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Exploring children's face-space: A multidimensional scaling analysis of the mental representation of facial identity

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ABSTRACT

We explored differences in the mental representation of facial identity between 8-year-olds and adults. The 8-year-olds and adults made similarity judgments of a homogeneous set of faces (individual hair cues removed) using an "odd-man-out" paradigm. Multidimensional scaling (MDS) analyses were performed to represent perceived similarity of faces in a multidimensional space. Five dimensions accounted optimally for the judgments of both children and adults, with similar local clustering of faces. However, the fit of the MDS solutions was better for adults, in part because children's responses were more variable. More children relied predominantly on a single dimension, namely eye color, whereas adults appeared to use multiple dimensions for each judgment. The pattern of findings suggests that children's mental representation of faces has a structure similar to that of adults but that children's judgments are influenced less consistently by that overall structure.

Introduction

Adults have a remarkable ability to remember and recognize many faces in their everyday lives. Adults' recognition of faces is impaired when faces are inverted, and this "inversion effect" is greater for faces than for non-face objects such as houses and airplanes (e.g., Yin, 1969). Adults appear to process faces holistically; they process the individual features, such as the eyes and mouth, together as a unitary whole or Gestalt percept (e.g., Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987). Adults also demonstrate acute sensitivity to changes in feature shape and second-order relations, which refer to the spatial relations among internal facial features, such as the distance between the two eyes, but

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more for upright faces than for inverted faces (e.g., Brooks & Kemp, 2007; Collishaw & Hole, 2000; Freire & Lee, 2001; Mondloch, Le Grand, & Maurer, 2002).

Like adults, children (and to a certain extent even infants) demonstrate a face inversion effect (e.g., Brace et al., 2001; Itier & Taylor, 2004a; Mondloch et al., 2002; Schwarzer, 2000; Turati, Sangrigoli, Ruel, & de Schonen, 2004). Children as young as 4 to 6 years of age also demonstrate holistic processing of faces (Carey & Diamond, 1994; de Heering, Houthuys, & Rossion, 2007; Mondloch et al., 2007; Pellicano & Rhodes, 2003; Pellicano, Rhodes, & Peters, 2006; Tanaka et al., 1998). In addition, 6-year-olds can recognize the identity of faces based on changes in external contour as accurately as adults, and 8-year-olds are nearly as good as adults in detecting changes in the shapes of internal features such as eyes and mouth (Mondloch et al., 2002).

However, it takes many years for children's face processing abilities to reach adult levels. For example, 8-year-olds are worse than adults at recognizing facial identity across changes in point of view (Mondloch, Geldart, Maurer, & Le Grand, 2003) or noticing subtle changes in the second-order relations (Mondloch et al., 2002). Their immaturity in processing the second-order relations of upright faces is evident even when memory demands are eliminated as well as when the salience of feature shapes is reduced (Mondloch, Dobson, Parson, & Maurer, 2004). Improvements with age in sensitivity to second-order relations continue into adolescence (Mondloch, Le Grand, & Maurer, 2003). These behavioral immaturities are consistent with neuroimaging data. Adults demonstrate face-selective activation in the right anterior fusiform gyrus, an area referred to as the face fusiform area or the FFA (e.g., Kanwisher, McDermott, & Chun, 1997). Under many conditions, such FFA activation is not observed in children until 12 to 16 years of age (Aylward et al., 2005; Gathers et al., 2004; Passarotti et al., 2003; Passarotti, Paul, & Stiles, 2001; Scherf, Berhmann, Humphreys, & Luna, 2007). However, when age-related differences in blood-oxygenation-level-dependent (BOLD) signals are controlled carefully, face-selective right FFA activation has been shown in children as young as 7 to 11 years of age, albeit in an area that is significantly smaller than that in adults (Golari et al., 2007). Similar developmental trajectories are revealed through event-related potentials (Itier & Taylor, 2004b; Taylor, Edmonds, McCarthy, & Allison, 2001).

The source of the immaturities in face processing may lie in children's mental representation of faces. A useful framework that describes adults' mental representation of faces is face-space, a multidimensional space in which individual faces are represented by unique multidimensional vectors from the origin (Valentine, 1991). The origin of face-space represents the average of previously encountered faces such that the distance from the origin represents the distinctiveness of a face (more typical faces will be located closer to the average), and the direction from the origin represents *how* the face deviates from average along dimensions that are important for face recognition (Valentine, 1991). The average of face-space is updated continuously with experience, and there may be separate averages for different populations of faces such as male versus female faces or faces of different races (e.g., Baudouin & Gallay, 2006; Byatt & Rhodes, 1998; Levin, 1996; Little, DeBruine, & Jones, 2005; Valentine, 1991; Watson, Rhodes, & Clifford, 2006).

Adaptation paradigms provide supporting evidence that adults indeed encode faces relative to an average that is updated constantly. For example, when an observer adapts for several seconds to a face that has been digitally compressed, he or she judges a previously normal face as being expanded (Rhodes et al., 2003; Watson & Clifford, 2003; Webster & MacLin, 1999). Presumably, adaptation has shifted the observer's perception of normality toward the adapting face (i.e., the observer's mental "average" is more compressed than it was prior to adaptation), so that a previously "normal" face looks "expanded" relative to the updated mental average. Similarly, when a pair of "opposite" faces (relative to an averaged morph) is created through digital morphing, adapting to one face shifts the perception of identity toward the other face (e.g., Anderson & Wilson, 2005; Leopold, O'Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006).

The face-space model is consistent with adults' faster classification judgments (i.e., judging whether a stimulus is a face or not) of typical faces than of distinctive faces but their slower individual recognition of faces (i.e., judging whether a face belongs to "Bob" or "Fred") for typical faces than for distinctive faces (e.g., Johnston & Ellis, 1995; Rhodes, Byatt, Tremewan, & Kennedy, 1997; Valentine, 1991; Valentine & Bruce, 1986). This effect is likely caused by the spatial gradient of face-space. Because the distance from the origin represents the distinctiveness of a face, and by definition there