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Children process the self face using configural and featural encoding: Evidence from eye tracking

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ABSTRACT

Much is known about how the self-face is processed neurologically, however there has been little work exploring how self, familiar, and unfamiliar faces are viewed differently. Eye-movement data provides insights for how these stimuli are encoded and pupilometry provides information regarding the amount of effort put in when processing these stimuli. In this study, we utilise eye-tracking to explore differences in the encoding of self, age- and gender-matched personally familiar faces and age- and gender-matched unfamiliar faces in school-aged children. The self face was processed using more fixations than familiar and unfamiliar faces, specifically to the most diagnostic features, indicating enhanced and efficient use of featural processing. Furthermore, the self face was processed with more and longer central fixations than unfamiliar faces, indicating enhanced use of configural processing. Finally, the self face seemed to be processed the most efficiently as revealed through our pupilometry data. These results are incorporated into a model of self face processing that is based on efficient and robust processing consistent with the neurological data indicating that multiple brain areas are used to process faces.

1. Introduction

People tend to process their own face differently to other faces (Ma & Han, 2010) due to its significance for the self concept and self awareness (Gallup, 1998). This differential processing results in faster responding to the self face when recognising faces compared to famous faces (Keenan, Wheeler, Gallup, & Pascual-Leone, 2000) and personally-familiar faces (Keenan et al., 1999) or when searching for faces in a visual search task (Tong & Nakayama, 1999). This advantage for the self face is found irrespective of viewing angle (Tong & Nakayama, 1999, but see Troje & Kersten, 1999) and is present for upright and inverted faces (Keenan et al., 1999; Tong & Nakayama, 1999) despite expert face recognition being based on the correct orientation of faces (e.g., Carey & Diamond, 1977).

Given that humans can quickly and efficiently differentiate between many thousands of highly similar faces, face recognition is considered an expert visual ability. Expert face recognition is said to based on configural processing (Maurer, Le Grand, & Mondloch, 2002) though these concepts are only loosely defined[1]. This expert processing is selectively disrupted by inversion (e.g., Valentine, 1988; Edmunds & Lewis, 2007; Rossion, 2008) and is employed for processing familiar and unfamiliar faces (Scapinello & Yarmey,

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[1] Maurer et al. (2002) describe three forms of configural processing: processing of the first-order relational information (i.e., the basic arrangement of a faces); processing of second-order relational information (i.e., the individual spatial relations between the features in a face (Diamond & Carey, 1986); and holistic processing, in which the features of a face and their interrelations are processed as a gestalt (Rossion, 2008). These three processes are distinct and do not correlate with each other (Rezlescu et al., 2017), yet many researchers use them interchangeably. Holistic processing is likely to be the basis for expertise with faces (Rossion, 2008).

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1970; Yarmey, 1971). Superior self face processing compared to other face processing and the fact that it is not disrupted by inversion, indicates that the self face is processed uniquely or employing both expert and inexpert processing mechanisms effectively. The second assertion may seem at odds with the notion that some authors may consider featural and configural processing to be contrasting processing mechanisms. This study will establish whether the self face is processed uniquely and the precise relationship to featural and configural processing.

There is evidence from neuroscience that the self face is processed in a special manner relative to other faces employing both expert configural and inexpert featural processing. Numerous neuroimaging studies have highlighted that there is a distributed right-hemisphere processing system for the self face compared to famous and stranger faces (Heinisch, Dinse, Tegenthoff, Juckel, & Brüne, 2011; Keenan, Nelson, O'Conner, & Pascual-Leone, 2001; Platek, Keenan, Gallup, & Mohamed, 2004) and to personally familiar faces (Platek et al., 2006; Platek, Wathne, Tierney, & Thomspn, 2008; Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2004). While increased left hemisphere involvement has also been established (Kircher et al., 2001), this is primarily increased activation to the left fusiform gyrus (Devue et al., 2007; Sugiura et al., 2005) indicating that the self face occupies the perceptual and attentional system more completely than other faces because it is so important (Uddin et al., 2004). Gunji, Inagaki, Inoue, Takeshima, and Kaga, (2009) have shown that an ERP associated with increased attention is found when children aged approximately 10.8 years process the self face (this is not present in children with pervasive developmental disorder known to affect self processing). Collectively, these results indicate that the self face is processed in a special way involving enhanced attention and potentially the involvement of the right and left fusiform gyrus. Given that the right hemisphere has been purported to process configurally (specifically, holistically) and the left hemisphere processes featurally (Rossion et al., 2000), these results indicate that the self-face may be processed both featurally and configurally. However, more direct tests of enhanced encoding of the self face involving both featural and configural processing have not been conducted.

One technique that has been recently used to explore how much holistic (and by extrapolation configural) and featural processing is employed is eye tracking (Bombari, Mast, & Lobmaier, 2009; Chan & Ryan, 2012; Guo, 2012). Eye-movements represent the information that is being collected by the brain and therefore offer a strong line of evidence for what processing types may be occurring. While there is no one-to-one relationship between eye movements and attention, there has been strong evidence to show that featural processing (such as when viewing inverted faces) produces different eye movement patterns than holistic processing. Holistic processing is typically associated with longer central fixations (Blais, Jack, Scheepers, Fiset, & Caldara, 2008; Hsiao & Cottrell, 2008; see also Miellet, Vizioli, He, Zhou, & Caldara, 2013): Each fixation is longer when processing holistically relative to featurally and these are usually to the top of the nose (between the eyes). Such fixations allow for the whole face to be sampled. Featural processing is associated with more shorter fixations to the centre of individual features (Bombari et al., 2009). Therefore, featural processing is represented by more fixations (of shorter duration each) to more facial features than holistic processing. This pattern has been observed when participants view inverted faces (Hills, Cooper, & Pake, 2013; Van Belle, De Graef, Verfaillie, Rossion, & Lefèvre, 2010) supporting the idea that inverted faces are processed featurally. This therefore suggests that eye movements offer a direct measure of holistic/configural and featural processing (Rossion, 2008).

In addition to eye movements, pupilometry can be used to explore how faces are coded. Pupilometry has been used widely as a measure of cognitive effort: when tasks are more difficult, pupils are wider (Polt, 1970; Porter, Troscianko, & Gilchrist, 2007) when participants are more engaged in a task, their pupils are wider (Fairclough, Moores, Ewing, & Roberts, 2009), and pupils are wider when more resources are devoted to a task (Van Der Meer et al., 2010). This indicates that pupilometry can be a useful metric for exploring the depth with which faces are coded. Given the importance of the self face to the self concept, one would imagine that it would be processed with more effort and depth irrespective of whether the self face is processed configurally and/or featurally. By coupling eye movement information with pupilometry data, it will be possible to establish whether participants put more effort into coding their own face, or that they engage in both configural and featural processing. This allows for a greater understanding of the importance of the self face and how it is processed.

In the present study, we employed eye tracking to explore whether participants tend to view the self face differently to age- and gender-matched personally familiar and age- and gender-matched unfamiliar faces. We explore this effect in school-aged children in order to establish if there is any effect of development on self-face perception. Recently, it has been established that adult eye-movement patterns develop around the age of nine years of age, but this is earlier for familiar faces than unfamiliar faces (Hills, Willis, & Pake, 2013), therefore we assessed the performance of children aged 6–11 years in the present study. We also assess eye movements across upright and inverted faces, in order to confirm the use of featural coding when processing self faces. We hypothesise that there will be eye movement differences when viewing upright and inverted unfamiliar and personally familiar faces for our older participants, though less so for our younger participants. We expect the self face to be viewed using a mixture of configural and featural processing strategies revealed through more fixations to individual features and longer central fixations, Bombari et al., 2009). We also expect that the self face would be processed more deeply as indexed by pupilometry.

2. Method

2.1. Participants

Forty three (21 female) ethnically-White children aged between 6 years and 11 years 8 months old took part in this study. Participants were divided into two groups: the younger group (6–8.5 years; 13 female, mean age = 7.21 years) and the older group (8.6–11 years; 8 female, mean age = 10.02 years)[2]. Participants were recruited from a sample whose parents returned consent forms from two local schools. All participants were considered typically developing by their schools and their parents reported that they had