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Common fronto-parietal activity in attention, memory, and consciousness: Shared demands on integration?

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Abstract

Fronto-parietal activity has been frequently observed in fMRI and PET studies of attention, working memory, and episodic memory retrieval. Several recent fMRI studies have also reported fronto-parietal activity during conscious visual perception. A major goal of this review was to assess the degree of anatomical overlap among activation patterns associated with these four functions. A second goal was to shed light on the possible cognitive relationship of processes that relate to common brain activity across functions. For all reviewed functions we observed a consistent and overlapping pattern of brain activity. The overlap was most pronounced for the bilateral parietal cortex (BA 7 and BA 40; close to the intraparietal sulcus), and dorsolateral prefrontal cortex (right BA 9 and left BA 6). The common fronto-parietal activity will be discussed in terms of processes related to integration of distributed representations in the brain.

Keywords: Conscious perception; Visual consciousness; Attention; Working memory; Episodic memory retrieval; Integration; Fronto-parietal network; Functional neuroimaging

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1. Introduction

Investigations into the neural correlates of consciousness are based on a variety of techniques, including EEG (Desmedt & Tomberg, 1995; Engel & Singer, 2001; Gaetz, Weinberg, Rzempoluck, & Jantzen, 1998; Kaernbach, Schroger, Jacobsen, & Roeber, 1999; Koivisto & Revonsuo, 2003; Ojanen, Revonsuo, & Sams, 2003; Rodriguez et al., 1999; Summerfield, Jack, & Burgess, 2002; Wilenius-Emet, Revonsuo, & Ojanen, 2004), MEG (Gaetz et al., 1998; Joliot, Ribary, & Llinas, 1994; Mäkinen, May, & Tiitinen, 2004; Strüber & Herrmann, 2002; Vanni, Revonsuo, Saarinen, & Hari, 1996; Walla et al., 2002), TMS (Overgaard, Nielsen, & Fuglsang-Frederiksen, 2004; Ro, Breitmeyer, Burton, Singhal, & Lane, 2003), single-cell recordings (Leopold & Logothetis, 1996; Logothetis, 1998; Sengpiel, Blakemore, & Harrad, 1995; Sheinberg & Logothetis, 1997), and studies of brain-damaged patients (Deouell, 2002; Driver & Vuilleumier, 2001; Farah, O'Reilly, & Vecera, 1997; ffytche et al., 1998; Sahraie et al., 1997; Vuilleumier et al., 2002; Whatham, Vuilleumier, Landis, & Safran, 2003). In the present article we will mainly be concerned with results from studies using functional magnetic resonance imaging (fMRI) and to a lesser degree the related method positron emission tomography (PET). With fMRI we specifically mean the common type of fMRI which uses blood oxygenation level dependent (BOLD) contrast, a method for indicating changes in neural activity through measurement of changes in the level of blood oxygenation. In PET changes in blood flow are examined by marking the blood with a radioactive tracer. The results from both fMRI and PET only indirectly reflect neural activity and the methods suffer from limitations in terms of spatial and temporal resolution (Logothetis & Wandell, 2004; Raichle, 1998). Still, fMRI and PET have been widely used for studying cognitive functions and seem to give robust and reproducible results.

Several fMRI studies have focused on the neural correlates of awareness of specific phenomenal content in the human visual system. A number of different experimental methods have been used in these studies for inducing changes in visual awareness, such as binocular rivalry (Lee & Blake, 2002; Lumer & Rees, 1999; Lumer, Friston, & Rees, 1998; Polonsky, Blake, Braun, & Heeger, 2000; Tong, Nakayama, Vaughan, & Kanwisher, 1998) and bistable perception (Kleinschmidt, Buchel, Zeki, & Frackowiak, 1998; Sterzer, Russ, Preibisch, & Kleinschmidt, 2002). The results from multiple studies converge to show that different areas of ventral visual cortex are related to visual awareness (see Rees, Kreiman, & Koch, 2002 for a review). However, Rees and colleagues concluded that although activity in ventral visual cortex is a consistent neural correlate of visual awareness, an additional contribution from parietal and prefrontal loci seems necessary. The nature of the cognitive processes that relate to fronto-parietal activity is not clear, but Rees et al. noted that this activation pattern has strong similarities with that associated with various forms of attention. They therefore encouraged work that explored similarities in functional activity and cognitive processes related to awareness and attention.

Fronto-parietal activity is also a consistent neural correlate of other cognitive processes, notably working memory and episodic memory (Cabeza & Nyberg, 2000). Several recent publications have been concerned with similarities in brain activity associated with working memory and episodic memory (Braver et al., 2001; Cabeza, Dolcos, Graham, & Nyberg, 2002; Nyberg, Forkstam, Petersson, Cabeza, & Ingvar, 2002, 2003; Ranganath, Johnson, & D'Esposito, 2003; for reviews, see Cabeza & Nyberg, 2002; Fletcher & Henson, 2001; Nyberg & Cabeza, in press) and also