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Configural face perception in childhood and adolescence: An individual differences approach

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ABSTRACT

Cognitive experimental and neuroscientific research in adults indicates that an important property of face perception is its specificity and reliance on configural processing. In addition, individual differences in face perception between adults cannot be entirely explained through general cognitive functioning and object cognition. Although recent years have witnessed growing interest in the development of face perception through childhood and adolescence, as yet, little is known about individual differences in configural face perception in this period of life, and whether these differences are face-specific. Here, we addressed these questions in a large sample (N = 338) drawn continuously from age six to 21. We applied a face composite task and a spatial manipulation task including stimulus inversion. Immediate and delayed face memory were assessed as covariates of configural face perception. Content specificity in configural face perception was tested by analogous tasks with houses as stimuli. In addition, we measured working memory and fluid intelligence. Our results show that there are large individual differences in configural face perception across the entire age range from six to 21 years. Supporting theories of early maturation, configural face perception was almost adult-like already at age six. Individual differences in configural face perception were related with immediate and delayed face memory and fluid intelligence across the whole age range. In sum, we provide novel evidence on large individual differences in configural face and object perception already in middle childhood, complementing findings from aging studies and providing new perspectives for further research.

1. Introduction

Perceiving and remembering faces are essential abilities for mastering social life. The present article is concerned with face perception and its variation across individuals in childhood, adolescence, and young adulthood. In contrast to most objects, faces are usually perceived as configurations of features (Maurer, Le Grand, & Mondloch, 2002). Within configural face perception the following aspects have been distinguished: (1) sensitivity to first-order relations, that is, perceiving a stimulus configuration as a face because two horizontally aligned features (eyes) are arranged symmetrically above one or two vertically aligned features (nose, mouth), (2) holistic processing, that is, binding face features into a gestalt, and (3) sensitivity to second-order relations, that is, perceiving relative distances between the face features.

Although it is widely accepted that already newborns (Di Giorgio, Leo, Pascalis, & Simion, 2012; Hole & Bourne, 2010; Johnson, Dziurawiec, Ellis, & Morton, 1991; Maurer et al., 2002; Mondloch et al., 1999; Turati, Simion, Milani, & Umilta, 2002) and even fetuses (Reid et al., 2017) are able to distinguish faces from non-face objects, previous studies on developmental trajectories of configural face perception arrived at inconsistent conclusions. It is still controversial, whether different aspects of configural face perception are adult-like already in the early childhood or need longer time for maturation (Crookes & McKone, 2009; McKone & Boyer, 2006 vs. Fuhrmann et al., 2016; Gur et al., 2012; Maurer et al., 2002; Meinhardt-Injac, Persike, & Meinhardt, 2014a; Meinhardt-Injac, Persike, & Meinhardt, 2014b). Possible reasons for these inconsistencies may be the use of only single tasks and different experimental designs, arbitrarily grouping age instead of treating it as continuous variable (e.g., Hildebrandt, Lüdtke, Robitzsch, Sommer, & Wilhelm, 2016; MacCallum, Zhang, Preacher, & Rucker, 2002), and neglecting individual differences within and across age cohorts.

In the present study, we addressed – to our knowledge for the first time – how configural face perception varies across individuals considering a broad age range from middle childhood until young

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adulthood. Importantly, the present approach allows us to investigate age effect on individual differences in face perception. Especially, we were interested, at which age the performance in configural face perception tasks and effect size of configural manipulations become adult-like. We used tasks that are believed to measure holistic face perception (composite face task) and perception of second-order relations among features of faces. In addition, we applied tests of short-term and delayed face recognition memory, fluid intelligence and working memory in order to test, whether higher order cognitive abilities can explain abilities of configural face perception. Furthermore, content-specificity was assessed with tasks analogous to the face perception tasks, but using houses as stimuli. These questions were statistically addressed by means of generalized linear mixed effects modeling (GLMM).

1.1. Configural face perception

From the earliest moments of life, individuals are able to distinguish faces from other objects. This ability is associated with the perception of first-order relations, that is, the meaningful view of two eyes above the nose and mouth. When adults encounter face-like first-order relations of features, they tend to process the stimulus as a gestalt or "holistically" (Maurer et al., 2002). Several tasks have been proposed for measuring holistic face perception, for example, the part-whole paradigm (Tanaka & Farah, 1993) and the composite paradigm (Hole, 1994; Young, Hellawell, & Hay, 1987). A further aspect of configural face perception, is the ability to perceive the relative distances between features (e.g., between the eyes, eyes and nose, nose and mouth), that is, the second-order relations. Tasks for measuring the sensitivity to second-order relations require comparing faces that differ in the relative spacing of their internal features (Barton, Keenan, & Bass, 2001; Freire & Lee, 2001; Freire, Lee, & Symons, 2000; Le Grand, Mondloch, Maurer, & Brent, 2001; Leder & Bruce, 1998; Leder, Candrian, Huber, & Bruce, 2001) or recognizing blurred faces (Costen, Parker, & Craw, 1994; Sergent, 1986). All three aspects of configural face processing are known to more easily occur when faces are presented in upright rather than in upside down position (face inversion effect; Yin, 1969). Therefore, the inversion paradigm is considered to be sensitive to all three aspects of configural face perception. Cognitive experimental and neuroscientific research indicates that configural perception is usually much less involved in the processing of non-face objects, such as houses (Maurer et al., 2002; Rossion, 2013; Tanaka & Gordon, 2011). This is also supported by psychometric research in young adults (e.g., Wilhelm et al., 2010) and across the adult lifespan (e.g., Hildebrandt, Wilhelm, Herzmann, & Sommer, 2013).

1.2. Developmental trajectories of configural face perception

Although it is widely accepted that already in early periods of life children are able to distinguish faces from non-face objects (Di Giorgio et al., 2012; Hole & Bourne, 2010; Johnson et al., 1991; Maurer et al., 2002; Mondloch et al., 1999; Turati et al., 2002), the developmental trajectory of configural face processing towards adulthood is controversially discussed (Crookes & McKone, 2009; McKone & Boyer, 2006 vs. Fuhrmann et al., 2016; Gur et al., 2012; Maurer et al., 2002, Meinhardt-Injac et al., 2014a; Meinhardt-Injac et al., 2014b).

Within the framework of the encoding-switch hypothesis, Carey and Diamond suggested that a feature-based strategy dominates face perception during childhood, which switches towards configural encoding during adolescence (Carey & Diamond, 1977; Carey, Diamond, & Woods, 1980; Diamond & Carey, 1977). The proponents of this hypothesis explain the late maturation of configural face perception by gains of social experience and the motivation of adolescents to communicate with others as compared with children. However, early studies of face perception development were criticized for using pictures of adult faces, which may put children at a disadvantage because they lack experience with adult faces (Anastasi & Rhodes, 2005; Flin, 1985; Hills, 2012; Hills & Lewis, 2011). As discussed by Crookes and McKone (2009) and McKone, Crookes, Jeffery, and Dilks (2012), effect sizes across age groups are often calculated with respect to different baselines, neglecting that overall performance levels also change with age. Because accuracy in a baseline condition (e.g., the whole condition in the part-whole task) improves with age, restriction of range problems (floor effect) may occur in the youngest age group but not in the older groups where performance is generally not yet at ceiling and varies across persons. Based on older participants' relatively better general face perception abilities, investigators may erroneously infer late development of configural face processing (Carey et al., 1980; Carey & Diamond, 1977; Sangrigoli & de Schonen, 2004). To avoid such challenges, Crookes and McKone (2009) recommended adjusting the difficulty of the reference condition to the same level in all age groups. Alternatively, Mondloch, Le Grand, and Maurer (2002) and Mondloch, Pathman, Maurer, Le Grand, and de Schonen (2007) avoided ceiling or floor effects in all age groups and demonstrated similar effect sizes for configural effects in both, composite and inversion paradigms, for six-year olds and adults. The findings of Mondloch et al. (2002, 2007) were supported by de Heering, Houthuys, and Rossion (2007) and Macchi-Cassia, Picozzi, Kuefner, Bricolo, and Turati (2009), reporting mature configural face processing already with three to four years.

A further problem in investigating the development of configural face perception is the lack of agreement on the appropriate measurement paradigm. The most frequently used measurement of holistic face processing is the composite face task (Hole, 1994; Young et al., 1987). In this task, the top and bottom halves of different faces are combined into a new face, which tends to perceptually merge into a new "whole" face if the two halves are aligned with each other. Participants decide whether the top (or bottom) halves of two composite faces are the same or different. When the face halves of the composite faces are aligned, it is more difficult to render the identity decision as compared with a non-aligned condition. This performance difference is termed composite face effect, which uncovers the problem to perceive the parts (halves) of a face independently from each other.

Although, > 60 studies demonstrate the composite effect in the classic paradigm, there are still controversies about the appropriate versions of this task (Richler & Gauthier, 2014; Rossion, 2013). It is debated whether the classical design (Rossion, 2013) or a modified, the so-called "complete design" (Richler & Gauthier, 2014) should be used for measuring whole face perception (both versions of the design are illustrated in Fig. A1). Richler and Gauthier (2014) proposed to vary both face halves (which is not done in the classic design), and thus in their complete design, one can distinguish congruent and incongruent trials. The difference between trials is that in congruent trials, both parts are same or both are different, and in incongruent trials one part is same and the other is different, causing a perceptual conflict. Furthermore, Richler and Gauthier (2014) suggested to omit the misaligned condition in order to increase reliability and power. Thus, the holistic face perception strategy is operationalized as a congruency effect – performance is more accurate in congruent trials. Richler and Gauthier (2014) criticized the classical design because it leads to response distortions. However, their modified design has been challenged by researchers supporting more conservative measures of holistic face processing. Thus, it is contested whether the complete design measures a specific holistic face perception strategy or response conflict (Rossion, 2013). Furthermore, the complete design has been advised against for studies with children, because the perceptual conflict may lead to high task difficulty and requires highly focused attention (Rossion, 2013).

Using the classical design, several studies showed adult-like abilities to perceive faces holistically already in early childhood (de Heering et al., 2007; Macchi-Cassia et al., 2009; Mondloch et al., 2002; Mondloch et al., 2007). However, there is no agreement between developmental trajectories acquired with both designs and there are no developmental studies using the complete design of Richler and Gauthier (2014).