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SPECIAL ISSUE INTRODUCTION

Attentional modulation of early visual areas

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ABSTRACT

This special issue of *Cognitive Neuroscience* focuses on the debate regarding whether spatial attention can rapidly modulate the event-related potential (ERP) C1 component, which reflects the initial feedforward signal in V1. A discussion paper by Baumgartner, Graulty, Hillyard, and Pitts (this issue) included an empirical experiment that failed to replicate the significant C1 attention effects of Kelly, Gomez-Ramirez, and Foxe. Commentaries were received by Ding (this issue), Klein (this issue), Pourtois, Rossi, Vuilleumier, and Rauss (this issue), Kelly and Mohr (this issue), Slagter, Alilovic, and Van Gaal (this issue), and Fu (this issue). The author response highlighted that C1 attention effects may be obtained in only limited conditions, considered problems of investigating C1 attention effects, and proposed future strategies. An empirical paper by Herde, Rossi, Pourtois, and Rauss (this issue) found that C1 was modulated by stimulus predictability, which indicates higher-level cognitive processes can modulate V1. A second discussion paper (Slotnick, this issue) compared experimental parameters across spatial attention studies and concluded certain stimulus, task, and analysis conditions were more likely to produce significant C1 attention effects. Commentaries were received by Fu (this issue), Qu and Ding (this issue), Zani and Proverbio (this issue), Pitts and Hillyard (this issue), Di Russo (this issue), and Mohr and Kelly (this issue). The author response included a more in depth analysis, and several studies that observed significant C1 attention effects survived critical analysis. The topics considered in this issue have clarified the current state of this debate and provided directions for future research.

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Functional magnetic resonance imaging (fMRI) evidence has shown that spatial attention can modulate activity in V1, but the timecourse of fMRI is limited such that V1 attention effects could be attributed to feedback from extrastriate cortex. Some ERP evidence has indicated the C1 component, which reflects the initial feedforward signal in V1 that occurs less than 100 milliseconds after stimulus onset, is not modulated by spatial attention, but that attentional modulation of V1 can occur later in time due to feedback from extrastriate cortex (Di Russo, Martínez, & Hillyard, 2003; Martínez et al., 1999, 2001; Noesselt et al., 2002). Other ERP evidence has indicated that the C1 component can be modulated by spatial attention. Thus, there is a current debate regarding whether or not spatial attention can modulate the ERP C1 component, which is the topic of this special issue of *Cognitive Neuroscience*.

The first article in the special issue is a discussion paper by Baumgartner, Graulty, Hillyard, and Pitts (this issue) that included an empirical experiment that attempted to replicate the significant C1 spatial attention effects observed by Kelly, Gomez-Ramirez, and Foxe (2008). Both Kelly et al. and Baumgartner et al. identified stimulus locations and electrode locations on an individual participant basis in an effort to maximize C1 attention effects. Although Kelly et al. reported significant C1 attention effects for both upper visual field stimuli and lower visual field stimuli, Baumgartner et al. found no evidence for attention effects in any quadrant of the visual field. The discussion paper is followed by six commentaries. Ding (this issue), Klein (this issue), and Pourtois, Rossi, Vuilleumier, and Rauss (this issue) highlighted differences in stimulus locations between the studies, as Kelly et al. employed stimuli that were in diagonally opposite visual quadrants while Baumgartner et al. employed stimuli that were symmetrical about the vertical meridian. Kelly and Mohr (this issue) highlighted that Baumgartner et al. and Kelly et al. employed stimuli with different spatial frequency profiles and suggested there may have been differences in participant task engagement. Slagter, Alilovic, and Van Gaal (this issue) discussed stimulus, motivation, and analysis

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factors that may affect C1 attention effects. Pourtois et al. and Klein suggested analysis methods that might be more sensitive at detecting C1 attention effects. Fu (this issue) proposed that C1 attention effects may be more likely under certain experimental conditions such as use of distractors, exogenous cuing, and high perceptual load. In the author response paper, Baumgartner et al. acknowledged the differences between their study and Kelly et al. and highlighted that the disparate results suggest C1 attention effects may be obtained in only a limited range of conditions. They also considered the inherent problems in investigating C1 attention effects, such as individual participant differences in V1 anatomy and the corresponding C1 variability, and proposed experimental and methodological strategies that should be employed in the future.

The previous set of articles is followed by an empirical paper by Herde, Rossi, Pourtois, and Rauss (this issue). Herde et al. employed a stimulus paradigm where faces with different emotional expressions predicted stimuli in the upper visual field or the lower visual field. On infrequent target trials, faces were followed by stimulation in both the upper visual field and the lower visual field. For target trials, the magnitude of the C1 component was modulated as a function of stimulus predictability, but only for participants who were aware of the face–stimulus location association. These findings indicate that V1 can be rapidly modulated by a higher-level cognitive process, which complements the results of the studies discussed in this special issue that observed C1 spatial attention effects.

In a second discussion paper (Slotnick, this issue), a selective review was conducted to compare experimental parameters across spatial attention studies to determine whether certain stimulus, task, or analysis conditions were more likely to produce significant C1 attention effects. It was concluded that to maximize sensitivity to C1 attention effects, stimuli should be in the upper visual field, there should be distractors, conditions should be high perceptual or attentional load, there should be exogenous cuing, and effects should be measured at midline parietal-occipital electrodes POz, Pz, and CPz. The discussion paper is followed by six commentaries. Fu (this issue) made a number of proposals to enhance the C1 attentional difference and minimize the standard deviation between attended and unattended conditions. Qu and Ding (this issue) highlighted that cue-related activity must be removed from activity associated with valid trials in exogenous cuing studies and proposed a new method to remove such overlapping activity. Zani and Proverbio (this issue) pointed out that exogenous cuing may only maximize C1 attention effects in spatial attention studies and proposed that endogenous cuing may maximize C1 attention effects in object-based attention studies. Pitts and Hillyard (this issue) made a number of critical comments and highlighted that there has yet to be a reproducible demonstration of a genuine C1 attention effect. Du Russo (this issue) took issue with the claim in the discussion paper that marginally significant results might not reflect null results. More and Kelly (this issue) made a number of critical comments and underscored that which parameters affect the C1 attention effect and why those parameters affect the C1 attention effect are largely open questions. In the author response paper, the critical comments led to a more in depth analysis of many issues pertaining to C1 attention effects including optimal electrode and stimulus locations, null V1 source localization attention effects, whether all significant C1 attention effects can be discounted, and the number of studies with null versus significant C1 attention effects. Analysis of the studies that survived critical analysis yielded several that observed significant C1 attention effects and led to the same conclusions as the discussion paper. Future directions include replicating studies that have observed C1 spatial attention effects using identical experimental parameters and systematically manipulating parameters to determine the impact of each parameter on C1 spatial attention effects.

The articles in this special issue illustrate that the debate regarding attentional modulation of the ERP C1 component rages on. It should be underscored that this debate exists because of the vision of Steven Hillyard, who has spearheaded the research on attentional modulation of early visual areas. The range of topics considered in this special issue have clarified the current state of this debate and provided directions for research in the immediate future.

Disclosure statement

No potential conflict of interest was reported by the author.

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