cortex 65 (2015) 50–64

Available online at www.sciencedirect.com

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Journal homepage: www.elsevier.com/locate/cortex

Research report

Reconstructing dynamic mental models of facial expressions in prosopagnosia reveals distinct representations for identity and expression

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ARTICLE INFO

Article history:
Received 18 November 2013
Reviewed 5 February 2014
Revised 7 May 2014
Accepted 25 November 2014
Action editor Jason Barton
Published online 24 December 2014

Keywords:
Prosopagnosia
Facial expressions of emotion
Reverse correlation

ABSTRACT

The human face transmits a wealth of signals that readily provide crucial information for social interactions, such as facial identity and emotional expression. Yet, a fundamental question remains unresolved: does the face information for identity and emotional expression categorization tap into common or distinct representational systems? To address this question we tested PS, a pure case of acquired prosopagnosia with bilateral occipitotemporal lesions anatomically sparing the regions that are assumed to contribute to facial expression (de)coding (i.e., the amygdala, the insula and the posterior superior temporal sulcus – pSTS). We previously demonstrated that PS does not use information from the eye region to identify faces, but relies on the suboptimal mouth region. PS's abnormal information use for identity, coupled with her neural dissociation, provides a unique opportunity to probe the existence of a dichotomy in the face representational system. To reconstruct the mental models of the six basic facial expressions of emotion in PS and age-matched healthy observers, we used a novel reverse correlation technique tracking information use on dynamic faces. PS was comparable to controls, using *all* facial features to (de)code facial expressions with the exception of fear. PS's normal (de)coding of dynamic facial expressions suggests that the face system relies either on distinct representational systems for identity and expression, or dissociable cortical pathways to access them. Interestingly, PS showed a selective impairment for categorizing many *static* facial expressions, which could be accounted for by her lesion in the right inferior occipital gyrus. PS's advantage for *dynamic* facial expressions might instead relate to a functionally distinct and sufficient cortical pathway directly connecting the early visual cortex to the spared pSTS. Altogether, our data provide critical insights on the healthy and impaired face systems, question evidence of deficits obtained from patients by using static images of facial expressions, and offer novel routes for patient rehabilitation.

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http://dx.doi.org/10.1016/j.cortex.2014.11.015

1. Introduction

The human face transmits a wealth of visual signals relevant for the identification and the categorization of facial expressions of emotion. The brain, as a decoder, flexibly filters the incoming visual information transmitted by the face to rapidly achieve complex perceptual categorizations (Schyns, Petro, & Smith, 2009). For example, the uniqueness of facial features characterizing a given individual, and their overall organization in the face, constitute the core information for identification and also for dissociating familiar from unfamiliar faces. Other signals can also be extracted from faces, such as the cues disclosing age (e.g., George & Hole, 1995), gender (e.g., Brown & Perrett, 1993; Ekman & Friesen, 1976, 1978; Schyns, Bonnar, & Gosselin, 2002; Tranel, Damasio, & Damasio, 1988), race (e.g., Caldara & Abdi, 2006; Caldara, Rossion, Bovet, & Hauert, 2004; Vizioli, Foreman, Rousselet, & Caldara, 2010; Vizioli, Rousselet, & Caldara, 2010) and emotional state (e.g., Bruce & Young, 1986; Calder & Young, 2005; Ekman & Friesen, 1976, 1978; Smith, Cottrell, Gosselin, & Schyns, 2005). Overt emotional states can also be extracted from face signals; they are mostly conveyed by facial expressions of emotion. The basic signals (i.e., "happy," "surprise," "fear," "disgust," "anger," and "sad") are only weakly correlated with each other to minimize confusions for their decoding (Smith et al., 2005), and we recently reported cross-cultural tunings in the way the emotion signals are transmitted and decoded (Jack, Blais, Scheepers, Schyns, & Caldara, 2009; Jack, Caldara, & Schyns, 2012; Jack, Garrod, Yu, Caldara, & Schyns, 2012). Yet, a fundamental question remains unresolved: does the face information used to recover identity and emotional expressions tap into common or distinct representational systems?

According to influential cognitive (Bruce & Young, 1986) and neuroanatomical (Haxby, Hoffman, & Gobbini, 2000) models of face processing, two distinct functional and neural systems accomplish the recognition of facial identity and facial expression. The first system – performing facial identification (Haxby et al., 2000) – is proposed to mainly involve the inferior occipital gyri and lateral fusiform gyrus, whereas the second system – performing facial expression categorization – is proposed to involve the inferior occipital gyri, the posterior superior temporal sulcus (pSTS) and the amygdala (for a review see, Calder & Young, 2005; Pessoa, 2008). However, some authors have questioned the idea of independence between those systems, by mainly relying on results from computational modelling and neuroimaging evidence (Calder, 2011; Calder & Young, 2005). A single model based on a Principal Component Analysis (PCA) can achieve independent coding of facial identity and facial expression, suggesting the possible existence of a multidimensional system, with a more partial than absolute independence (Calder, Burton, Miller, Young, & Akamatsu, 2001). These simulations have thus challenged the view of an independence between the coding for identity and expression, at least suggesting that those models are less strongly supported than what is often assumed (Calder & Young, 2005). In line with this position, Palermo, O'Connor, Davis, Irons, and McKone (2013) have recently put forward the theory of a first common step in the processing of expression and identity, and the occurrence of a splitting at a later stage; a view that is in agreement with the functional involvement of the inferior occipital gyrus as the entry level for both tasks (Calder & Young, 2005; Haxby et al., 2000; Pitcher, 2014). However, even though a neural dissociation for the processing of identity and emotional expression is supported by electrophysiological studies in primates (e.g., Hasselmo, Rolls, & Baylis, 1989) functional neuroimaging in humans (e.g., Winston, Henson, Fine-Goulden, & Dolan, 2004) and brain-damaged patients (Haxby et al., 2000), recent evidence suggests that the neural computations occurring in the inferior occipital gyrus and the right pSTS are functionally distinct and have a causal involvement in processing facial expressions (Pitcher, Duchaine, & Walsh, 2014). To sum up, more evidence is necessary to clarify this debate and, as acknowledged by Calder and Young (2005), further studies with brain-damaged patients are necessary to probe the hypothesis of distinct visuoperceptual systems for facial identity and facial expression categorization.

Following brain lesions, some patients lose the ability to recognize facial identity, despite no other obvious impairments of the visual system and a preserved identification via other modalities (e.g., voice, gait and so forth). The specificity of this face recognition deficit is spectacular, rare and has elicited considerable attention within the neuropsychological literature since the first clinical observations (Quaglino, 1867; Wigan, 1844) and the introduction of the term *prosopagnosia* by Bodamer (1947). Acquired prosopagnosia typically follows brain damage to bilateral occipitotemporal areas (e.g., Damasio, Damasio, & Van Hoesen, 1982; Farah, 1990; Landis, Regard, Bliestle, & Kleihues, 1988; Sergent & Signoret, 1992). Anatomical descriptions of prosopagnosia endorse the necessary and sufficient role of the right hemisphere (Landis et al., 1988; Sergent & Signoret, 1992) in the occipitotemporal pathway of face processing (for a review see, Bouvier & Engel, 2004). The clinical and anatomical conditions of prosopagnosia have always received great interest in cognitive neuroscience, as they clarify the neurofunctional mechanisms of normal face processing. The different sub-functions of the cognitive architecture of face processing have been isolated by the occurrence of distinct double dissociations in brain-damaged patients, for instance: a functional segregation between the ability to recognize unfamiliar and familiar faces (e.g., Malone, Morris, Kay, & Levin, 1982) and between lip reading and face identification (Campbell, Landis, & Regard, 1986). Yet, the neuropsychological literature remains controversial on the spared ability of prosopagnosic patients to identify facial expressions despite their impairment to recognize facial identity, and on patients showing impaired facial expression recognition with preserved facial identity recognition (for a detailed review see, Calder, 2011). Some *acquired* prosopagnosic patients showed a marked impairment in the categorization of facial expressions (Bowers, Bauer, Coslett, & Heilman, 1985; De Gelder, Pourtois, Vroomen, & Bachoud-Levi, 2000; De Renzi & Di Pellegrino, 1998; Humphreys, Donnelly, & Riddoch, 1993). Other studies reported preserved recognition of emotion in *acquired* prosopagnosia (Bruyer et al., 1983; Cole & Perez-Cruet, 1964; Mattson, Levin, & Grafman, 2000; Sergent & Villemure, 1989; Shuttleworth, Syring, & Allen, 1982; Tranel et al., 1988; Young, Newcombe, de