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The development of face expertise: Evidence for a qualitative change in processing

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ABSTRACT

There is conflicting evidence regarding the development of expert face recognition, as indexed by the face-inversion effect (FIE; de Heering, Rossion, & Maurer, 2011; Young and Bion, 1981) potentially due to the nature of the stimuli used in previous research. The developmental trajectory of the FIE was assessed in participants aged between 5- and 18-years using age-matched and adult stimuli. Four experiments demonstrated that upright face recognition abilities improved linearly with age (presumably due to improved memory storage capacities) and this was larger than for inverted faces. The FIE followed a stepped function, with no FIE for participants younger than 9-years of age. These results indicate maturation of expert face processing mechanisms that occur at the age of 10-years, similar to expertise in other domains.

1. Introduction

While adult face recognition is one of the most impressive human visual skills given the ability to differentiate and recognise many thousands of faces (Ellis, 1986), the face recognition abilities of children are poorer (Adams-Price, 1992; Blaney & Winograd, 1978). Adult face processing is assumed to be based on some form of expert processing mechanism (Farah, Wilson, Drain, & Tanaka, 1998) that may well be specific to the processing of faces (Kanwisher, Tong, & Nakayama, 1998). Poorer face-recognition performance in children could be due to generally poorer cognitive, attentional, and perceptual systems (see e.g., Crookes & McKone, 2009) or a specific deficit in this expert face processing (e.g., Carey & Diamond, 1977).

Expert processing is typically referred to as configural processing and is made up of three components (Maurer, Le Grand, & Mondloch, 2002): processing of the first order relations (i.e., two eyes level, side-by-side and above the nose); the processing of second-order relational information (i.e., idiosyncratic deviations to the basic template; Carey & Diamond, 1994); and holistic processing, which is processing the face as a gestalt whole (Rossion, 2008), integrating the multiple sources of information (Farah et al., 1998; Searcy & Bartlett, 1996). While researchers may not entirely understand what drives expertise in face recognition, there is consensus that faces are processed differently to objects and this is likely due to some form of configural processing (Piepers & Robbins, 2012). There are many sources of evidence to suggest that expert processing is not based on second-order relational information (Burton, Schweinberger, Jenkins, & Kaufmann, 2015) but is based on this final form of configural processing, known as holistic processing (Hole, George, Eaves, & Rasek, 2002; Mondloch & Desjarlais, 2010). Configural processing is usually contrasted with the featural coding, which is not indicative of expertise. Featural coding is typically defined as the processing of individual features in isolation (see Cabeza & Kato, 2000; Tanaka & Sengco, 1997). One method typically employed to assess configural coding is that of inversion (e.g., Freire, Lee, & Symons, 2000). Indeed, Sergent (1984) suggests that configural encoding is what is disrupted by

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inversion, whereas featural encoding is far less disrupted by inversion (see also Lewis & Glenister, 2003). Therefore, the face-inversion effect (FIE) is a reliable index of expert face processing (Edmonds & Lewis, 2007; Gauthier et al., 2000; Yin, 1969).

While there is no doubt that face recognition is expert in adults, there is a debate about when this expertise develops. One theory suggests that there is an early development of expert face processing mechanisms complete by the age of approximately 5-years (Crookes & McKone, 2009; Gilchrist & McKone, 2003; Want, Pascalis, Coleman, & Blades, 2003). While face recognition improves with age, this view suggests that age-related improvements in face recognition are explained by general improvements in the ability to attend and focus on the demands of the task (Crookes & McKone, 2009). These general improvements increase with age and continue to develop throughout childhood and adolescence (Betts, McKay, Maruff, & Anderson, 2006; Pastò & Burack, 1997; Skoczenski & Norcia, 2002). An alternative view is that the expert processing mechanisms do not develop until around 10 years of age (Carey & Diamond, 1977, 1994), consistent with the notion that many forms of perceptual expertise take approximately 10 years of practice and development (Akhtar & Enns, 1989; Brodeur & Enns, 1997; Enns & Brodeur, 1989; Ericsson, Krampe, & Tesch-Römer, 1993; Pearson & Lane, 1991).

Recently, a view was put forward that there might be differential effects for the development of face perception and face memory, with face memory developing late and face perception developing early (Weigelt et al., 2013). Wiegelt et al. have presented evidence highlighting that the mechanisms that control expert face processing are not necessarily the same as expert face memory. Memory for faces, apparently, develops later than the perceptual expertise for faces. Memory for faces can be revealed through an increase in hit rate and response bias (as hit rate represents more faces being stored in memory and more efficient encoding) without affecting false alarm rate (which better reflects poorer encoding and poorer access to memory: Hills, 2012). General memory (Chi, 1977; Dempster, 1981; Kail, 1992) and memory for faces (Flin, 1980), does improve with increased age.

Consistent with the view that the FIE is a measure of expert face perception, then there should be sufficient evidence to establish whether face perception develops early or late. If face perception expertise develops late, then one would expect that children would show a smaller FIE than adults. The evidence for this is mixed. Most authors agree that face recognition abilities improve approximately linearly with age, reaching an asymptote at the age of 12 (Feinman & Entwisle, 1976), 17 years (Ellis, Shepherd, & Bruce, 1973; Golarai et al., 2007; Lawrence et al., 2008; O'Hearn, Schroer, Minshew, & Luna, 2010), or well into adulthood (e.g., Germine, Duchaine, & Nakayama, 2011; Susilo, Germine, & Duchaine, 2013) depending on the stimuli set used.[1] However, Flin (1980, 1985) has reported a face recognition performance "dip" at age 11 years[2] (see also, Carey, 1978, 1981; Carey, Diamond, & Woods, 1980). The improvement in recognition for inverted faces may also be linear, but at a slower rate. Using a novel (for this field) statistical procedure, de Heering, Rossion, and Maurer (2012) found that performance on the Benton Face Recognition Test (Benton, Sivan, Hamsher, Vareny, & Spreen, 1983) correlated with age, between the ages of 6-years and 12-years. This correlation was stronger for upright than inverted faces indicating that the magnitude of the FIE also correlated with age. Such an improvement for upright faces over inverted faces potentially reflects that the expert face processing system has developed and there is a general improvement in task performance or face memory. Alternatively, this improvement may reflect a protracted development of expert face processing skills.

Data from matching tasks reveal that children younger than 10 years of age are more likely to be affected by paraphernalia and pose changes than children older than 10 years and adults (Diamond & Carey, 1977; Ellis, 1992a, 1992b; Freire & Lee, 2001; Saltz & Sigel, 1967). These results indicate that children are not coding faces in the most effective configural manner. Indeed, six- and eight-year-old children do not show the FIE when tested in matching paradigms (Carey & Diamond, 1977; Hay & Cox, 2000; Joseph et al., 2006; Schwarzer, 2000) or recognition paradigms (Goldstein, 1975) indicating a greater reliance on featural processing (Schwarzer, 2000). In these studies, the FIE was found by some ten-year-old participants indicating some individual difference in the development of expert face processing which may sometimes mask effects when development is tested cross-sectionally. These results indicate a qualitative shift in the way children code faces at age 10 from an inexpert to expert mechanism (Baudouin, Gallay, Durand, & Robichon, 2010; Mondloch, Leis, & Maurer, 2006).

However, other authors have reported that the FIE is apparent in three- (Carey, 1981), five- (Fagan, 1972; Flin, 1983), or seven-year-old children (Young and Bion, 1981, 1982) leading to parallel improvements in recognition skills (Itier & Taylor, 2004). Proponents of the view that the FIE does not increase with age highlight that the studies that fail to show an FIE in younger participants suffer from floor effects (Young and Bion, 1981). Nevertheless, an age-by-orientation interaction is often found in studies that claim there is an FIE in younger participants,[3] indicating that the magnitude of the FIE increases with age (Brace et al., 2001; Carey, 1981; Carey & Diamond, 1994; Flin, 1983; Goldstein & Chance, 1964). Any effect of age on the magnitude of the FIE would indicate that children rely more on featural rather than configural coding (e.g., Hay & Cox, 2000).[4]

There are a number of methodological and statistical issues with the studies on children's face recognition. Firstly, most of the

[1] Ellis et al. (1973), Germine et al. (2011), and Susilo et al. (2013) used adult faces in their experiments, whereas Feinman and Entwisle (1976) used children's faces. These results are consistent with the own-age bias in face recognition (Anastasi & Rhodes, 2006) rather than demonstrating the developmental trajectory of face recognition.

[2] However, if a linear function is fitted to Flin's data, the *d'* measure does not show a significant blip at age 11 years. A blip in performance is observed only if a curvilinear function is fitted.

[3] For example, the significant age-by-orientation effect observed by Flin (1985) was put down to the recognition "blip" rather than a change in the magnitude of the FIE with age, even though the FIE was 1.5 times larger in her oldest age group than the youngest age group she tested.

[4] Using the parts and wholes test (Tanaka & Farah, 1993), Pellicano and Rhodes (2003) found evidence that children as young as four-years old use holistic processing. Similarly, Carey and Diamond (1994) have shown that 6- and 10-year-old show a composite face effect of a similar magnitude to adults. However, performance on these tasks may be unrelated (Konar et al., 2010; Rezlescu, Susilo, Wilmer, & Caramazza, 2017; Wilhelm et al., 2010), at least in children, to performance in the FIE.