



## Reading the mind from eye gaze

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### Abstract

Baron-Cohen [Mindblindness: an essay on autism and theory of mind. Cambridge, MA: MIT Press, 1997] has suggested that the interpretation of gaze plays an important role in a normal functioning theory of mind (ToM) system. Consistent with this suggestion, functional imaging research has shown that both ToM tasks and eye gaze processing engage a similar region of the posterior superior temporal sulcus (STS). However, a second brain region associated with ToM, the medial prefrontal (MPF) cortex, has not been identified by previous eye gaze studies. We discuss the methodological issues that may account for the absence of MPF activation in these experiments and present a PET study that controls for these factors. Our experiment included three conditions in which the proportions of faces gazing at, and away from, the participant, were as follows: 100% direct [0% averted], 50% direct—50% averted, and 100% horizontally averted [0% direct]. Two control conditions were also included in which the faces' gaze were averted down, or their eyes were closed. Contrasts comparing the gaze conditions with each of the control conditions revealed medial frontal involvement. Parametric analyses showed a significant linear relationship between increasing proportions of horizontally averted gaze and increased rCBF in the MPF cortex. The opposite parametric analysis (increasing proportions of direct gaze) was associated with increased rCBF in a number of areas including the superior and medial temporal gyri. Additional subtraction contrasts largely confirmed these patterns. Our results demonstrate a considerable degree of overlap between the medial frontal areas involved in eye gaze processing and theory of mind tasks. © 2002 Elsevier Science Ltd. All rights reserved.

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### 1. Introduction

A recent functional imaging study by Hoffman and Haxby [19] has shown that matching faces for their direction of gaze engages different brain areas to matching the same faces for their identity. The gaze task was associated with a significantly larger signal in the left posterior superior temporal sulcus (STS) and intraparietal sulcus, whereas the facial identity task produced significantly larger bilateral signals in the fusiform gyri and inferior occipital gyri. The same study also found that averted gaze was associated with a higher left STS signal than direct gaze.

The above results replicate and extend the findings of two earlier neuroimaging studies. The first showed that viewing faces with direct and averted gaze produced an increase in the regional cerebral blood flow (rCBF) of areas adjacent to

the posterior STS when compared with viewing faces with downward gaze [31]. In contrast to Hoffman and Haxby, however, Wicker et al. [31] found no reliable difference between their averted and direct gaze conditions. The second study showed posterior STS involvement when participants were shown a dynamic facial stimulus switching between averted and direct gaze [30], relative to when they were shown a static facial image looking directly at them. Interestingly, the results of none of these three studies bear much resemblance to an investigation of eye gaze processing by Kawashima et al. [22] that found no evidence of STS involvement. Instead, both direct and averted gaze conditions in the Kawashima et al. study produced amygdala activation, with the direct gaze condition showing significantly greater right amygdala activation than the averted gaze condition: Kawashima et al. attributed the amygdala involvement to the emotional component of processing another person's gaze.

More recent research has examined the neural correlates of eye gaze in more detail. George et al. [15] showed that relative to averted gaze, direct gaze produced more metabolic

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