



Research report

Impaired body perception in developmental prosopagnosia

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ABSTRACT

Developmental prosopagnosia (DP) is a lifelong neurodevelopmental disorder associated with difficulties recognising and discriminating faces. In some cases, the perceptual deficits seen in DP appear to be face-specific. However, DP is known to be a heterogeneous condition, and many cases undoubtedly exhibit impaired perception of other complex objects. There are several well-documented parallels between body and face perception; for example, faces and bodies are both thought to recruit holistic analysis and engage similar regions of visual cortex. In light of these similarities, individuals who exhibit face perception deficits, possibly due to impaired holistic processing or aberrant white matter connectivity, might also show co-occurring deficits of body perception. The present study therefore sought to investigate body perception in DP using a sensitive delayed match-to-sample task and a sizeable group of DPs. To determine whether body perception deficits, where observed, co-vary with wider object recognition deficits, observers' face and body matching ability was compared with performance in a car matching condition. Relative to age-matched controls, the DP sample exhibited impaired body matching accuracy at the group level, and several members of the sample were impaired at the single-case level. Consistent with previous reports of wider object recognition difficulties, a number of the DPs also showed evidence of impaired car recognition.

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1. Introduction

Developmental prosopagnosia¹ (DP) is a lifelong neurodevelopmental disorder associated with difficulties recognising familiar faces and deficits of unfamiliar face discrimination. The condition occurs in people with normal

intelligence, typical low-level vision, and with no apparent brain lesions (Behrmann & Avidan, 2005; Duchaine & Nakayama, 2006b; Susilo & Duchaine, 2013). As many as one in every 50 people are thought to experience lifelong face recognition difficulties severe enough to disrupt their daily lives (Kennerknecht, Ho, & Wong, 2008; Kennerknecht et al., 2006). Individuals with DP identify others using non-face

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¹ We use the term *developmental prosopagnosia* instead of *congenital prosopagnosia* to indicate the possibility that in some cases the disorder may appear during development and not necessarily from birth.

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cues, including hairstyle, voice, and gait. Consequently, DPs often experience great difficulty when familiar people are met in unusual contexts or when they alter their appearance (Cook & Biotti, 2016; Shah, Gaule, Sowden, Bird, & Cook, 2015). In addition to problems recognising facial identity, some DPs also exhibit problems perceiving facial emotion (Biotti & Cook, 2016; Duchaine, Yovel, Butterworth, & Nakayama, 2006).

DP frequently runs in families, indicating that the condition has a genetic component (Duchaine, Germine, & Nakayama, 2007; Johnen et al., 2014; Schmalzl, Palermo, & Coltheart, 2008). However, the origins of DP remain poorly understood. From a cognitive perspective, reduced holistic processing – whereby information from disparate facial regions is integrated into a unified perceptual description – may underlie the face recognition difficulties seen in DP (Avidan, Tanzer, & Behrmann, 2011; DeGutis, Cohan, & Nakayama, 2014; DeGutis, Cohan, Mercado, Wilmer, & Nakayama, 2012; Palermo et al., 2011). At the neurological level, studies have revealed reduced grey matter volume in occipitotemporal cortex of individuals with DP (Behrmann, Avidan, Gao, & Black, 2007; Garrido et al., 2009), and have suggested atypical functional connectivity in high-level visual areas (Avidan & Behrmann, 2009; Avidan et al., 2013; Lohse et al., 2016). In addition, recent studies have revealed striking white matter differences in the occipital and temporal lobes of DPs (Gomez et al., 2015; Song et al., 2015; Thomas et al., 2009). Reduced density and coherence of the inferior longitudinal fasciculus (ILF) may impair information exchange within the face processing network.

In some cases, the perceptual deficits seen in DP appear to be face-specific; many individuals achieve perfect or near-perfect performance on standardised object recognition batteries (e.g., Bentin, Deouell, & Soroker, 1999; Nunn, Postma, & Pearson, 2001). For example, Duchaine et al. (2006) described Edward, a 53-year old male, who exhibited a pure case of DP. Despite severe face recognition difficulties, Edward showed typical recognition of a range of objects including cars, tools, guns, horses, and sunglasses. Moreover, Edward was able to discriminate houses either on the basis of elemental or configural differences, and showed typical learning and individuation of Greebles. However, DP is known to be a heterogeneous condition, and many cases undoubtedly exhibit impaired perception of other complex objects (Behrmann, Avidan, Marotta, & Kimchi, 2005; Dalrymple, Elison, & Duchaine, 2016; De Haan & Campbell, 1991; Duchaine et al., 2007). For example, of seven siblings with DP tested by Duchaine et al. (2007), five were significantly impaired at car perception, and 3 showed significant gun perception deficits. The extent to which cases of DP are face-specific or extend to other classes of object, may depend on the nature and extent of an individual's aberrant white matter connectivity (see Gomez et al., 2015).

There has been much interest in potential similarities between the visual processing of faces and bodies in typical observers (Minnebusch & Daum, 2009; Peelen & Downing, 2007; Slaughter, Stone, & Reed, 2004; de Gelder et al., 2009). Like faces, bodies are salient stimuli that capture attention when other classes of object go undetected (Downing, Bray, Rogers, & Childs, 2004; Stein, Sterzer, & Peelen, 2012). Faces and bodies both appear to preferentially engage regions of visual cortex. Strikingly, two areas thought to play a crucial role in body

perception, the extrastriate (EBA; Downing, Jiang, Shuman, & Kanwisher, 2001) and fusiform (FBA; Peelen & Downing, 2005) body areas, are spatially adjacent to the occipital (OFA; Pitcher, Walsh, & Duchaine, 2011) and fusiform (FFA; Kanwisher & Yovel, 2006) face areas, respectively, suggestive of parallel networks (Peelen & Downing, 2007). Similar event-related brain potentials (ERPs) are elicited by both faces (N170; Bentin, Allison, Puce, Perez, & McCarthy, 1996; Eimer, 2011) and bodies (N190; Stekelenburg & de Gelder, 2004; Thierry et al., 2006). Both the N170 and N190 components are delayed and increased when stimuli are presented upside-down, however their origin appears to be distinct and dissociable (Sadeh et al., 2011).

There has also been great interest in whether or not bodies recruit holistic processing similar to that engaged by faces. Composite effects, whereby the presence of an aligned task-irrelevant region alters observers' perception of a target region, provide direct evidence of holistic face processing (Murphy, Gray, & Cook, 2017; Rossion, 2013). Interestingly, similar composite effects have recently been reported with expressive body postures (Willems, Vrancken, Germeys, & Verfaillie, 2014), but not for body shapes in neutral poses (Bauser, Suchan, & Daum, 2011). Sizeable inversion effects, often cited as an indirect measure of holistic processing, are seen for both faces and bodies (Cook & Duchaine, 2011; Robbins & Coltheart, 2012a). Inversion effects are particularly strong when participants are required to match sequentially presented body postures (Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb, & McGoldrick, 2006). It is unclear, however, whether these effects reveal holistic body processing; for example, the magnitude of the posture inversion effect is disproportionately affected by the presence and position of the head (Yovel, Pelc, & Lubetzky, 2010).

Where individuals exhibit deficits of face perception, possibly due to impaired holistic processing or aberrant white matter connectivity, one might therefore expect co-occurring deficits of body perception. Consistent with this intuition, Righart and de Gelder (2007) found that the N170 marker of body processing exhibits atypical modulation following orientation inversion in three observers with DP. Nevertheless, many DPs report using body shape and bodily motion cues to recognise others (Biotti & Cook, 2016), and several empirical results suggest that body perception may be broadly typical in this population. For example, a recent study found no differences in torso matching accuracy when a sample of 11 DPs were compared with matched controls² (Rivolta, Lawson, & Palermo, 2016). Similarly, a sample of 16 DPs exhibited typical discrimination of hands – stimuli known to elicit strong responses in EBA (see Peelen & Downing, 2007) – in a match-to-sample procedure (Shah, Gaule, Gaigg, Bird, & Cook, 2015). Typical body matching has also been described in individual cases of DP (Duchaine et al., 2006). DPs and matched controls show broadly similar responses to body stimuli in core areas of the body processing network, including EBA and FBA (Van den Stock, van de Riet, Righart, & de Gelder, 2008), and multi-voxel pattern analysis (MVPA) suggests that distributed neural representations of body stimuli in inferotemporal cortex are largely typical (Rivolta et al., 2014).

² While prosopagnosics and controls did not differ in body matching accuracy, the prosopagnosics responded slower.

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