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HANDBOOK OF COGNITIVE AGING: CAUSES, PROCESSES AND EFFECTS

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Chapter IX

Age-Related Changes in Visual Search Mechanisms: A Perspective from Cognitive Neuroscience

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Abstract

The ability to actively search for relevant information in our visual field has an essential adaptive value, and it is markedly affected by normal aging. Recent developments in visual search investigation in aging have come out of research in Cognitive Neuroscience. In this chapter, we present some of our own recent published studies in which differences in the neural systems underlying visual search processes in young and healthy older observers were studied by combining Event-Related Potentials (ERP) and standardized Low-Resolution brain Electromagnetic Tomography (sLORETA). This helps us in understanding the contribution of specific selective attention deficits to the frequently observed age-related behavioral decrements in visual search, and in identifying the neurofunctional changes underlying them. In this context, we describe two studies in which we evaluated age-related changes in visual search by recording two ERP components, N2pc (N2-posterior-contralateral), which has been validated as an electrophysiological correlate of the allocation of visuospatial attention (Lorenzo-López et al., 2008a), and P3, related to stimulus evaluation processes underlying attention and memory tasks (Lorenzo-López et al., 2008b). The results of the first study provided evidence that N2pc component was significantly delayed and attenuated in older adults, suggesting a specific impairment in the allocation of visuospatial attention resources with advancing age. In the second study, the analysis of age-related differences in neural activation associated to P3 generation during the

processing of different search arrays led us to propose that the decrement in performance in searching visual stimuli in healthy older adults may be partially due to an age-related selective attentional deficit characterized by (1) a delay in the evaluation time of the stimulus, (2) a slow and less efficient allocation of attentional resources, (3) a reduced neural specialization, and finally (4) an hypoactivation of several brain structures critically involved in selective attention performance in young adults. This kind of studies may lead to future intervention protocols to improve visual search capabilities, and thus enhancing cognitive ability and daily functioning in older adults. Finally, we conclude the chapter by discussing possible future directions in this research context.

1. Introduction

Visual selective attention is a fundamental cognitive function that can be defined as the ability to enhance the processing of visual information relevant to our goals and to inhibit the processing of what is irrelevant. This ability is essential for everyday functioning since people often confront natural complex scenes in which they must select currently relevant information from an enormous amount of other, irrelevant but potentially distracting information. Due to the fact that the visual search paradigm captures these qualities of everyday visual tasks, it has been extensively used in laboratory studies of selective attention in humans (Luck and Ford, 1998; Luck and Hillyard, 1995). The typical visual search task requires participants indicate whether a predefined target stimulus is present or absent among a variable number of nontarget distractors (Treisman and Gelade, 1980). The efficiency of visual search (measured in terms of reaction times and accuracy for detecting the target) has been shown to be dependent on the properties of the target and distractors and the number of distractors in the search array (set size).

1.1. Evidence for Age-Related Visual Search Deficits

An age-related decline in tasks involving visual selective attention has been well documented in the behavioral and neuroimaging literature (Kok, 2000; Madden et al., 2005; Raz, 2000), suggesting that older adults are less able to selectively focus on relevant stimuli in their environment than young adults. In particular, during visual search tasks, it has been reported that older observers often have substantially more difficulties than young observers in locating and identifying targets defined by a conjunction of features among heterogeneous distractors, and with increasing number of distractors (Hommel et al., 2004; Madden and Whiting, 2004; McDowd and Shaw, 2000; Plude and Hoyer, 1986; Scialfa et al., 1998; Scialfa and Joffe, 1997; Tales et al., 2004; Trick and Enns, 1998).

Influential theories of cognitive aging have attributed decrements in attentional performance with advancing age to a generalized slowing of information processing (Salthouse, 1996, 2000). However, due to the fact that the age-related deficit in visual search is exacerbated as the number of distractor stimuli in the search array increases, it has also been interpreted in terms of a decline in inhibitory control functions of selective attention with aging (Hasher and Zacks, 1988; Lustig et al., 2001), leading to an age-related decrease

in the ability to focus attention to relevant stimuli and to ignore or inhibit the irrelevant distractors (Colcombe et al., 2003; Madden and Whiting, 2004). Additionally, other studies have pointed to more specific mechanisms, such as an age-related decrease in target detectability (Madden et al., 1999), an impairment in spatial localization ability (Plude and Hoyer, 1985), or a reduction in the flexibility of reorienting attention in the visual field (Greenwood and Parasuraman, 1999).

As previously mentioned, there is considerable evidence in the literature that older adults are behaviorally slower and less accurate than young adults in tasks involving visual search, especially in difficult or complex search conditions. However, it is not clear whether these age differences represent a specific slowing in the allocation of attention itself, or a generalized age-related slowing of information processing. With their excellent temporal resolution, electrophysiological techniques, such as ERP, represent a good tool to investigate this question.

2. Age-Related Changes in Brain Mechanisms Mediating Visual Search

Neuroimaging studies of positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) in young adults have provided evidence relating frontal, parietal, and occipito-temporal regions to performance in visual search tasks (Corbetta et al., 1995; Leonards et al., 2000, 2003; Miyauchi et al., 1996; Nobre et al., 2003).Within this network, the dorsal regions of the frontal and parietal lobes seem particularly important for top-down attentional guidance during visual search, while occipito-temporal regions seem to mediate bottom-up attentional aspects (Corbetta et al., 1993; Giesbrecht et al., 2003; Nobre et al., 2003).

Neuroimaging studies of normal aging have yielded recent evidence of substantial age-related changes within the dorsal component of the fronto-parietal attentional network (see Madden, 2007 for a recent review). For example, an age-related increase in the activation of frontal regions during cognitive tasks has been observed, which may reflect an increased emphasis of older adults on the top-down attentional-control processes mediated by these brain regions (Cabeza, 2002; McIntosh et al., 1999). Little is known, however, regarding age-related changes in the ventral component mediating the detection of target-relevant features. Activation of occipital cortical regions mediating visual processing is often lower for older adults than for young adults, which has been interpreted as reflecting an age-related decline in the quality of the bottom-up sensory input (see Madden, 2007 for a review). In the visual search context, the age-related increase in fronto-parietal activation has been associated with top-down attentional guidance, and interpreted as a compensatory response to decline in the bottom-up input from sensory pathways (Madden et al., 2007).

Taking into account that the exact nature of the age-related attentional decline and its neural substrate is not clear, the general aim of our experiments was to characterize the age-related changes in selective attention processes involved in the execution of a visual search task, whose electrophysiological correlates have been previously described in young adults (Luck and Hillyard, 1994a).

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