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Sensitivity to spatial frequency and orientation content is not specific to face perception

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ABSTRACT

Prior work using a matching task between images that were complementary in spatial frequency and orientation information suggested that the representation of faces, but not objects, retains low-level spatial frequency (SF) information [Biederman, I., & Kalocsai, P. (1997). Neurocomputational bases of object and face recognition. *Philosophical Transactions of the Royal Society of London, Series B Biological Sciences*, 352, 1203–1219]. In two experiments, we reexamine the claim that face perception is uniquely sensitive to changes in SF. In contrast to prior work, we used a design allowing the computation of sensitivity and response criterion for each category, and in one experiment, equalized low-level image properties across object categories. In both experiments, we find that observers are sensitive to SF and orientation changes for upright and inverted faces and non-face objects. Differential response biases across categories contributed to a larger sensitivity for faces, but even sensitivity showed a larger effect for faces, especially when faces were upright and in a front-facing view. However, when objects were inverted, or upright but shown in a three-quarter view, the matching of objects and faces was equally sensitive to SF changes. Accordingly, face perception does not appear to be uniquely affected by changes in spatial filter components.

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1. Introduction

Broadly speaking, two categories of information are thought to be more critical for face than object perception: information about the configural relations between parts and the specific spatial frequency (SF) information present in images. Generally, studies report quantitative differences between face and object perception on measures designed to index how observers rely on these sources of information. For instance, a disadvantage for processing upside-down faces (a face inversion effect, see Rossion and Gauthier (2002) for review) has been used as an indirect measure of sensitivity to configural relations. But inversion typically also affects the perception of objects, just less so than it affects face perception (Rossion & Gauthier, 2002). Such evidence may not be strong enough to support the claim that face perception relies on one or several processes that are not available to object perception (McKone, Kanwisher, & Duchaine, 2007). Typically, such claims are made on the basis of qualitative differences between faces and non-face objects. In this work, we revisit prior claims that face perception differs qualitatively from that of objects in terms of its sensitivity to SF information (Biederman & Kalocsai, 1997).

There could be a process unique to face perception even if behavioral measures generally find only a *quantitative* difference between faces and objects. This would be the case if face perception also relies to some degree on part-based processes that are shared with generic object processing. Ideally, however, some tasks could be designed to be sensitive only to the process hypothesized to be face-specific, so that a *qualitative* behavioral difference can be documented. One measure that was suggested to reveal such a qualitative difference is the alignment effect in the composite task (Robbins & McKone, 2003; Young, Hellawell, & Hay, 1987). In this task, participants are asked to selectively attend to one part of a face made of the top and bottom halves of different faces, with these two halves aligned or misaligned. When the parts are aligned, participants have difficulty ignoring the irrelevant part of the composite[1]. However, a recent study showed that observers trained to individuate objects from a novel category also demonstrated an alignment effect in a composite task (Wong, Palmeri, & Gauthier, in press). While some hallmarks of face processing can be obtained only in expert observers, other effects once thought to be unique to faces have been obtained with objects in novice

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[1] See Gauthier & Bukach (2007) and McKone & Robbins (2007) for a debate regarding different experimental designs to measure configural and holistic processing using composite stimuli.

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observers. This is the case with the whole-part advantage: the finding that face parts studied in the context of a whole face are better recognized than in isolation (Tanaka & Farah, 1993). While the effect was originally obtained for faces and not houses, later studies reported a significant, albeit smaller, whole-part advantage in novice viewers with dogs, cars, and novel objects called Greebles (e.g., Tanaka & Gauthier, 1997).

The present study is an investigation of one of the rare behavioral effects so far only observed for faces. We call this effect the "Complementation Effect" (CE), and it indexes the sensitivity of face perception to manipulations of spatial filter components. Although this has been relatively less studied than other effects, face perception is reported to be highly sensitive to SF filtering (Fiser, Subramaniam, & Biederman, 2001; Goffaux, Gauthier, & Rossion, 2002) and to other types of manipulations of image format, such as contrast reversal (Gaspar, Bennett, & Sekuler, 2008; Hayes, 1988; Subramaniam & Biederman, 1997) and the use of line drawings (e.g., Bruce, Hanna, Dench, Healey, & Burton, 1992). These manipulations have a more limited impact on object recognition (Biederman, 1987; Biederman & Ju, 1988; Liu, Collin, Rainville, & Chaudhuri, 2000; Nederhouser, Yue, Mangini, & Biederman, 2007), suggesting that face and object perception may rely on different mechanisms and/or representations. Specifically, Biederman and Kalocsai (1997) explored the SF sensitivity of face perception. Complementary images were created by dividing the SF-by-orientation space into an 8×8 matrix and filtering out every odd diagonal of cells to form one version of an image and every even diagonal of cells to form the second image. These two versions of the same image are complementary in the sense that they do not overlap in any specific combination of SF and orientation (see Fig. 1). As might be expected, participants demonstrated a CE for faces, whereby they were poorer verifying and matching complementary faces relative to identical faces in both a name verification priming task and a same–different sequential matching task. But, perhaps more surprisingly, no CE was observed in either paradigm for common objects or chairs. Because the naming task was inherently confounded by task demands and the level of categorization (i.e., objects were named at the basic-level while famous faces were named at the subordinate-level), we are focusing here on understanding the face-object discrepancy observed via the sequential matching paradigm. Biederman and Kalocsai argue that this difference arises because the visual system represents faces and objects in distinct ways. They propose that non-face objects are stored as qualitative constructions of volumetric structural units (geons) that can be recovered from images based on non-accidental properties found in an edge description of the object, devoid of the original SF image information (Biederman, 1987). In contrast, face representations are thought to preserve the specific information from V1-type cell outputs, accounting for why face perception is highly sensitive to SF–orientation manipulations.

Given that the CE was originally obtained for faces but not for non-face objects in novice observers (Biederman & Kalocsai, 1997), another study asked whether this effect may increase with perceptual expertise. Yue, Tjan, and Biederman (2006) trained participants with novel objects called blobs. All participants – those trained with blobs and those with no pre-testing exposure – showed robust CEs for faces and none for blobs. In addition, using fMRI these authors found that relative to an identical pair of images, a complementary pair of faces, but not blobs, reduced fMRI adaptation in the fusiform face area. The results of Biederman and Kalocsai (1997) and Yue et al. (2006) suggest that the CE is unique to faces. This is consistent with other work finding that the matching of objects such as chairs shows little sensitivity to manipulations of the overlap in SF content (Collin, Liu, Troje, McMullen, & Chaudhuri, 2004).

In the following experiments we revisit the question of whether the CE is unique to faces, guided by four main motivations. First, Biederman and Kalocsai (1997) and Yue et al. (2006) measured the CE by comparing accuracy in identical vs. complementary trials, when face or object identity was the same. The trials in which item identity (and thus the correct response) was different were pooled together, without being assigned to either condition (identical or complementary). Therefore, it is possible that observers applied different response criteria to face and non-face conditions tested in Biederman & Kalocsai and Yue et al.'s same–different matching tasks. Yue et al. reported errors collapsing over both same and different trials. While they reported no main effect for whether trials were same vs. different, it is nonetheless possible that an interaction with this factor approached significance and influenced the results.

Indeed, important differences in response biases between conditions, even when trials are not presented in different blocks, have been observed in other face processing studies and, when not accounted for, can lead to misleading conclusions (e.g., Cheung, Richler, Palmeri, & Gauthier, 2008; Wenger & Ingvalson, 2002). Therefore, to verify that the interaction between category and complementation is not due to differential response bias, we blocked trials by complementation condition so that two sets of different trials would be associated with identical vs. complementary

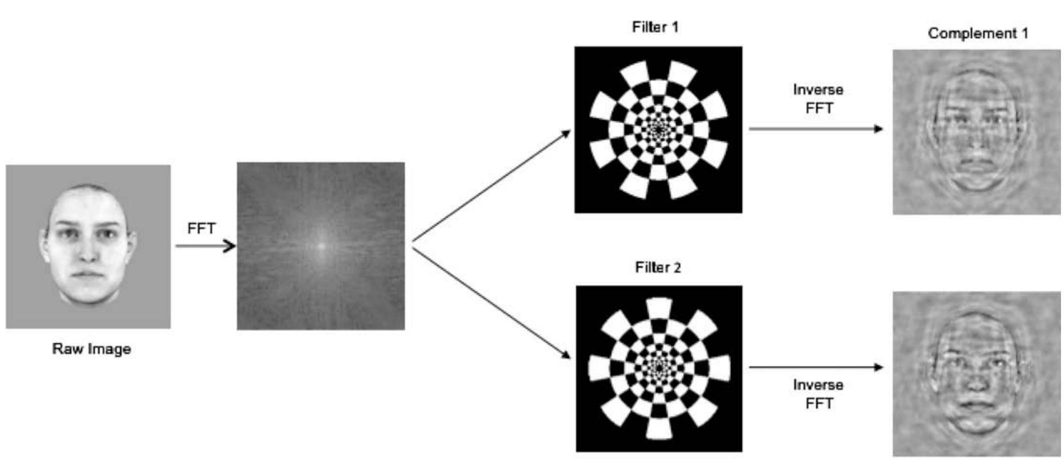

Fig. 1. Spatial frequency (SF) and orientation filtering. Two complementary images were created by filtering a single input image in the Fourier domain into an 8×8 radial matrix of SF–orientation information. Two separate filters were applied to preserve alternating combinations of the SF–orientation content of the original image. Thus, when returned to the spatial domain via inverse FFT, the complementary images share no overlapping combinations of SF and orientation information.