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The development of holistic face processing: An evaluation with the complete design of the composite task

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ABSTRACT

The composite paradigm is widely used to quantify *holistic processing* (HP) of faces: participants perform a sequential *same-different* task on one half (e.g., top) of a test-face relative to the corresponding half of a study-face. There is, however, debate regarding the appropriate design in this task. In the *partial* design, the irrelevant halves (e.g., bottom) of test- and study-faces are always different; an alignment effect indexes HP. In the *complete* design, besides alignment, *congruency* between the irrelevant and critical halves of the test-face is manipulated regarding the same/different response status of the study-face. The HP indexed in the complete design does not confound congruency and alignment and has good construct and convergent validities. De Heering, Houthuys, & Rossion (2007) argued that HP is mature as early as 4-year-olds but employed the partial design. Here we revisit this claim, testing four groups of 4- to 9/10 year-old children and two groups of adults. We found evidence of HP only from 6-year-olds on when considering the complete design, whereas significant alignment effects were found in the index adopted in the partial design already in 4-year-olds but which we demonstrate that reflects other factors besides HP, including response bias associated with congruency.

1. Introduction

Face recognition is a crucial aspect of human social interaction. One hallmark of face processing is that faces are processed holistically (Farah, Wilson, Drain, & Tanaka, 1998; Maurer, Le Grand, & Mondloch, 2002; Young, Hellawell, & Hay, 1987), with little involvement of part-based decomposition. Instead, there is strong integration among face parts. All faces consist of the same kind of features (eyes, nose and mouth), the same gross configural information (eyes above nose, nose above mouth), and different individuals have similar facial features (e.g., eye colour). Yet, most adults are able to differentiate and identify thousands of (individual) faces (Diamond & Carey, 1986). This implies that information about specific features of a face does not seem to be reliable to identify a face at the individual level. Holistic processing is considered crucial to differentiate visual similar objects, like faces, by using subtle differences in the configuration or relations between different visual features.

The *composite effect* is one of the most compelling demonstrations of holistic processing of faces. It refers to the observation that recognition of a critical part of a face (e.g., top half) is influenced by the irrelevant half (e.g., bottom), even though participants are explicitly asked to selectively attend to the critical half only. The rationale is that the two halves of a face are "glued" together into a whole, making difficult to selectively attend to one part, while ignoring the other.

The composite effect is usually assessed in a *same-different* classification task (e.g., Richler, Mack, Gauthier, & Palmeri, 2009): in each trial, two faces are sequentially presented (a first, *study* face, followed after a brief delay, by a *test* face) and participants are asked to judge whether the target-half (e.g., top) of the test face is the same as or different from the corresponding half of the study face, while ignoring the irrelevant part (e.g., bottom). Holistic processing is inferred from an inability to ignore the irrelevant face half. This is a failure of selective attention (cf. Harrison, Gauthier, Hayward, & Richler, 2015): the irrelevant part affects performance on the critical part because the face (the composite constituted by the top and bottom halves) is processed as a whole (but see Rossion, 2013).

Two versions of the composite same-different classification task have been used with different indexes computed to estimate holistic processing (Gauthier & Bukach, 2007; Ross & Gauthier, 2015). In the *partial design*, the irrelevant half of the face is always different, while the critical, target-half can be either the same or different. Holistic processing is operationalized as an *alignment* effect considering only the *same*-response trials: worse performance when the two halves of the face are *aligned* than when *misaligned* through a lateral shift (e.g.,

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Goffaux & Rossion, 2006; Hole, 1994; Young et al., 1987). However, given that the irrelevant part of the test and of the study faces is always different, there is a confound between response bias and *congruency* between the same/different response status of the critical half and the irrelevant half: *same*-response trials are *incongruent* trials because the irrelevant part of the study and test faces is different but the critical part is the same; *different*-response trials are *congruent* trials as both the irrelevant and the critical parts of the study and test faces are different. Therefore, the alignment effect derived from the partial design includes not only an index of holistic processing but also of response bias, without a way of disentangling them (for a clear demonstration see, Richler & Gauthier, 2014; Cheung, Richler, Palmeri, & Gauthier, 2008; Richler, Cheung, & Gauthier, 2011a, 2011b; Richler, Mack, Palmeri, & Gauthier, 2011).

Recent work has questioned the results derived from the partial design and suggests that "the partial measure of holistic processing should be abandoned" (p. 1287; Richler & Gauthier, 2014), considering at least three reasons. First, as aforementioned, the partial design is susceptible to a response bias confounded in the index of holistic processing (Cheung et al., 2008; Richler, Cheung, & Gauthier, 2011a, 2011b; Richler, Mack, et al., 2011). For example, this was directly demonstrated by manipulating participants' expectation regarding the proportion of *same*- and *different*-response trials. Merely deceiving participants about this proportion predicts the magnitude of the alignment effect (that is, the putative holistic-processing index in the partial design; e.g., Harrison et al., 2015; Richler, Cheung, & Gauthier, 2011b). Furthermore, the partial design does not correlate with other measures of holistic processing, including those derived from other tasks as the part-whole task (DeGutis, Wilmer, Mercado, & Cohan, 2013; Wang, Li, Fang, Tian, & Liu, 2012). Critically, the index computed with the partial design and the one with the complete design have produced qualitatively different results on a number of issues (cf. Horry, Cheong, Brewer, Horry, & Brewer, 2015), including the role of low spatial frequencies in face perception (Cheung et al., 2008, vs. Goffaux & Rossion, 2006), the influence of local and global priming on face perception (Gao, Flevaris, Robertson, & Bentin, 2011, vs. Weston & Perfect, 2005), and the holistic processing of own-race vs. other-race faces (e.g., Harrison et al., 2015; Horry et al., 2015, vs. Michel, Caldara, & Rossion, 2006; Michel, Corneille, & Rossion, 2007). Altogether, the susceptibility to response biases, and the poor convergent validity of results based on this design question the results that were obtained only with the partial design.

The *complete* design circumvents these limitations by orthogonally manipulating alignment and congruency (Gauthier & Bukach, 2007). Both *same*- and *different*- response trials include congruent and incongruent trials, and holistic processing is signaled by a significant interaction between alignment and congruency across response-type: stronger congruency effect (better performance in congruent than incongruent trials) in the aligned than in the misaligned condition. In this way, congruency and response-type are no longer confounded. Noteworthy, from the participants' view the task is exactly the same in both designs, but, crucially, the index of holistic processing derived from the complete design is much less prone to response bias, and is associated with indexes of holistic processing obtained in other tasks as the part-whole task (DeGutis et al., 2013; Richler, Cheung, & Gauthier, 2011a; for a meta-analysis see, Richler & Gauthier, 2014).

This methodological discussion is especially important regarding the development of holistic face processing, given that two opposing theories have been on the table.

In a classic theoretical stance, Carey and Diamond (1977) proposed an *encoding switch hypothesis* in which children, at least until 6 years of age, encode upright faces according to their constituent features (e.g., eyes, nose, mouth), and then, around the age of 10, begin to process faces holistically. This hypothesis thus presupposes a face-specific perceptual development, with face processing maturing fully only later in development. Carey and Diamond (1994) (cf. also e.g., Crookes & Robbins, 2014) argued that, although there may be no qualitative change across childhood in the way faces are processed, there is quantitative development in the strength of, or reliance on, face-specific processing mechanisms.

In contrast, the *general cognitive development theory* proposes that face processing mechanisms are fully quantitatively mature in early childhood (Crookes & McKone, 2009; McKone, Crookes, Jeffery, & Dilks, 2012). All development found in performance in (laboratory) tasks thereafter reflects improvements in general cognitive mechanisms such as concentration, sustained visual attention, and explicit memory ability (Bunge & Wright, 2007).

The developmental evidence available thus far seems to be compatible with the latter proposal. Indeed, Carey and Diamond (1994) tested 7- and 10-year-old children and adults and found evidence for a composite effect which magnitude was independent of age. Note, however, that these results regarded familiar faces, either of classmates (Experiment 1) or to which children were familiarized within the laboratory prior to testing (Experiment 2). Mondloch, Pathman, Maurer, Le Grand, and de Schonen (2007) extended these results to 6-year-olds in an experiment with unfamiliar faces. Most important, the composite face effect (i.e., the alignment effect) for 6-year-olds was of a similar size as the effect obtained for adults tested with the same stimuli (Le Grand, Mondloch, Maurer, & Brent, 2004). Critically, De Heering, Houthuys, and Rossion (2007) tested 6-year-olds and 4/5-year-olds and in Experiment 1 found evidence of a composite effect but only at the age of six which was equivalent to the effect of adults. De Heering et al. (2007) considered the possibility of a response bias in younger children, because in the misaligned condition, the study face was always aligned but the test face was misaligned. Thus, children might have based their decisions on the format of the stimuli rather than on their identity. In Experiment 2, where both study and test composite faces were misaligned, a significant effect of alignment was also found in 4- and 5-year-old children.

Macchi Cassia, Picozzi, Kuefner, Bricolo, and Turati (2009) adopted a two-alternative forced-choice version of the composite task on which the target was always only the top half of the face followed by the presentation of two simultaneous probes, both either aligned or misaligned, which were whole faces that differed one from the other in both the top and bottom halves. Macchi Cassia et al. (2009) found some evidence of holistic processing at 3 1/2 years, signaled by an alignment effect: children showed a decrement of performance for aligned compared to misaligned stimuli. Besides the differences in paradigm, in this study, holistic processing was not involved in the initial encoding of the target stimulus which was a face top-half presented in isolation.

From the reviewed literature it thus seems that sensitivity to holistic facial information could be already present at 4 years of age and would not undergo significant developmental change throughout childhood. However, not only de Heering et al. (2007; Experiment 1) noted that 4-year-olds were particularly prone to a response bias, but all these studies adopted the partial design, and hence, suffer from its methodological limitations. It is thus necessary to revisit claims about the development of holistic processing available thus far (Harrison et al., 2015; Richler & Gauthier, 2014).

Our hypothesis in the present work is that previous studies using the partial design may have mistaken response bias for holistic coding in children. It, therefore, remains possible that, very young children, before the age of six, do not use holistic processing for faces or that the strength of/or reliance on holistic processing may indeed increase with age. To the best of our knowledge no study has hitherto examined the preschool group that is critical to test the two developmental proposals.

Nonetheless, two studies have adopted the composite task with the complete design in older children. In a study about holistic processing in autism, Gauthier, Klaiman, and Schultz (2009) tested a control group of 12-year-olds, who showed stronger congruency effects in the aligned than in the misaligned condition, that is, the significant interaction between congruency and alignment that signals holistic processing. Meinhardt-Injac, Boutet, Persike, Meinhardt, and Imhof (2017) extended these results by examining the congruency effect in 8-years-olds