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Developmental changes in the microgenesis of face perception revealed by effects of context and inversion

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ABSTRACT

Present studies on the development of face perception mechanisms are ambiguous about the question of whether holistic face vision arises early, or in the second decade of life (Crookes & McKone, 2009). Measuring the time course of face matching we assess effects of context and inversion as correlates of holistic processing in the microgenesis of face perception within the first 650 ms, and compare among 8- to 10-year-old children and adults. Results for adults indicate dominance of holistic viewing at brief timings, which is gradually replaced by feature selective strategies enabling them to selectively attend either internal or external features, as demanded by instruction. For children, however, effects of context and inversion are absent at brief timings, but gradually increase to strong levels with increasing viewing times. Moreover, we find a pronounced asymmetry in face matching performance with internal and external features. While face matching by attending external features is well developed and robust against variable facial contexts, face matching by attending internal features is generally poor, and strongly affected by interleaved congruent and incongruent contextual information. These results indicate that children and adults differ not only in the kind of featural information they preferentially encode in face perception, but also in the processing time they need to build holistic representations. While these are fast and automatic in adults' face vision, children's face representations are part based at brief timings, but develop to integrated wholes as more temporal resources are made available.

1. Introduction

Adults with matured face perception abilities view faces by integrating information from across the entire face, including the characteristics of basic facial features and the spatial relations among them (Bartlett & Searcy, 1993; Diamond & Carey, 1986; Rhodes, Brake, & Atkinson, 1993; Rossion & Boremanse, 2008; Searcy & Bartlett, 1996). The main characteristic of holistic viewing is fast and automatic access to the representation of the whole face, while access to individual parts is possible only with detailed scrutiny (Tanaka & Farah, 1993). Although the mechanisms of holistic processing are not yet completely understood there are two major findings demonstrating strong integration of face parts and reliance on configural relations, defined as the spatial arrangement of the basic features of an individual face (for a review see, Maurer, Le Grand, & Mondloch, 2002). In the whole-part paradigm subjects are trained to name a series of faces, and they recognize face features better when viewed in the context of a whole face, compared to seeing parts in isolation (Tanaka & Farah, 1993). The advantage of identifying parts in wholes is not found with non-facial objects, and is specific of faces (Farah, 1996; Farah, Tanaka, & Drain, 1995; Tanaka & Farah, 1993). In the composite face paradigm it has been demonstrated that recognition and comparison of chimeric faces by attending just upper or lower half is seriously hampered when the unattended face half is incongruent with the target face. Misaligning both halves resolves perceptual fusion, and the observer is able to attend the two face halves independent of each other (Hole, 1994; Richler, Tanaka, Brown, & Gauthier, 2008; Young, Hellawell, & Hay, 1987).

In both paradigms holistic effects are obtained in upright orientation, but diminish when faces are presented upside down, indicating that holistic encoding of inverted faces is strongly reduced. Generally, differences of faces are hard to detect when they are presented upside down. Even severe distortions, making faces look grotesque in upright orientation, are hardly perceived when they are inverted (Bartlett & Searcy, 1993; Thompson, 1980; Yin, 1969). The strong vulnerability to inversion is a further property making faces "special", since other objects do not suffer

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from inversion to comparable degrees (Tanaka & Farah, 1993; Yin, 1969). As an interpretation of the face inversion effect it was suggested that configural information, as an integral part of holistic representations, is seriously disturbed for upside down faces, such that processing is mostly "featural" with inverted faces (Bartlett & Searcy, 1993; Farah et al., 1995; Maurer et al., 2002; Mondloch, Le Grand, & Maurer, 2002; Leder & Bruce, 2000; Rhodes et al., 1993; Rossion & Gauthier, 2002; Tanaka & Sengco, 1997). Consequently, turning faces upside down is thought to be accompanied by a switch from holistic to more part based viewing strategies, and the performance difference obtained for both orientations in face perception experiments is thought to reflect the advantage of exploiting holistic effects when viewing faces in their normal upright orientation. Although there are observations of inversion effects for isolated facial features (Rakover & Teucher, 1997) pointing to possible alternative origins, there is agreement that inversion effects generally indicate disruption of the relational description of faces, and are therefore apt to reveal holistic effects, particularly when used in combination with a part-whole or composite face paradigm (see Rossion, 2008, for a critical discussion).

As a face specific mechanism holistic viewing is thought to reflect adults' expertise gained through viewing experience with upright human faces over more than two decades. Comparable immediate access and high accuracy in judging other visual objects is observed only after extensive perceptual training (Diamond & Carey, 1986; Gauthier & Tarr, 1997). Although some developmental studies support the expertise hypothesis demonstrating increase of face viewing capabilities with age (Carey & Diamond, 1977; Schwarzer, 2000), altogether empirical evidence is far from univocal. Developmental studies on face processing have shown that even young infants demonstrate remarkable face recognition abilities and can recognise their mother (Bushnell, 2001; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995), discriminate between individual faces (de Haan, Johnson, Maurer, & Perrett, 2001; Turati, Macchi Cassia, Simon, & Leo, 2006), discriminate among emotional expressions (D'Entremont & Muir, 1997) and respond to facial attractiveness (Rubenstein, Kalakanis, & Langlois, 1999; Slater et al., 1998; Slater, Quinn, Hayes, & Brown, 2000). Nevertheless, while face specific viewing abilities may be available very early in life, studies of preschool and school-aged children suggest that face processing undergoes rapid and dramatic changes particularly over the first decade of life. The question under debate is whether performance differences reflect different degrees of maturation in the substrate of face perception, or just differences in general cognitive development, but no or minor developmental differences in genuine perceptual mechanisms (for a review see, Crookes & McKone, 2009).

Experimental studies favoring the hypothesis of face specific development aimed at showing that progress in face processing with age is accompanied by a increase in the capabilities of holistic viewing, which first emerges within the age range between 6 and 10 years, and develops until the adolescence (e.g., Carey, Diamond, & Woods, 1980; Freire & Lee, 2001; Mondloch, Dobson, Parsons, & Mauer, 2004; Mondloch et al., 2002; Mondloch, Geldart, Maurer, & Le Grand, 2003; Schwarzer, 2002). The "encoding switch hypothesis" was firstly proposed by Carey and Diamond (1977) who demonstrated that young children (age of 6) are less impaired by inversion when recognizing "old" faces than older children (8–10 years old) and adults. Similarly, in the study by Mondloch and her colleagues a same/different task was used to test the sensitivity of 6-, 8-, and 10-year-old children and adults to changes in second-order feature relations by varying the position of eyes and mouth in upright and inverted faces (Mondloch et al., 2002). Their results demonstrate an increase in the size of the inversion effect with age, which is larger for older than for younger children, and reaches the highest magnitude in adult subjects. At the same time there were no striking differences in the results obtained for children and adults for detecting featural changes in faces. Based on the data of this and related studies the authors propose that there are early developing skills of feature based face viewing, but slow development of adult expertise in exploiting spatial relations among features (Mondloch et al., 2004, 2002, 2003). Results obtained in a categorization task by Schwarzer (2000, 2002) further corroborated the encoding switch hypothesis by showing that 2- to 5-year-old and 7 year-old children process faces by taking single facial attributes into account, whereas 10-year-old children and adults process faces holistically by adopting a face specific mode of processing.

There are, however, contrary results indicating early presence of holistic processing under certain conditions already in infancy (e.g., Turati, Sangrigoli, Ruel, & de Schonen, 2004; Schwarzer, Zauner, & Jovanovic, 2007). Studies on preschool and school children provide further evidence supporting early maturity of holistic face processing by using standard experimental paradigms (e.g, composite face effect, inversion effect; whole-part effect) (Carey & Diamond, 1994; Crookes & McKone, 2009; de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007; Pellicano & Rhodes, 2003; Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998). Carey and Diamond (1994) tested 6- to 10-year-old children and adults in a composite face task, letting them identify personally familiar or experimentally familiarized faces. By taking the performance difference in aligned and misaligned condition as a measure of holistic processing the authors found no differences in the magnitude of holistic effects across age (see also Mondloch et al., 2007, for similar results). In a recent study the composite effect was compared for faces and frontal images of cars in 3- to 5-year-old children and adults (Macchi Cassia, Picozzi, Kuefner, Bricolo, & Turati, 2009). Subjects indicated target halves of faces and cars in aligned and misaligned composite probe stimuli. Results showed that a composite effect was present in 3 year-old children for faces, but not for cars, suggesting that face selective holistic processing matures early (see also de Heering et al., 2007). Better recognition of the facial parts when presented in face context than in isolation (whole-part paradigm) was demonstrated in two studies with preschool children (Pellicano & Rhodes, 2003; Tanaka et al., 1998). In the whole-part paradigm children learned sets of unfamiliar faces and were then required to recognize target facial features (eyes, mouth, nose) in a forced-choice task, with features either presented in full face context, or individually. Better recognition of target features in the context of whole upright faces was demonstrated already for children of age 4. Inverted face recognition was similar in whole and part test conditions, verifying the dichotomy of holistic and featural face vision modes, as mediated by orientation (Pellicano & Rhodes, 2003).

The results of these behavioral studies indicate that holistic mechanisms involved in face processing are thought to be fully developed in early childhood, i.e., within the first 5 years, maybe even earlier. However, this is concluded from experimental tasks where face processing was tested under conditions without substantial speed stress. Earlier studies (Bachmann, 1991; Sergent, 1986) showed that the microgenetic evolvement of the facial percept is most important for understanding mechanisms of holistic vision. According to these early approaches the facial percept evolves through an accumulating process that builds face representations by first extracting a low resolution image, and then progressively refines it with finer details, particularly of internal facial features. At any moment in time the facial representation is thought to stay fully integrated (holistic), but at different resolution levels. Recent studies on the microgenesis of face perception were able to show that, for adults, holistic face representations evolve fast, and are available starting with the first 50 ms of processing (Richler, Mack, Gauthier, & Palmeri, 2009). In a subsequent