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Research Report

Holistic face perception is impaired in developmental prosopagnosia

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ABSTRACT

Individuals with developmental prosopagnosia (DP) have severe difficulties recognising familiar faces. A current debate is whether these face recognition impairments derive from problems with face perception and in particular whether individuals with DP cannot utilize holistic representations of individual faces. To assess this hypothesis, we recorded event-related potentials (ERPs) during a sequential face identity matching task where successively presented pairs of upright faces were either identical or differed with respect to their internal features, their external features, or both. Participants with DP and age-matched controls reported on each trial whether the face pair was identical or different. To track the activation of cortical visual face memory representations, we measured N250r components over posterior face-selective regions. N250r components to full face repetitions were strongly attenuated for DPs as compared to control participants, indicating impaired face identity matching processes in DP. In the Control group, the N250r to full face repetitions was superadditive (i.e., larger than the sum of the two N250r components to partial repetitions of external or internal features). This demonstrates that holistic face representations were involved in identity matching processes. In the DP group, N250r components to full and partial identity repetitions were strictly additive, indicating that the identity matching of external and internal features operated in an entirely part-based fashion, without any involvement of holistic representations. In line with this conclusion, DPs also made a disproportionate number of errors on partial repetition trials, where they often failed to report a change of internal facial features. This suggests an atypical strategy for encoding external features as cues to identity in DP. These results provide direct electrophysiological and behavioural evidence for qualitative differences in the representation of face identity in the occipital-temporal face processing system in developmental prosopagnosia.

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1. Introduction

Developmental prosopagnosia (DP) is a neurodevelopmental disorder characterised by a severe and specific difficulty recognising the faces of familiar people in daily life (for recent reviews, see: Towler, Fisher, & Eimer, 2017; Susilo & Duchaine, 2013; Towler & Eimer, 2012). Individuals with DPs do not appear to have suffered from brain injury, have normal intelligence, and intactlvisual and social cognitive abilities. Instead, these individuals appear to have specifically failed to develop the normal cognitive and neural mechanisms that allow for the rapid and effective recognition of individual faces. All individuals with DP have trouble recognising familiar faces, but the mechanisms that are responsible for this impairment are not yet fully understood. One fundamental question is whether DP is the result of some form of visual-perceptual face processing deficit, or whether it exclusively reflects later memory-related or associative impairments (e.g. Bate & Tree, 2017). Some investigations found deficits in perceptual face matching tasks for DPs (e.g. Duchaine, Yovel, & Nakayama, 2007; White, Rivolta, Burton, Al-Janabi, & Palermo, 2017; Yovel & Duchaine, 2006), while others failed to find such impairments (e.g. Le Grand et al., 2006; Ulrich et al., 2017). However, because different aspects of perceptual face processing and their possible impairment in DP have so far not been studied systematically, it remains unclear if and to what degree specific deficits in face perception contribute to the face recognition problems experienced by individuals with DP. The goal of the present study was to investigate whether the holistic perceptual processing of faces is selectively impaired in DP.

Holistic face processing refers to the ability to simultaneously apprehend the whole face in a single glance. This ability involves the integration of the internal facial features (such as the eyes, nose, and mouth), along with external facial features such as the hair and overall shape of the head, into a single visual representation that can be used for fast and effective face recognition. Perhaps the most compelling demonstration of holistic face processing comes from the composite face task (Young, Hellawell, & Hay, 1987) where participants have to match the identity of the top half of face pairs while ignoring the task-irrelevant bottom halves. Performance is impaired when the bottom halves depict different individuals, and this interference is abolished or strongly reduced when the top and bottom face halves are spatially misaligned (thus breaking the canonical face configuration) or when faces are inverted. This composite face illusion (CFI) provides direct evidence for the holistic processing of upright faces (for a review, see Rossion, 2013). Studies with DP using this task have produced inconsistent results, with some reporting a reduced CFI for DPs (e.g. Avidan, Tanzer, & Behrmann, 2011), while others find no difference in the size of the CFI between DPs and control participants (e.g., Biotti, Wu, Yang, Jiahui, Duchaine, Cook, 2017). Clearer evidence for deficits in holistic face processing deficits for DPs comes from part-whole face matching tasks. In this task, participants encode the identity of a whole face, are tested with either a whole face or face parts, and have to decide whether the whole face is the same as the sample face, or whether the face part is the same or different to the part presented in the sample face (e.g., Tanaka & Farah, 1993). Performance is generally better when the test image is a whole face. Importantly, this whole-face advantage is abolished by face inversion or by the spatial scrambling of face parts, suggesting that it reflects benefits produced by holistic face processing. DPs show a normal whole-face-advantage for the mouth, but no such effect for the eyes (DeGutis, Cohan, Mercado, Wilmer, & Nakayama, 2012). This result suggests a deficit of holistic face processing in DP that is specific to the eye region. Individuals with DP may be impaired in integrating the eye region within the context of the rest of the face. A third line of evidence for atypical holistic face processing in DP comes from observations that the effects of face inversion on performance in face identity matching tasks are often absent or reduced in individuals with DP (e.g. Duchaine et al., 2007). Because face inversion effects are often seen as the hallmark of holistic face processing, their absence may be interpreted as indication that this type of processing is impaired or absent in DP.

As the current evidence for deficits of holistic face processing in individuals with DP from composite and part-whole face matching tasks is limited and inconclusive, we employed a new face matching task that was designed to reveal such impairments with both behavioural and electrophysiological measures, and was first used in a previous study with participants with typical face recognition ability (Towler & Eimer, 2016). In this task, participants' attention is directed to the entire face and a holistic style of face processing is required for successful task performance. On each trial, a pair of face images is presented sequentially, and participants are instructed to detect repetitions and changes of these faces. Critically, repetitions or changes in the internal features of (the eyes, nose, and mouth) and external features (hair, ears, and head outline) of these face pairs are orthogonally varied. On half of all trials, internal and external features are both identical or both different (full repetition and full change trials). On the other half, there is a change in the internal features while the external features are repeated or vice versa (external or internal feature repetition trials). Participants' task is to report whether the two faces were identical or whether there was a change between them (either a partial change of external or internal features, or a full change). Because response selection cannot be based exclusively on repetition or changes of internal or external features alone, this task encourages participants to form holistic face representations that integrate across both types of features.

Our previous study (Towler & Eimer, 2016) provided behavioural and electrophysiological evidence for holistic face processing in participants with unimpaired face recognition ability. In different parts of this experiment, the face images were either presented in their normal upright orientation or upside-down. Face inversion increased the percentage of incorrect responses, specifically for trials with a partial change in either external or internal facial features, which were more likely to be reported as full face repetitions. This suggests that holistic face representations were