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From development to aging: Holistic face perception in children, younger and older adults

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ABSTRACT

Few published reports examine the development of holistic face processing across the lifespan such that face-specific processes are adequately differentiated from general developmental effects. To address this gap in the literature, we used the complete design of the composite paradigm (Richler & Gauthier, 2014) with faces and non-face control objects (watches) to investigate holistic processing in children (8–10 years), young adults (20–32 years) and older adults (65–78 years). Several modifications to past research designs were introduced to improve the ability to draw conclusions about the development of holistic processing in terms of face-specificity, response bias, and age-related differences in attention. Attentional focus (narrow vs. wide focus at study) influenced the magnitude of the composite effect without eliminating holistic face processing in all age groups. Young adults showed large composite effects for faces, but none for watches. In contrast, older adults and children showed composite effects for both faces and watches, although the effects for faces were larger. Our findings suggest that holistic processing, as measured by the composite effect, might be moderated by less efficient attentional control in children and older adults. The study also underscores the importance of including comparable complex objects when investigating face processing across the lifespan.

1. Introduction

Humans display a striking proficiency for recognizing faces. As such, how these abilities develop across the lifespan has been the subject of considerable attention in the literature over the past several decades. Face perception abilities appear to improve gradually during childhood reaching adult-like levels of performance by late adolescence (reviewed by McKone, Crookes, Jeffery, & Dilks, 2012). Some have suggested that gradual maturation in face perception can be explained by the parallel development of general perceptual mechanisms (Robbins, Shergill, Maurer, & Lewis, 2011; Wakui et al., 2013; Zhu et al., 2010). In contrast, other researchers have reported that face perception abilities in children are poorly correlated with visual and memory abilities for non-face stimuli (Wilmer et al., 2010). At the other end of the lifespan, a decline in face recognition becomes notable between 60 and 80 years of age (reviewed by Boutet, Taler, & Collin, 2015). This decline appears to be only partially related to general age-related impairments in cognition, and is characterized by high false alarms rates to unfamiliar faces.

Differences in face perception ability at different ages might be attributable to changes in unique cognitive strategies that faces elicit. Despite lack of a definitive consensus, it is generally agreed that face perception relies not only on the analysis of individual features but also on the relations between these features (for reviews see Maurer, Le Grand, & Mondloch, 2002; Richler, Palmeri, & Gauthier, 2012). Although a variety of terminologies and paradigms have been used to elucidate the nature of relational processing, we focus herein on holistic processing as measured by the composite effect (for a review see Richler & Gauthier, 2014). Composite stimuli are created by combining the top-half of one face with the bottom-half of a second face. When they are aligned, the two half faces are processed holistically such that when participants are asked to match or recognize the top half, they have difficulty ignoring the irrelevant bottom half (and vice-versa). However, when top and bottom halves are misaligned, that is when each image is shifted separately to the right and left, the interference produced by the irrelevant bottom half is substantially reduced (Hole, 1994; Rossion & Boremanse, 2008). Because the task-irrelevant part (i.e., the bottom half) interferes with matching

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of the task-relevant part (i.e., the top half), holistic processing measured by the composite effect is interpreted as a failure of selective attention to face parts (see review by Richler et al., 2012; Richler & Gauthier, 2014; but see also Rossion, 2013). Research using the composite paradigm has revealed that the composite effect for faces can be similarly observed for non-face objects after extensive training (Gauthier & Bukach, 2007; Gauthier, Curran, Curby, & Collins, 2003). In novices, non-face objects typically yield modest or no composite effects (Farah, Wilson, Drain, & Tanaka, 1998; Gauthier, Curran, Curby, & Collins, 2003; Meinhardt, Meinhardt-Injac, & Persike, 2014; Richler, Bukach, & Gauthier, 2009; Richler, Mack, Gauthier, & Palmeri, 2011; but see Curby, Goldstein, & Blacker, 2013; Zhao, Bülthoff, & Bülthoff, 2016 in the Discussion).

Studies that have used the composite effect to investigate the development of holistic processing have reported adult-like composite effects for young children as of 4–6 years of age (de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007). Cassia, Picozzi, Kuefner, Bricolo and Turati, (2009) reported that children as young as 3 1/2 years of age displayed statistically significant composite effects for faces but not non-face stimuli, suggesting that the effect is face-specific in this age group. Studies comparing older adults to younger adults have yielded inconsistent results. Some have provided evidence that the composite effect is present in older adults (Konar, Bennett, & Sekuler, 2013; Wiese, Kachel & Schweinberger, 2013; Meinhardt-Injac, Persike, & Meinhardt, 2014), while others failed to find significant composite effects in older adults (Boutet & Faubert, 2006; Hildebrandt, Sommer, Herzmann, & Wilhelm, 2010), though a trend in the direction of a composite effect was found in Boutet and Faubert (2006). Methodologies employed to test the composite effect vary substantially across studies, which may explain inconsistencies in reported findings.

The goal of the present study was to investigate the development of holistic face processing across the lifespan using the so-called complete design of the composite paradigm (see Fig. 1). In the complete design, the composite effect is measured in terms of a congruency effect, namely a difference in performance between congruent and incongruent trials. In congruent trials, the response to the target part matches the same/different status of the irrelevant part (i.e., both parts are the same, or both parts are different). In incongruent trials, when the relevant part is the same, the irrelevant is different (and vice-versa). Holistic processing is considered present when discriminability is better in congruent than incongruent trials. Most of the developmental studies have employed the partial design of the composite task (i.e., Cassia et al., 2008; de Heering et al., 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007; Hildebrandt, Sommer, Herzmann, & Wilhelm, 2010; Konar et al., 2013; Wiese, Kachel, & Schweinberger, 2013), which provides a less valid measure of holistic processing than the complete design (see Richler & Gauthier, 2014 for detailed discussion).

In addition to using the complete composite paradigm, we included other methodological elements to address limitations of previous research. First, we included both face and non-face (i.e., watch) stimuli to examine whether age-differences, if any, are face-specific. Unfortunately, very few studies investigating holistic processing in different age groups have included this control condition. Inclusion of a non-face object category is paramount to demonstrating that the processes being investigated are unique to faces. Only one study that tested children (Cassia et al., 2009) used cars as control objects and these researchers failed to find a composite effect. To the best of our knowledge, the composite effect has only been investigated with faces in older adults. In the present study, we employed watches as non-face control objects because they closely resemble faces in their structure, but do not elicit face-like processing in young adults (see Daniel & Bentin, 2013; Meinhardt-Injac, 2013; Meinhardt-Injac, Persike, & Berti, 2013). If a congruency effect were found for watches, it would suggest that the composite effect is not a pure measure of face-specific processing, implying that the failure of selective attention to parts may also have roots in mechanisms other than those shaped by expertise over the lifespan.

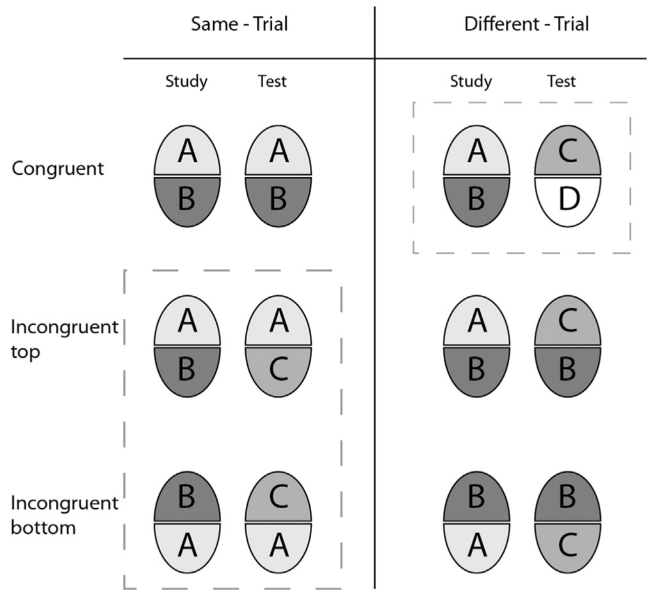

Fig. 1. Overview of the trial types used in the complete design. Stimulus half identity is marked by a letter. In congruent "same" trials, both the relevant top and bottom half of the study and test faces are the same. In congruent "different" trials, both the top and bottom halves of the study and test faces are different. The middle row illustrates incongruent trials where the top half is the target and the bottom row illustrates incongruent trials where the bottom half is the target. In incongruent "same" trials, only the relevant half of the study and test faces is the same. In incongruent "different" trials, only the relevant halves of the study and test faces are different. Conditions of the partial design are indicated by grey dashed boxes.

Second, we added a manipulation of attention to the paradigm to examine if differences in the deployment of attention might explain some of the inconsistent results reported in the literature. Even though holistic processing of faces appears to be automatic in young adults (Boutet, Gentes-Hawn, & Chaudhuri, 2002; but see Palermo & Rhodes, 2002 for opposite findings), there is evidence that the strength of the composite effect is influenced by learned attention to diagnostic parts (Chua, Richler & Gauthier, 2014, 2015). There is also evidence that cueing global versus local processing modulates congruency effects (Gao, Flevaris, Robertson, & Bentin, 2011). Consistent with this finding, Meinhardt et al. (2014) showed that introducing an attentional cue in the complete paradigm influences the magnitude of the composite effect. In a narrow attentional focus condition, a cue appears at the study phase directing participant's attention to the face half that is relevant for the subsequent discrimination task. In a wide attentional focus condition, the cue appears after the presentation of the study face to encourage attention to the whole face during study. Results of this manipulation indicate that congruency effects are weaker when participants' attention is directed to the relevant half already during the study phase. Considering that attentional control is impaired in older adults (e.g., Georgiou-Karistianis et al., 2006; Greenwood, Parasuraman, & Haxby, 1993; Lincourt, Folk, & Hoyer, 1997) and not fully developed in children (Booth et al., 2003; Tipper, Bourque, Anderson, & Brehaut, 1989), we included the same attentional manipulation as in Meinhardt et al. (2014) in our study in an attempt to examine the influence of attentional cueing on the composite effect at different ages.