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Using regression to measure holistic face processing reveals a strong link with face recognition ability

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ABSTRACT

Although holistic processing is thought to underlie normal face recognition ability, widely discrepant reports have recently emerged about this link in an individual differences context. Progress in this domain may have been impeded by the widespread use of subtraction scores, which lack validity due to their contamination with control condition variance. Regressing, rather than subtracting, a control condition from a condition of interest corrects this validity problem by statistically removing all control condition variance, thereby producing a specific measure that is uncorrelated with the control measure. Using 43 participants, we measured the relationships amongst the Cambridge Face Memory Test (CFMT) and two holistic processing measures, the composite task (CT) and the part-whole task (PW). For the holistic processing measures (CT and PW), we contrasted the results for regressing vs. subtracting the control conditions (parts for PW; misaligned congruency effect for CT) from the conditions of interest (wholes for PW; aligned congruency effect for CT). The regression-based holistic processing measures correlated with each other and with CFMT, supporting the idea of a unitary holistic processing mechanism that is involved in skilled face recognition. Subtraction scores yielded weaker correlations, especially for the PW. Together, the regression-based holistic processing measures predicted more than twice the amount of variance in CFMT ($R^2 = .21$) than their respective subtraction measures ($R^2 = .10$). We conclude that holistic processing is robustly linked to skilled face recognition. In addition to confirming this theoretically significant link, these results provide a case in point for the inappropriateness of subtraction scores when requiring a specific individual differences measure that removes the variance of a control task.

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1. Introduction

Holistic face processing has popularly been defined as the simultaneous integration of the multiple features and components of a face into a single perceptual representation (Rossion, 2008). Alternatively, others have conceived of holistic face processing as an obligatory attentional strategy, in which parts are represented independently but are not treated as such during perceptual decision-making (e.g., Richler, Tanaka, Brown, & Gauthier, 2008). Classic demonstrations of holistic face processing include the following phenomena, in which faces show consistently larger effects than objects: (a) face recognition is disrupted when inverting the picture-plane (face inversion effect, Yin, 1969); (b) immediate memory for a face part is much more accurate when that part is presented in the

Abbreviations: CFMT, Cambridge Face Memory Test; CT, Composite task; PW, Part-whole task.

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whole face than when it is presented alone (part-whole task, Tanaka & Farah, 1993); and (c) aligning two half faces of different individuals decreases performance for tasks that require perception of either half independently (composite task, Young, Hellawell, & Hay, 1987). More recently, Van Belle and colleagues (2010) discovered that when a mask covers participants' fixation area, participants show a marked impairment in discriminating inverted faces but are not impaired at upright faces, indicating that participants integrate other information around the masked portion in the upright faces. These works provide rich converging evidence for the existence of holistic face processing.

In addition to the specialized ability to perceptually integrate faces into a coherent whole, neurotypical individuals also have excellent short-term and long-term face memory abilities. For example, visual short-term memory for faces is significantly better than for objects (Curby & Gauthier, 2007). Long-term recognition of faces from memory is extremely accurate and fast, especially for well-known faces (Ramon, Caharel, & Rossion, 2011; Tanaka, Curran, Porterfield, & Collins, 2006), and is robust to perceptual degradation (Liu, Seetzen, Burton, & Chaudhuri, 2003).

It is commonly assumed that face-specific holistic processing abilities underlie our impressive ability to recognize faces. Though several findings are consistent with this possibility, the assumption has yet to receive strong empirical support. First, studies suggest that both holistic face processing and face recognition improve throughout infancy (e.g., Cashon & Cohen, 2003, though both may reach adult levels by age 5, Crookes & McKone, 2009). Such parallel improvements over development, however, are not uncommon even for functionally independent abilities. Second, studies of prosopagnosics, individuals with severe face recognition deficits, have shown that they also have significant deficits in holistic processing of face identity (Busigny, Joubert, Felician, Ceccaldi, & Rossion, 2010; Ramon et al., 2011; DeGutis et al., submitted for publication). Yet while these neuropsychological studies provide a powerful means of dissociating abilities (e.g., face and object processing), their capacity to *associate* impaired abilities is more limited (Caramazza, 1984; though see individual differences approach in DeGutis et al., submitted for publication). Third, reports suggest that the other-race effect, the recognition advantage for own-race compared to other-race faces, co-occurs with an own-race advantage in holistic processing as well as an own-race advantage in processing configural face information (Hancock & Rhodes, 2008; Sporer, 2001). Again, however, these findings could exist in parallel, and are only weak evidence for a functional linkage. Moreover, researchers have largely failed to find significant correlations between the size of an individual's own-race recognition advantage and the size of their own-race holistic processing advantage (e.g., Michel, Rossion, Han, Chung, & Caldara, 2006; though see Rhodes, Brake, Taylor, & Tan, 1989). Such a lack of correlation provides evidence *against* the hypothesis of a functional linkage between holistic processing and the other-race effect in face recognition. Taken together, these previous studies neither strongly support nor strongly falsify the notion that holistic processing plays a role in skilled face recognition.

Three recent studies have examined individual differences in holistic processing and face recognition. A robust individual differences-based correlation between face recognition and measures that isolate holistic processing would provide strong evidence for the presence of a specific functional linkage. However, the results of these three studies differ widely, and it is therefore difficult to draw clear conclusions from them. These studies report nearly the full range of possible non-negative relationships between holistic processing and face memory: zero ($R^2 = 0.003$; Konar, Bennett, & Sekuler, 2010a), non-zero but quite small ($R^2 = 0.02$; Wang, Li, Fang, Tian, & Liu, 2012), and rather sizable ($R^2 = 0.16$; Richler, Cheung, & Gauthier, 2011a). Additionally, these studies have either failed to establish significant associations between multiple measures of holistic processing (Konar, Bennett, & Sekular, 2010b; Wang et al., 2012) or have found a holistic processing/face recognition link only using one holistic processing measure (Richler et al., 2011a), calling into question whether different holistic processing tasks are measuring similar aspects of a unitary holistic construct rather than certain task-specific effects.

Konar and colleagues (2010a, b), the first to gather such data, reported that individual differences in their composite task (CT) did not significantly correlate with performance on a face identification task. In contrast, Richler and colleagues (2011a) demonstrated a sizable positive relationship between face recognition ability and the complete design of the CT, which reduces confounding response bias effects, ostensibly providing a better measure of holistic processing. While this article made a strong case that Konar and colleagues' failure to find a correlation may have resulted from confounding factors in the partial design of the CT, it left open the possibility that this holistic/face recognition link is due to task-specific aspects of the CT rather than holistic processing, per se. Wang and colleagues (2012) most recently added to this debate by showing that face recognition performance, when subtracting object recognition performance, was significantly but quite modestly correlated with both CT (using a similar partial design as Konar et al., 2010a) and part-whole task (PW). Moreover, they demonstrated that PW and CT did not correlate with each other. Wang and colleagues also added to this debate by reporting the reliabilities of their measures, indicating that the relationship between holistic processing and face recognition may be substantially attenuated by the lack of reliability of the measures used.

In sum, while individual differences-based analyses can provide a strong test for a functional linkage (Wilmer, 2008), the results reported to date have either failed to show construct validity for holistic processing, have demonstrated only small holistic processing/face recognition effect sizes, or have not provided converging evidence from multiple measures of holistic processing. Here, we clarify this debate with an improved analytic approach. The above studies all calculated measures of holistic processing by numerically subtracting the control condition (parts trials in PW and misaligned trials or misaligned congruency effect in CT) from the condition of interest (whole trials in