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Are you always on my mind? A review of how face perception and attention interact

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Abstract

In this review we examine how attention is involved in detecting faces, recognizing facial identity and registering and discriminating between facial expressions of emotion. The first section examines whether these aspects of face perception are "automatic", in that they are especially rapid, non-conscious, mandatory and capacity-free. The second section discusses whether limited-capacity selective attention mechanisms are preferentially recruited by faces and facial expressions. Evidence from behavioral, neuropsychological, neuroimaging and psychophysiological studies from humans and single-unit recordings from primates is examined and the neural systems involved in processing faces, emotion and attention are highlighted. Avenues for further research are identified.

Keywords: Faces; Identity; Expression; Emotion; Attention; Automatic; Amygdala; Prefrontal cortex; Fear

When scanning our complex visual environment we encounter too many items to fully analyze at one time. The brain must therefore evaluate incoming stimuli and devote more cognitive resources to processing important items and events. But what counts as important? Compton (2003) suggests that a primary way to determine importance is to evaluate the *emotional significance* of a stimulus or event. She further argues that stimuli deemed emotionally significant receive enhanced processing and that this occurs via the operation of *two attentional mechanisms*: one that evaluates emotional significance preattentively or "automatically", and another that gives these significant stimuli priority in the competition for selective attention. Although the emotional value of stimuli may differ between individuals, there are some stimuli – such as snakes, spiders, and human faces – that are emotionally significant to most individuals. Faces are probably the most biologically and socially significant visual stimuli in the human environment, and might therefore be expected to receive enhanced processing as outlined above.

In this review we examine whether faces are indeed processed preattentively and whether they preferentially engage mechanisms of selective attention. We consider the role of attention in detecting and categorizing faces, in recognizing the identity of individuals and in registering different expressions displayed by faces. In addition, we examine the interactions between neural systems involved in processing faces, emotion and attention. We begin by outlining current neuropsychological models of face perception.

Current cognitive and neural models of face perception propose an initial stage of encoding, after which changeable aspects of a face, which are involved in the analysis of expression and eye gaze, are processed relatively independently of its invariant aspects, which are used to determine identity (Bruce & Young, 1986; Haxby, Hoffman, & Gobbini, 2000, 2002). Processing of identity proceeds via the lateral fusiform gyrus (including the fusiform face area, FFA; Kanwisher, McDermott, & Chun, 1997) to anterior temporal regions that are involved in the recollection of biographical information (Haxby et al., 2000, see Fig. 1, yellow shading). Processing of changeable aspects of faces is mediated by the superior temporal sulcus (STS) (Haxby et al., 2000). Perceiving and recognizing emotion from facial expressions involves a complex network of partially independent neural structures (Adolphs, 2002a,b, see Fig. 1, red shading). *Cortical* pathways, in occipital and temporal neocortex (in particular the FFA and STS), conduct the detailed perceptual analyses necessary to make fine discriminations between facial expressions (Adolphs, 2002a,b, Fig. 1, solid lines). A "dual-route" fear or threat detection system has also been proposed, with a parallel *subcortical* route to the

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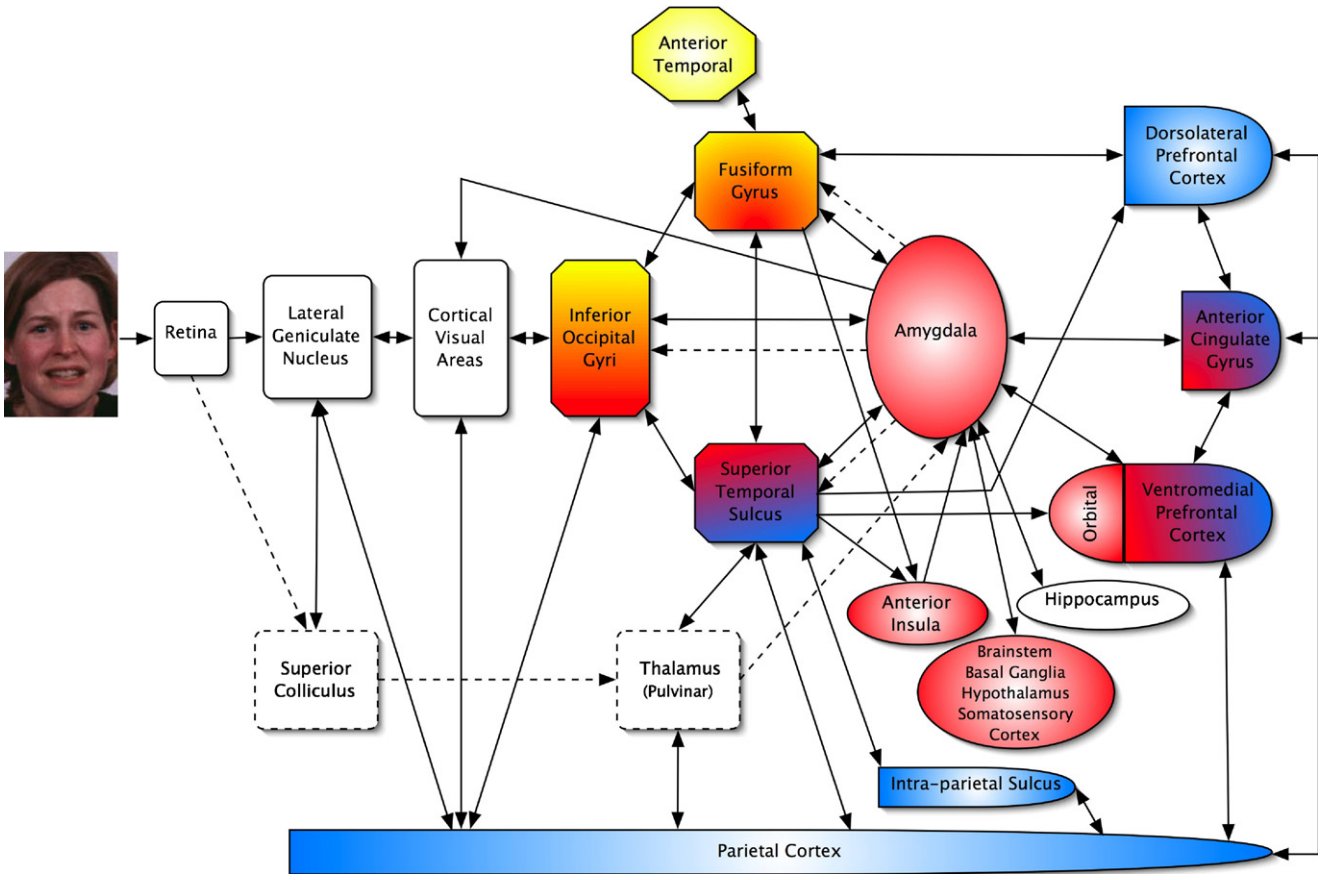

Fig. 1. Face perception and attention systems. The three rectangles with beveled edges indicate the core system for face perception (Haxby et al., 2000). Areas shaded in yellow represent regions involved in processing identity and associated semantic information, areas in red represent regions involved in emotion analysis (Adolphs, 2002b), and those in blue reflect the fronto-parietal cortical network involved in spatial attention (Hopfinger, Buonocore, & Mangun, 2000). Solid lines indicate cortical pathways and dashed lines represent the subcortical route for rapid and/or coarse emotional expression processing. This model is highly simplified and excludes many neural areas and connections. In addition, processing is not strictly hierarchical (i.e., from left to right) but involves multiple feedback connections (Bullier, 2001). The face displayed is from the database collected by Gur et al. (2002).

amygdala[1], via the superior colliculus and pulvinar thalamus (Fig. 1, dashed lines), providing a rapid but coarse analysis, perhaps based on salient individual features (LeDoux, 1996, 1998; Morris, Öhman, & Dolan, 1999; Öhman, 2002).

Regardless of its expression, a face is a salient emotional stimulus, allowing us to distinguish friend from foe and conveying crucial information for social interactions (e.g., identity, race, sex, attractiveness, direction of eye gaze). Thus, all faces, even so called "unexpressive" or "neutral" faces will have emotional significance and so may have special access to visual attention. However, automatic processing and/or attentional biases seem most likely for facial expressions displaying threat or danger, which if rapidly detected may confer a crucial survival advantage (e.g., Öhman, 2002; Vuilleumier, 2002). These include fearful faces, which may warn of an environmental threat to be avoided, angry faces, which signify impending aggression and disgusted faces which reflect the possibility of physical contamination (Adams, Gordon, Baird, Ambady, & Kleck, 2003; Adolphs, 2002b; Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003). The impact of attention on the processing of fear, anger and disgust is often contrasted with the processing of other "basic" or universal expressions (see Ekman, 1999), such as happiness, sadness and surprise.

1. Are faces processed "automatically"?

The emotional significance and neural specificity of face processing make faces an ideal candidate for automatic or preattentive processing (Öhman, 2002; Öhman & Mineka, 2001). Automatic processes have some or all of the following characteristics: they are *rapid* (e.g., Batty & Taylor, 2003; Öhman, 1997), *non-conscious* (e.g., Bargh, 1997; Öhman, 2002; Robinson, 1998), *mandatory* (e.g., Wojciulik, Kanwisher, & Driver, 1998) and *capacity-free*, requiring minimal attentional resources (e.g., Schneider & Chein, 2003; Vuilleumier, Armony, Driver, & Dolan, 2001). We discuss the evidence for each separately.

[1] Technically, this structure is known as the "amygdaloid complex" because it is composed of a number of nuclei that are organized into a number of divisions, which appear to have different functions and connections (see Davis & Whalen, 2001; Holland & Gallagher, 2004). There are two "amygdalae"—one in each hemisphere. Both appear to be involved in processing facial expressions, with differences between the two not clearly understood at this stage (see Adolphs, 2002b; Zald, 2003, for reviews on laterality). For brevity, we will use the term "amygdala".