Neuropsychologia ■ (■■■■) ■■■–■■■

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Do I know you? Examining face and object memory in frontotemporal dementia

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ARTICLE INFO

Article history:
Received 30 January 2015
Received in revised form
17 March 2015
Accepted 19 March 2015

Keywords:
Face perception
Frontotemporal dementia
Memory
Fusiform cortex
Temporal lobe

ABSTRACT

The ability to perceive, learn and recognise faces is a complex ability, which is key to successful social interactions. This ability is proposed to be coordinated by neural regions in the occipital and temporal lobes, specialised for face perception and memory. While previous studies have suggested that memory for faces is compromised in some dementia syndromes, it remains unclear whether this simply reflects more generalised memory deficits. Here, we examined basic face perception (Identity-Matching), face recognition (Cambridge Face Memory Task) and object recognition (Cambridge Car Memory Task) in 11 semantic dementia (SD) patients (8 left-lateralised, 3 right-lateralised) and 13 behavioural-variant frontotemporal dementia (bvFTD) patients, compared with 11 controls. On the Identity-Matching task, bvFTD were impaired compared to controls, with a similar trend observed in the SD group. Importantly, both bvFTD and SD also demonstrated impaired face recognition. In contrast, only bvFTD showed impaired object recognition, with SD performing within normal limits on this task. Voxel-based morphometry analyses revealed that Identity-Matching and face recognition were associated with partly dissociable regions including the fusiform cortex and anterior temporal lobe. Object-memory was associated with thalamic integrity in the bvFTD group only. These results reveal that face perception and face memory deficits are common in bvFTD and SD, and have been previously underestimated. These deficits are due to neurodegeneration of key regions within the'core' and'extended' face processing system, providing convergent evidence of the neural regions supporting face perception. From a clinical perspective, impaired ability to recognise faces is common in bvFTD and SD and therefore strategies to improve face perception and memory may be beneficial for these patients.

1. Introduction

The ability to perceive and recognise faces is arguably one of the most highly specialised skills in humans. It enables us to recognise friends or family members, as well as acquaintances or even famous individuals that we have not met before in real life. This capacity occurs with ease and requires minimal cognitive effort. In addition, the ability to learn and remember new faces appears to be virtually unlimited. Despite this ostensible simplicity, the cognitive and neural mechanisms supporting face perception and recognition are complex.

Stages involved in face perception include early perception of facial features supported by the inferior occipital gyri (Haxby et al., 2000). This is followed by extraction of invariant facial features (i.e., facial identity), while simultaneously disregarding any changeable facial information (e.g., emotional expression, age, lip movements during speech) (Bruce and Young, 1986; Calder and Young, 2005; Haxby et al., 2000). This stage is supported by the inferotemporal cortex, including the lateral fusiform face area. Other neural regions including the superior temporal sulcus, purportedly involved in processing changeable face features, have also been implicated (for reviews see Calder and Young (2005); Haxby et al. (2000)). Retrieval of biographical/semantic information related to the face then involves the anterior temporal lobe (for review see Haxby et al. (2000)). Finally, successful face recognition, as well as (re-)encoding of facial information and its related contextual information may recruit additional memory

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http://dx.doi.org/10.1016/j.neuropsychologia.2015.03.020
0028-3932/

systems including the medial temporal lobe and prefrontal regions (e.g., Bernstein et al., 2002). Breakdown at any of these cognitive or neural stages will compromise face perception and memory for faces.

Impaired recognition of familiar or famous faces (i.e., prosopagnosia) has received considerable interest from a cognitive and neural perspective, with a large number of studies reporting impairment, in several neurodegenerative disorders (e.g., Gefen et al., 2013; Josephs et al., 2008; Mendez et al., 1992; Snowden et al., 2004). The extent that impaired face perception and recognition of *novel* faces is present in dementia, however, is less clear.

Frontotemporal dementia (FTD) is an umbrella term, referring to a group of progressive, neurodegenerative brain disorders that affect the frontal and temporal lobes (Gorno-Tempini et al., 2011; Rascovsky et al., 2011). Three clinical subtypes are typically recognised: behavioural-variant frontotemporal dementia (bvFTD), semantic dementia (SD) and progressive nonfluent aphasia (PNFA). This study focuses on the bvFTD and SD subtypes. Individuals with bvFTD present with a marked disturbance of behaviour and personality, which is associated with degeneration of the orbitofrontal and medial prefrontal cortices (Kipps et al., 2009; Seeley et al., 2008). Episodic memory performance is often impaired, and in many cases individuals with bvFTD are as impaired as disease-matched individuals with Alzheimer's disease on standard neuropsychological tests of episodic memory (Hornberger and Piguet, 2012; Hornberger et al., 2010; Irish et al., 2014b).

In contrast, individuals with SD present with a multimodal loss of general conceptual/semantic knowledge, which is usually associated with atrophy in the left anterior temporal lobe (Chan et al., 2001; Galton et al., 2001; Mion et al., 2010). Despite this profound loss of semantic memory, non-verbal episodic memory is usually well-preserved (Hodges et al., 1992). Of relevance here, a proportion of patients (~30%) present with right- rather than left-lateralised temporal lobe degeneration, referred to as right SD (Chan et al., 2009). Clinically, right SD is often characterised by a change in behaviour and personality, with reports of prosopagnosia also common (Irish et al., 2013; Josephs et al., 2009; Kamminga et al., in press; Snowden et al., 2004; Thompson et al., 2004). Although few studies have systematically examined episodic memory performance in right SD, some evidence suggests that non-verbal episodic memory and spatial navigation is compromised in this phenotype (Chan et al., 2009; Irish et al., 2013).

FTD provides a unique model to study the neurobiological basis of face perception and memory. While a large number of studies have reported impaired memory for famous faces in FTD, with divergent profiles in left SD compared to right SD (e.g., Gefen et al., 2013; Josephs et al., 2008; Snowden et al., 2004; Thompson et al., 2004), far fewer studies have examined memory for novel faces, with mixed findings. Omar et al. (2010) used the Benton Facial Recognition Test (Benton, 1994), which assesses face perception by asking participants to match a target face to those in a simultaneously presented set. Patients with SD (12 left SD; 1 right SD) and bvFTD ($n=19$) all performed within normal limits. Many healthy individuals, however, score in the normal range on the Benton Facial Recognition Test when only the eyebrows are visible, suggesting a piecemeal face matching approach is sufficient to complete this task successfully (Duchaine and Weidenfeld, 2003). Indirect evidence from emotion processing tasks using caricatures further suggests that face perception is abnormal in bvFTD (Kumfor et al., 2011), although this has not been studied systematically. Thus, the integrity of basic face perception in SD and bvFTD is unknown.

One of the earliest studies to examine recognition memory for novel faces in FTD used the Warrington Recognition Memory Test for Faces (Warrington, 1984), an old/new test of face memory (Simons et al., 2001). Consistent with clinical reports, only the group with predominant right-lateralised SD ($n=4$) were impaired, while the left-lateralised SD group ($n=4$) performed within normal limits. The SD group with relatively bilateral atrophy ($n=5$) was more impaired than the left-lateralised patients, but less impaired than the right-lateralised patients (Simons et al., 2001). In contrast, no significant differences were observed between left and right SD on standard neuropsychological tests of episodic memory (e.g., Rey Complex Figure, Warrington Recognition Memory Test for Words). These results led the authors to propose that the right temporal lobe is specialised for memory for faces (Simons et al., 2001) and therefore, apart from right SD, this function should be relatively intact in other FTD phenotypes. Importantly, however, the stimuli in the Warrington Recognition Memory Test for Faces contain substantial non-face information (e.g., hairstyles, clothing) that can be used to support recognition memory. Indeed, healthy individuals are able to score within the normal range on this test, even when all facial information is occluded (Duchaine and Weidenfeld, 2003). Moreover, other evidence suggests that face memory, at least for familiar faces, is compromised in the other FTD subtypes. Individuals with left SD tend to be impaired on tests of memory for famous faces, even when only recognition and not naming is required (Gefen et al., 2013). Thus, face recognition deficits in left SD and bvFTD may have been previously underestimated. Further, no studies to date have directly compared faces recognition with recognition of visual non-face stimuli of similar complexity. It is therefore unclear whether any observed face memory deficits in FTD are due to the degradation of face perception, a specific recognition memory deficit, or a combination of both.

Systematic investigation of the neural correlates of face memory in FTD is also currently lacking. Existing studies investigating famous face recognition, and clinical reports of prosopagnosia in SD, highlighted the importance of the right anterior temporal lobe as a key region supporting recognition of known faces (Gefen et al., 2013; Hsieh et al., 2011; Josephs et al., 2008). To our knowledge, however, no studies have directly investigated the neural correlates of basic face identity perception and memory for novel faces in this population. Further, the extent that common or divergent neural correlates contribute to face memory disturbance across FTD subtypes is unknown.

Thus, the current study had two broad aims: (i) To investigate face perception and face memory in bvFTD and SD using more sensitive tasks than used in previous studies, by employing both a face memory task and a well-matched object memory task and; (ii) to identify the neural correlates underlying face perception, face memory and object memory in bvFTD and SD. Given the degradation to regions within the frontal and temporal lobes in bvFTD and SD, we hypothesised that face perception and face memory deficits would be observed in both FTD subtypes. In addition, we predicted bvFTD would show impaired object memory performance, in line with previous reports of episodic memory deficits in this syndrome.

2. Methods

2.1. Participants

Thirteen bvFTD and 11 SD patients (8 SD with predominantly left-sided atrophy, 3 SD with predominantly right-sided atrophy) were consecutively recruited from FRONTIER, the frontotemporal dementia research group in Sydney, Australia and compared with 11 healthy age- and education-matched controls. All patients were assessed by an experienced behavioural neurologist, underwent comprehensive neuropsychological assessment (Table 1) and neuroimaging, and a reliable informant was interviewed. Based on

Please cite this article as: Kumfor, F., et al., Do I know you? Examining face and object memory in frontotemporal dementia. Neuropsychologia (2015), http://dx.doi.org/10.1016/j.neuropsychologia.2015.03.020