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Development of sensitivity to spacing versus feature changes in pictures of houses: Evidence for slow development of a general spacing detection mechanism?

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ABSTRACT

Adults are expert at recognizing faces, in part because of exquisite sensitivity to the spacing of facial features. Children are poorer than adults at recognizing facial identity and less sensitive to spacing differences. Here we examined the specificity of the immaturity by comparing the ability of 8-year-olds, 14-year-olds, and adults to discriminate houses differing in the spacing between features versus those differing in the shape of the features themselves. By 8 years of age, children were more accurate for discriminations involving the feature set compared with the spacing set, and the difference in accuracy compared with adults was greater for the spacing set than for the feature set. Importantly, when sets were matched in difficulty for adults, this greater immaturity on the spacing set than on the feature set remained. The results suggest that, at least by age 8, immaturities in sensitivity to the spacing of features may be related to immaturities in general perceptual mechanisms rather than face-specific mechanisms.

Introduction

Many aspects of vision are fully developed by 6 or 7 years of age, including spatial and temporal contrast sensitivity (Ellemberg, Lewis, Liu, & Maurer, 1999) and the extent of the peripheral visual field (Bowering, Maurer, Lewis, & Brent, 1997). However, some aspects of vision continue to develop after age 7 and even into early adolescence, including vernier acuity, three-dimensional object recognition,

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and sensitivity to contour integration, subjective contours, and biological motion (Hadad, Maurer, & Lewis, 2010a, 2010b, 2011; Lewis et al., 2004; Rentschler, Juttner, Osman, Muller, & Caelli, 2004; Skoczenski & Norcia, 2002).

Early research suggested that face recognition does not become adult-like until 10 years of age or even later (Carey & Diamond, 1977; Carey, Diamond, & Woods, 1980; Diamond & Carey, 1977; but see Carey, 1981). However, the differences between adults and children may be related to general perceptual and/or cognitive development rather than changes in face processing per se (Crookes & McKone, 2009), at least after age 8 (Mondloch, Maurer, & Ahola, 2006b). A recent review by Nishimura, Scherf, and Behrmann (2009) suggested that object recognition also continues to develop into adolescence. In this article, we compare the ability of 8-year-olds, 14-year-olds, and adults to discriminate houses using stimulus manipulations used previously with faces. The aim was to test whether the pattern of development is similar to or different from that found previously for faces, as well as to add to the literature on the development of object recognition more generally.

Adults can use several different cues to recognize a face, including the shape of the external contour, hair and eye color, the shape of individual internal features (e.g., shape of the nose), and the spacing among the internal features (e.g., interocular distance). Rapid integration of information across the whole face (''holistic processing'') may facilitate the use of such cues. Although adults are better at using any of these cues in upright own-race human faces than in any other category (e.g., inverted faces, other-race faces, monkey faces, objects), their sensitivity to the spacing of features appears to be tuned especially tightly (e.g., Bredart & Devue, 2006; Brooks & Kemp, 2007; Ge, Luo, Nishimura, & Lee, 2003). This conclusion is supported by evidence that adults' discrimination of spacing changes is less accurate for monkey faces than for the same-sized changes in human faces (Mondloch et al., 2006b), that their certainty about vertical eye position is lower for inverted faces than for upright faces (Robbins, McKone, & Edwards, 2007), and that extremely large changes are needed in upright houses to bring accuracy up to the level found for smaller spacing changes in upright faces (Robbins, Nishimura, Mondloch, Lewis, & Maurer, 2010; Yovel & Duchaine, 2006).

Newborns orient toward face-like stimuli (stimuli that have more high-contrast elements in the top half of an oval pattern [e.g., Cassia, Turati, & Simion, 2004; Johnson, Dziurawiec, Ellis, & Morton, 1991]) and can recognize a face learned *en face* when it is turned to a three-quarters view (Turati, Bulf, & Simion, 2008). By 5 months of age, infants can discriminate faces based only on the spacing of features so long as the changes are large (Bhatt, Bertin, Hayden, & Reed, 2005, Experiment 2; Hayden, Bhatt, Reed, Corbly, & Joseph, 2007, Experiment 2; see Mondloch & Thomson, 2008, for a review). This ability to detect spacing changes is, of course, also present in older children (e.g., Freire & Lee, 2001; McKone & Boyer, 2006; Pellicano, Rhodes, & Peters, 2006).

Studies of older children asked to recognize the identity of faces based on the spacing of features indicate, however, that it takes many years for accuracy to reach adult levels. For example, Mondloch, Le Grand, and Maurer (2002) studied children's and adults' ability to discriminate faces by comparing faces that differed only in features (i.e., a face with the eyes and mouth swapped with those from other faces to make four new versions) or differed only in spacing among features (i.e., a face with the eyes and mouth moved to create four new combinations). They used a sequential same/different task with children (6-, 8-, and 10-year-olds) and adults (18- to 28-year-olds). By 6 years of age, children were nearly as accurate as adults in detecting the feature changes, but even at age 10 they were significantly worse than adults at detecting the spacing changes. The authors concluded that face processing is immature until at least age 10 and that spacing discrimination takes longer to become adult-like than feature discrimination. Later results indicate that even 14-year-olds are not as accurate as adults at detecting spacing changes (Mondloch, Le Grand, & Maurer, 2003) and that until age 11 children are not as accurate as adults in judging whether the spacing of the eyes is the same or different in two images of the same face (Baudouin, Gally, Durand, & Robichon, 2010).

Interestingly, two pieces of evidence suggest that development in the ability to discriminate differences in feature spacing may reflect the development of general mechanisms rather than mechanisms tuned to upright faces, at least after 8 years of age. First, the difference in accuracy between 8-year-olds and adults is reduced (but not eliminated) by reducing memory demands (Mondloch, Dobson, Parsons, & Maurer, 2004). Second, accuracy in detecting spacing changes