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Review

Two neural pathways of face processing: A critical evaluation of current models

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ABSTRACT

The neural basis of face processing has been extensively studied in the past two decades. The current dominant neural model proposed by Haxby et al. (2000); Gobbini and Haxby (2007) suggests a division of labor between the fusiform face area (FFA), which processes invariant facial aspects, such as identity, and the posterior superior temporal sulcus (pSTS), which processes changeable facial aspects, such as expression. An extension to this model for the processing of dynamic faces proposed by O'Toole et al. (2002) highlights the role of the pSTS in the processing of identity from dynamic familiar faces. To evaluate these models, we reviewed recent neuroimaging studies that examined the processing of identity and expression with static and dynamic faces. Based on accumulated data we propose an updated model, emphasizing the dissociation between form and motion as the primary functional division between a ventral stream that goes through the FFA and a dorsal stream that goes through the STS, respectively. We also encourage future studies to expand their research to the processing of dynamic faces.

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1. Introduction

Face perception has long been the center of intense behavioral and neuroscience research. Functional MRI (fMRI) studies have revealed well-defined cortical regions that generate a highly selective neural response for faces (for review see Kanwisher and Yovel, 2006). These regions have been suggested to form a neural network specialized in face processing. Furthermore, the functional role of each of the different face-selective areas and possible dissociations among them has been extensively studied and discussed. In this review, we evaluate the two primary neural models of face processing, the Haxby face neural model (Haxby et al., 2000; Gobbini and Haxby 2007) and an extension to this model for dynamic faces that was suggested by O'Toole et al. (2002). We start with an overall description of the face-selective neural network and the functional roles that have been suggested for its different components by current neural models of face processing. We then evaluate these models in light of recent empirical findings. Based on the data that have been accumulated about the neural underpinning of face processing since the proposals of the Haxby and O'Toole models nearly 15 years ago, we propose an updated model that may better fit existing data and suggest directions for future investigations.

2. Functional neuroanatomy of face processing

The functional neuroanatomy of face processing has been investigated in the past two decades in numerous fMRI experiments. Faces were shown to elicit face-selective neural responses in multiple regions along the occipital-temporal cortex. Such face-selective activations are typically found in the inferior occipital cortex (OFA – occipital face area), the fusiform gyrus (FFA – fusiform face area) and the posterior part of the superior temporal sulcus (pSTS Face Area (pSTS-FA)) (Fig. 1). The functional role of each of these face-selective areas and their connections has been extensively discussed. Two main models have been suggested over 10 years ago to describe the functional role of the face-selective network, one by Haxby and colleagues in 2000 and the other by O'Toole and colleagues in 2002. Both models postulate that the face system is composed of two pathways, a dorsal one that goes from the occipital face area to the superior temporal sulcus and a ventral one that also starts at the occipital face area and projects to the fusiform gyrus. In both models the two pathways play different roles in face processing but the models differ in the roles they assign to the two pathways as described in detail below.

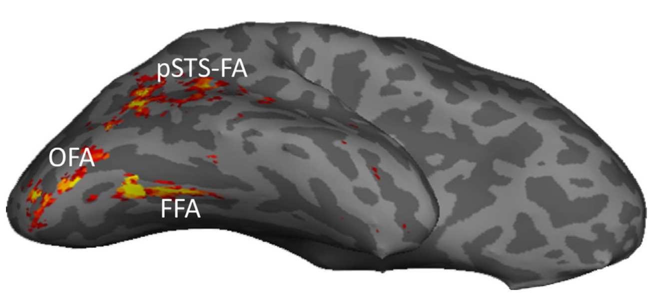

Fig. 1. Anatomical locations of the three core face-selective areas: the fusiform face area (FFA), the occipital face area (OFA) and the face-selective area in the posterior superior temporal sulcus (STS-FA).

3. Two pathways of face processing: two models

3.1. The Haxby model: invariant vs. changeable aspects of faces

The Haxby model is considered the most dominant neural model of face processing (Haxby et al., 2000, 2007). According to this model the OFA, FFA and pSTS-FA constitute the core system of face processing. The model postulates that the OFA provides inputs to both FFA and pSTS-FA and each plays a different role in face processing: the FFA is involved with the representation of invariant aspects of the face, such as face identity, while the pSTS-FA is involved with the representation of changeable aspects, such as facial expression, eye-gaze and lip movement. The OFA is responsible for early stages of face processing and sends its output to both the FFA and pSTS-FA (Fig. 2A). Additional areas outside this core network that are not face-selective but are involved in face processing were suggested, but will not be further discussed here.

3.2. The O'Toole model: extension for dynamic faces

O'Toole et al. (2002) proposed two modifications to the Haxby model in order to account for the processing of dynamic faces (Fig. 2B): the first modification concerns the role of pSTS-FA in dynamic identity information processing of familiar faces, and the second modification concerns structure-from-motion analysis. Thus, in addition to the role of the pSTS-FA in extraction of expression, eye gaze and lip movement, this pathway also aids in the processing of identity information that can be extracted from motion, but this is done only for familiar faces for which we have a "dynamic signature" that may contribute to face recognition as much as the static form of the face (and in some cases even more than the static form, see O'Toole et al., 2002). Furthermore, O'Toole and colleagues suggested that the two streams might interact in a "structure-from-motion" analysis, in which dynamic information is processed in the motion-selective area, MT, and then sent to the ventral areas as static form information. Similar to the Haxby model, O'Toole's model still suggests that facial expressions are processed by the dorsal and not the ventral stream.

In summary, both face neural models suggest two pathways of face processing in which the FFA is specialized in the processing of face identity from static face images and that the pSTS-FA is involved in the processing of the changeable aspects of faces including expression, eye gaze and lip movement. The O'Toole model further suggests an important role for the pSTS-FA in the processing of identify of familiar faces from dynamic information. In the next sections we review studies that examined the processing of identity and expression followed by studies that examined the processing of static and dynamic faces in the FFA and STS-FA to evaluate the extent to which these models are supported by existing empirical data.

Table 1 lists studies that examined the processing of identity and expression for static and dynamic faces in the FFA and pSTS-FA. Initial inspection of Table 1 already shows that current findings may not support the suggested division to expression and identity in the dorsal and ventral face pathways, respectively. It also highlights that more research needs to be done to explore the processing of identity from dynamic faces. In the next sections we discuss these studies in detail and based on their findings suggest the following modifications to current models: First, the primary functional division between the dorsal and the ventral streams may be to motion and form, respectively, rather than changeable and invariant facial