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Comparing the role of selective and divided attention in the composite face effect: Insights from Attention Operating Characteristic (AOC) plots and cross-contingency correlations

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ABSTRACT

Composite faces combine the top half of one face with the bottom half of another to create a compelling illusion of a new face. Evidence for holistic processing with composite faces comes primarily from a matching procedure in a selective attention task. In the present study, a dual-task approach has been employed to study whether composite faces reflect genuine holistic (i.e., fusion of parts) or non-holistic processing strategies (i.e., switching, resource sharing). This has been accomplished by applying the Attention Operation Characteristic methodology (AOC, Sperling & Melchner, 1978a, 1978b) and cross-contingency correlations (Bonnel & Prinzmetal, 1998) to composite faces. Overall, the results converged on the following conclusions: (a) observers can voluntarily allocate differential amounts of attention to the top and bottom parts in both spatially aligned and misaligned composite faces, (b) the interaction between composite face halves is due to attentional limitations, not due to switching or fusion strategies, and (c) the processing of aligned and misaligned composite faces is quantitatively and qualitatively similar. Taken together, these results challenge the holistic interpretation of the composite face illusion.

1. Introduction

Composite faces are created by aligning the top and bottom face halves from two well-known people (Young, Hellawell, & Hay, 1987). These stimuli are now famous for the compelling perceptual illusion of a novel face they elicit in their perceivers. The illusion is gone when the faces are inverted or spatially misaligned (Rossion, 2013). The composite face phenomenon is arguably one of the most powerful pieces of evidence in favor of holistic face processing. According to the holistic approach, faces are processed and perceived as unitary wholes rather than parts or features (Farah, Wilson, Drain, & Tanaka, 1998; Maurer, Le Grand, & Mondloch, 2002). In the laboratory, the composite face illusion is gauged via the slower and more error prone responses to the top half of aligned composite faces relative to a condition in which the two halves are misaligned. This composite face effect (i.e., CFE) has also been demonstrated with unfamiliar faces (Curby, Goldstein, & Blacker, 2013; Fitousi, 2013, 2015; Fitousi, Wenger, der Heide, & Bittner, 2010; Hole, 1994; Michel, Rossion, Han, Chung, & Caldara, 2006; Weston & Perfect, 2005).

A popular explanation of the composite face effect postulates that the composite face half is not perceived independently of the other half, such that parts are grouped together into a unified holistic representation (cf. Richler & Gauthier, 2014; Rossion, 2013). However, the internal representations that govern the alleged dependency between the two constituent halves in the CFE are not well understood. In order to gain novel insights on the mechanisms that allow holistic processing with composite faces (and faces in general) a series of converging operations (Garner, Hake, & Eriksen, 1956) should be developed and applied to composite faces. These operations may confer validation support to the notion of holistic face processing. Using such operations, the present study has adduced evidence that challenges the traditional holistic interpretation of the composite face effect, proposing instead an alternative non-holistic mechanism.

2. The present study

The present study has sought to examine the processing mechanisms that govern composite faces from the view point of selective attention (Hole, 1994) and divided attention tasks (Fitousi, 2013, 2015; Richler, Gauthier, Wenger, & Palmeri, 2008). These two types of attention confront the participant with two

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diametrically opposed demands. In selective attention tasks, observers are asked to *dissociate* information from two sources/facial parts, whereas in divided attention tasks or dual-tasks (Pashler, 1994) observers are asked to *associate* information from the two sources/facial parts (Algom, Eidels, Hawkins, Jefferson, & Townsend, 2015; Allport, 1971; Melara & Algom, 2003; Shaw, 1982).

The majority of composite face studies typically employ selective attention tasks in which participants report on the top half of the face and ignore the bottom half (but see Fitousi, 2013, 2015; Richler et al., 2008). However, when testing for facial holism, various reasons motivate the use of divided attention tasks as surrogates to the routine selective attention tasks. In his seminal review of dual-task interference, Pashler (1994) argued that: "There is also an important scientific reason to try to understand dual-task performance limitations: Overloading a system is often one of the best ways to figure out what the parts of the system are and how these parts function together." (p. 220). Pashler's proposal can readily justify the application of divided attention tasks to the study of composite faces. But, there are other reasons for doing so. First, note that the knowledge that researchers can derive from selective attention tasks has been confined to the top part. Often, the role of the bottom part is simply ignored (see Rossion, 2013, p. 83, for a discussion of this point). Second, divide attention tasks are of higher ecological validity than selective attention tasks. In their everyday encounters with faces rarely are people encouraged to exclude their perception to the top half of the face. A natural and more pervasive strategy is that of dividing attention across facial parts (Yarbus, 1967). Third, under selective attention instructions, researchers cannot really monitor the level of attention allocated to the irrelevant (bottom) part. Townsend and Wenger (2014) argued persuasively that divided attention tasks allow researchers to glean information on the observers' state of knowledge with respect to all parts of the face, and thus enable researchers to construct rigorous tests of perceptual independence (Ashby & Townsend, 1986; Fitousi, 2013, 2015; Garner & Morton, 1969; Richler et al., 2008).

Another reason for employing divide attention tasks is that an exclusive reliance on the selective attention version of the CFE is susceptible to circularity. On the one hand, holistic processing of faces serves to explain the CFE, but, on the other hand, the evidence comes mainly from the same CFE that faces are processed holistically. As a result, the CFE cannot remain the sole arbiter of facial holism. What is needed is a series of converging operations that are capable of measuring the same psychological construct (i.e., facial holism) via different measurement procedures (Fitousi, 2013, 2014, 2015; Garner et al., 1956; Richler, Palmeri, & Gauthier, 2012). Divided attention tasks can serve as good candidates for such converging operations. In combination with the routine selective attention tasks, divided attention tasks may offer a double-pronged attack on the notion of holistic processing.

The present work has employed the well-known methodology of Attention Operating Characteristic (AOC, Sperling & Dosher, 1986; Sperling & Melchner, 1978a, 1978b) to study how information from the constituent composite face halves is processed. The methodology draws on both selective and divided attention tasks and can thus provide a set of converging operations on the independence of dimensions/features. As such, it can speak directly to the issue of whether composite faces halves are dependent or independent in processing, and thus elucidate the level of holism in the perception of the entire face (for a similar approach see also Fitousi, 2013; Richler et al., 2008; Wenger & Ingvalson, 2002, 2003).

To be able to relate the measures of the AOC methodology to the traditional CFE in the current study, the AOC paradigm has been combined with a composite face "sequential matching paradigm" (Hole, 1994). A standard experimental trial in the sequential matching paradigm consists of a sequence of: a study face, masking patterns, and a test face (see Fig. 1). Observers are asked to respond to the test face by indicating whether the top half matches (i.e., "same" or "different") to the study face. The composite face effect is computed as a difference in performance between congruent trials (i.e., status of top and bottom composite halves match) and incongruent trials (i.e., status of top and bottom parts mismatch). This congruency effect is either reduced or completely abolished when the face halves are spatially misaligned (Richler & Gauthier, 2014).[1]

Testing in the present study consisted of two types of blocks: (a) selective attention blocks, in which participants were attending exclusively to the top part and reported only on the status of this half. The task performed in those blocks was identical to the traditional sequential matching task (Richler & Gauthier, 2014), and thus served as a baseline condition, (b) divided attention blocks, in which participants were attending to *both* top and bottom halves (Fitousi, 2013; Richler et al., 2008; Thomas, 2001a, 2001b). In these blocks participants responded to both face halves. A crucial step administrated in the divided attention blocks consisted of an attention manipulation, in which observers were instructed to allocate differential amounts of attention to top and bottom halves (i.e., 100–0%, 90–10%, 50–50% and 10–90%). This attention manipulation was held in separate blocks, establishing the basis for the construction of the Attention Operating Characteristic (AOC) measures and the cross-contingency correlations.

3. AOC methodology

The AOC paradigm (Bonnel & Prinzmetal, 1998; Braun & Julesz, 1998; Braun & Sagi, 1991; Joseph, Chun, & Nakayama, 1997; Lee, Itti, Koch, & Braun, 1999; Lee, Koch, & Braun, 1999; Morrone, Denti, & Spinelli, 2002, 2004; Reddy, Reddy, & Koch, 2006; Reddy, Wilken, & Koch, 2004; Rodriguez, Valdes-Sosa, & Freiwald, 2002; Saenz, Buracas, & Boynton, 2003; Sperling & Melchner, 1978a, 1978b; VanRullen, Reddy, & Koch, 2004) allows researchers to simultaneously measure performance on two attributes/features under variable levels of attentional allocations, and thus to probe the level of independence (or its lack thereof) between the two attributes.

The logic behind the AOC is straightforward (cf. Sperling & Melchner, 1978a, 1978b). When two visual objects are presented simultaneously and briefly, observers may be able to report on either of the features; however, participants might find it difficult to report the features of both (Duncan, 1984). The difficulty that observers experience in this dual-task situation may reveal the limitation of visual attention in perceiving the two features together (Bonnel & Miller, 1994). This would lead to a cost or a trade-off in accuracy between the two objects/face parts. That is, observers might be able to improve the accuracy of their report for one object at the expense of the other (Norman & Bobrow, 1975; Sperling & Dosher, 1986). This trade-off in accuracy is known as the "Attention-Operating Characteristic" (AOC, Sperling & Melchner, 1978a, 1978b). Plotting the performance measure for the first attribute (e.g., top composite half) against the other attribute (e.g., bottom composite half) will yield an AOC plot.

The AOC plots are augmented by an allied tool – the cross contingency correlations (Bonnel & Prinzmetal, 1998; Sperling & Melchner, 1978a). This tool has proved useful in testing for two types of hypotheses that are stated at the at the within-trial level. The first hypothesis addresses the independence of the two

[1] Rossion (2013) has proposed an alternative measure of the composite face effect that is based on difference in performance between aligned and misaligned conditions only for the "same" trials.