flanker task, the Stroop word-color task and negative priming tasks (e.g., [13]). The Stroop task is probably the most widely used experimental paradigm to induce conflict and interference in cognitive psychology [40]. The principle of the Stroop task is the handling of two types of conflicting information, i.e., meaning and color of the written word. In the congruent condition word meaning and color of the written word match (i.e., "red" written in red ink). In the incongruent condition word meaning and color of the written word do not match (i.e., "red" written in blue ink). Cognitive interference occurs when the processing of a specific stimulus feature (i.e., color) impedes the simultaneous processing of a second stimulus attribute (i.e., word meaning). Consequently, response latencies and error rates generally increase in the incongruent condition, and this delay has been termed Stroop interference effect (for review see [27]). In the last decades, numerous studies have demonstrated a more pronounced Stroop effect with increasing age [9,25,26], suggesting an age-dependent loss of ability to cope with conflicting stimuli. Most authors attributed this phenomenon to less efficient inhibitory processes in elderly people [9,20,39]. For the classical Stroop task, this implies a disinhibition of word processing at the cost of color information. However, inhibition, even in a broad sense, is not the only possible mechanism causing Stroop interference. Prolonged processing of incongruent stimuli may also contribute to the interference effect. The problem of most Stroop studies is that stimulus-related and response-related interference are confounded, i.e., in the incongruent condition stimulus attributes as well as the related responses are incongruent. Thus, on top of the stimulus-interference as described above there also occurs response-interference because different colors are associated with different response buttons. Hence, increased reaction time (RT) and error rate may be a result of stimulus or response incongruence or a mixture of the two. In order to better understand the source of enhanced interference in older subjects it is crucial to separate response-related from stimulus-related interference. Therefore, we focused on stimulus-related interference in the present study.

1.2. PET and fMRI studies

Neuroimaging studies have identified brain regions involved in conflict handling and allocating resources during cognitive interference [4,5,7,23,32,41]. The areas consistently reported to be activated when tasks require conflict detection/resolution include the anterior cingulate cortex (ACC), dorsolateral prefrontal cortex (DLPFC), and other areas of the PFC. A recent functional magnetic resonance imaging (fMRI) study addressing age effects in a Stroop interference task showed comparable activation of predominantly prefrontal regions in young and older adults, but older adults exhibited a greater activation magnitude during interference. The authors argued that these findings were consistent with the hypothesis that older adults recruit additional, particularly prefrontal, but also more posterior (e.g., temporal) areas during the interference task [22,31]. To our knowledge, the only fMRI study focussing on stimulus-related interference is reported by Zysset et al. [51]. Zysset et al. presented two rows of letters on the screen. Their subjects had to decide by pressing one of two response keys if the color of the top row letters corresponded to the color name written at the bottom row. In this Stroop version, interference takes place at a conceptual level and is separated from the response preparation. The authors found a frontoparietal network, involving activation of structures in the lateral prefrontal cortex, the frontopolar region, the intraparietal sulcus, as well as the lateral occipitotemporal gyrus in the incongruent versus a neutral condition. Importantly, no ACC activity was found in the incongruent condition. This suggests that response-related conflict and interference depends on ACC function, while stimulus-related conflict does not.

1.3. Evoked potential studies

Studies employing positron emission tomography (PET) or fMRI are not suitable to show up the timing of interference-related processes. In contrast, measurement of scalp-recorded event-related potentials (ERPs) offers unique real-time monitoring of neural processes. Early reports failed to show latency effects on ERP components accounting for the longer RTs with incongruent versus congruent Stroop stimuli [11,19]. Other studies revealed ERP amplitude modulations that differentiated congruent from incongruent stimuli. Rebai et al. [36] reported an enhanced midline fronto-central negativity between 350 and 450 ms after incongruent stimuli. Using a modified version of the Stroop task, West and Alain [45] confirmed this finding. In subsequent studies, they described an attenuation of this phenomenon in elderly subjects [44,46]. A consistent neurophysiological finding is an increased negativity in the range of 350–650 ms in response to incongruent versus congruent stimuli. Using high-density ERPs, Liotti et al. showed this negativity to have a different scalp distribution in a verbal compared to a manual Stroop version [24] suggesting that response-related processes modulate this negativity. Dipole source analysis suggested two independent generators in the ACC. In line with previous PET and fMRI findings, ERP data support the hypothesis that the negativity correlates with increased interference-related activity in the ACC [24,28]. In addition to this negative activity, some authors described a sustained temporoparietal positivity between 500 and 800 ms after incongruent stimuli [24,28,45] which might be related