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Sensitivity to spacing changes in faces and nonface objects in preschool-aged children and adults

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ABSTRACT

Sensitivity to variations in the spacing of features in faces and a class of nonface objects (i.e., frontal images of cars) was tested in 3- and 4-year-old children and adults using a delayed or simultaneous two-alternative forced choice matching-to-sample task. In the adults, detection of spacing information was robust against exemplar differences for faces but varied across exemplars for cars (Experiment 1A). The 4-year-olds performed above chance in both face and car discrimination even when differences in spacing were very small (within ±1.6 standard deviations [*SD*s]) and the task involved memory components (Experiment 1B), and the same was true for the 3-year-olds when tested with larger spacing changes (within ±2.5 *SD*s) in a task that posed no memory demands (Experiment 2). An advantage in the discrimination of faces over cars was found at 4 years of age, but only when spacing cues were made more readily available (within ±2.5 *SD*s). Results demonstrate that the ability to discriminate objects based on feature spacing (i.e., sensitivity to second-order information) is present at 3 years of age and becomes more pronounced for faces than cars by 4 years of age.

Introduction

Despite the early emergence of many face processing skills, adult-like expertise at face recognition is slow to develop. Children's performance in face recognition memory (e.g., Carey, Diamond, & Woods, 1980; Johnston & Ellis, 1995) and face matching tasks (e.g., Bruce et al., 2000; Carey et al.,

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1980) improves greatly between 5 and 6 years of age and adulthood, with adult-like levels being reached only during late adolescence.

Much effort has been devoted to identify the nature of children's immaturity in recognizing faces. The most popular theory proposes that a crucial contributing factor to age-related changes in face processing abilities is ongoing development of face-specific perceptual mechanisms driven by increasing experience with faces (e.g., Carey & Diamond, 1977, 1994; Diamond & Carey, 1986; Mondloch, Le Grand, & Maurer, 2002). Adults base their recognition of individual faces on multiple perceptual cues: the shape of individual features (i.e., featural processing), the overall gestalt of the face (i.e., holistic processing), and the spatial distances among the internal features (i.e., a configurational cue sometimes referred to as second-order relations; for a review, see Maurer, Le Grand, & Mondloch, 2002). Developmental researchers have linked children's poor performance on face recognition tasks to immaturity in sensitivity to holistic and second-order relational cues (e.g., Carey & Diamond, 1977; Mondloch, Geldart, Maurer, & Le Grand, 2003; Mondloch et al., 2002; Schwarzer, 2000).

Nevertheless, recent research has demonstrated that most of the face-specific behavioral effects shown in adults, such as the face inversion effect (Picozzi, Macchi Cassia, Turati, & Vescovo, 2009; Sangrigoli & de Schonen, 2004; Turati, Sangrigoli, Ruel, & de Schonen, 2004), the composite effect (Macchi Cassia, Picozzi, Kuefner, Bricolo, & Turati, 2009; Turati, di Giorgio, Bardi, & Simion, 2010), and the part–whole effect (Pellicano & Rhodes, 2003), are also present in young children and sometime even in infants, suggesting that there are no qualitative changes in face perception between earlier and later stages of development. In addition, there is ample evidence that 3- to 4-month-old infants (e.g., Quinn & Bhatt, 2005; Quinn, Bhatt, & Hayden, 2008) and even newborns (Farroni, Valenza, Simion, & Umiltà, 2000; Macchi Cassia, Simion, Milani, & Umiltà, 2002) manifest perceptual organization abilities with nonface stimuli, which reflect second-order relational processing. Finally, a right hemisphere advantage in processing configural information, analogous to that observed in adults, has been found in infants as young as 4 months in tasks involving faces (Deruelle & de Schonen, 1991, 1998) as well as nonface stimuli (Deruelle & de Schonen, 1991, 1995).

This evidence has been taken as challenging the hypothesis that experience-based face-specific perceptual development is responsible for improvements in face recognition abilities and supports the alternative claim that such improvements reflect the development of general neurocognitive factors such as memory or attentive abilities, neural processing speed affecting reaction times (Crooks & McKone, 2009; Pellicano, Rhodes, & Peters, 2006; Want, Pascalis, Coleman, & Blades, 2003), and specific visual skills that could be particularly relevant to the detection of featural displacement (Mondloch, Maurer, & Ahola, 2006).

The contribution of face-specific perceptual factors and general cognitive factors to the protracted development of face processing abilities currently remains an open question (e.g., Crookes & McKone, 2009). Particularly relevant to this question is evidence on the development of sensitivity to second-order relational information, defined by the spacing of the inner features of the face. Although there is general consensus that the ability to extract this type of configural information from faces is present in school-aged children (Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch et al., 2002, 2003), there is much debate as to how this aspect of face processing expertise develops before 6 years of age. It has been recently reported that 5- and 7-month-old infants, but not 3-month-olds, can use normal variations in the spacing of facial features to discriminate between two individual faces in visual habituation tasks measuring looking times (Hayden, Bhatt, Reed, Corbly, & Joseph, 2007). However, existing studies provided mixed results as to whether sensitivity to facial feature spacing is present in preschool-aged children, particularly 4-year-olds, when tested with tasks measuring response accuracy. Three studies reported that 4-year-olds are sensitive to differences among faces in the spacing of the inner features (McKone & Boyer, 2006; Mondloch & Thomson, 2008, Experiment 2; Pellicano et al., 2006), whereas three other studies found that this is not the case (Mondloch, Leis, & Maurer, 2006; Mondloch & Thomson, 2008, Experiments 1 and 3).

All of the studies used child faces as stimuli and spacing changes that remained within the normal range of human variability, thereby not generating weirdness or bizarreness effects. However, the amplitude of the spacing differences between the faces to be discriminated varied between the studies (from ±2.5 to ±5 standard deviations [*SD*s] of normal variability) as well as the specific task conditions