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Holistic processing as measured in the composite task does not always go with right hemisphere processing in face perception

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ABSTRACT

Holistic processing has long been considered as a property of right hemisphere processing. Nevertheless, a counterexample was recently found: Chinese character recognition expertise is associated with reduced holistic processing (as measured in the composite task) and increased right hemisphere lateralization (as indicated by a left-side bias in character perception), revealing that they may be separate processes. Through computational modeling, in which we implemented a theory of hemispheric asymmetry in perception that posits a low spatial frequency bias in the right hemisphere and a high spatial frequency bias in the left hemisphere, we showed that when the face recognition task relied purely on featural information, there was a negative correlation between holistic processing and right hemisphere lateralization. In contrast, when the task relied purely on configural information, there was a positive correlation between holistic processing and right hemisphere lateralization. In another simulation with real face images, which naturally embed both featural and configural changes, we observed no correlation between holistic processing and right hemisphere lateralization. This result was replicated behaviorally with human participants. Together, these results suggest that holistic processing (as measured in the composite task) and right hemisphere lateralization are separate processes that can be influenced differentially by task requirements.

1. Introduction

In the literature on face recognition, a mechanism thought to be central to face recognition is holistic processing. Holistic processing of faces commonly refers to the phenomenon of experiencing viewed faces as a whole instead of independent facial parts (e.g., [50]). In contrast, complex objects are thought to be represented through the assembling of primitive parts [2,36].

In the literature, holistic face processing has been conceptualized as effects in different tasks, with each focusing on a slightly different aspect of face recognition. For example, in a review on holistic face perception, Behrmann et al. (in press) [3] described three main accounts of holistic processing: the "all of a piece" holistic representational account, the interactive account, and the automatized attentional account (see also [42] for a list of additional accounts of holistic processing and their corresponding measurements). The "all of a piece" account assumes that perceived faces undergo no or minimal part decomposition and are represented as an undifferentiated whole [13]. The interactive account stipulates that features of faces (i.e., the facial parts) are automatically processed conjointly with second-order configural information (i.e., the distance between facial features). This integration of featural and configural information is rooted in our experience of perceiving dynamic or expressive faces, in which facial parts and second-order configuration simultaneously interact [3]. The automatized attentional account originates from studies using composite faces [24,52]. In these studies, participants commonly have to selectively attend to and match the top halves of two faces and to ignore the bottom halves. Participants demonstrate lower accuracy in matching two identical tops when the two bottoms are different compared with when they are the same. This suggests that participants fail to selectively engage attention to the tops, and integrate automatically the top and bottom halves [17]. This automaticity of failure of selective attention is limited to faces and other objects for which we have expertise [44].

For the holistic representational account, the part-whole paradigm is used [50]. After learning a face ("This is Bob."), participants perform two-alternative forced choice recognition memory tests. In the isolated part condition, participants see for example two noses and identify which one is Bob's. In the full-face condition, participants see two faces that differ only in the part (e.g., the nose) tested in the isolated face condition and identify which face is Bob's. In [50], participants showed better recognition

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in the full-face condition than in the isolated part condition, suggesting that a face representation is better retrieved from the whole face than from any of its parts. For the interactive account of holistic processing, Amishav and Kimchi [1] used Garner's speeded classification task [15] to test whether facial features are processed independently from their configurations, and vice versa. In a featural judgment task, participants discriminate faces using featural information while ignoring configural information kept either constant (the baseline condition) or varied (the filtering condition). In the configural judgment task, the manipulation between featural and configural information is reversed. Amishav and Kimchi found a "Garner interference": participants performed worse in the filtering condition than the baseline condition in both the featural and configural judgment tasks, indicating that features and configurations are processed conjointly. For the automatized attentional account of holistic processing, the common task for measuring holistic processing is the complete composite paradigm [17], inspired by the seminal composite tasks of Hole [24] and Young et al. [52]. In a simultaneous complete composite paradigm, participants are presented with two composite faces: each face is made of top and bottom halves of one face or two different faces. Participants are asked to attend only to the two top halves and judge whether they are identical or not. If face processing is holistic, participants will automatically attend to and process the bottom halves in addition to the top halves. In congruent trials, the irrelevant bottom halves lead to the same response as the top halves. In incongruent trials, the irrelevant bottom halves lead to a response conflicting with the response from the top halves. HP is characterized by the interference from the bottom halves while matching the top halves. It is measured by the performance difference between congruent trials and incongruent trials. A positive difference is indicative of holistic processing. Because the complete composite task taps into automatic attentional processes, the amount of holistic processing yielded by the complete composite task can be interestingly modulated by a prior task priming local or global attention by using for example Navon stimuli [16]. Using hierarchical letter stimuli, Gao et al. [16] found that global priming augments holistic processing, and that local priming did not affect holistic processing as compared with a non-priming baseline. Hence, holistic processing as measured by complete composite seems closely related to global processing. Similarly, part-based processing may be associated with local attention.

These three accounts of holistic processing are assessed with different tasks. They may conceptualize holistic processing differently, focusing on different aspects of how faces are represented and recognized. To have different tasks to measure holistic processing may seem problematic. Indeed, Richler et al. [43] raised the problem of multiple definitions and measurements of holistic processing, which may hinder the integration of research results. It is possible that different tasks tap into different mechanisms involved in holistic face processing (see, e.g., [43]); it is also possible that one account, if formalized into a computational model, can account for effects in all these tasks (see., e.g., [9]). Since the automatized attentional account of holistic processing, as assessed through the composite paradigm, has been commonly used in both behavioral and computational studies (e.g., [8,41]), here we focus on this account of holistic processing and assess holistic processing through the complete composite paradigm.

In addition to the holistic processing effect, face processing has been shown to involve right hemisphere lateralization. A seminal functional Magnetic Resonance Imaging (fMRI) study identified an area inside the fusiform gyrus (the *fusiform face area, FFA*) responding preferentially to faces, with larger activation in the right hemisphere than the left hemisphere [33]. Follow-up fMRI studies confirmed the dominance of the right hemisphere during face processing, and a more complex network of face-preferential areas has emerged [32,46]. Event related potential (ERP) data also show that faces elicit larger N170 amplitude than other types of objects, especially in the right hemisphere [47].

Consistent with these findings, behaviorally a left side bias effect has been consistently observed in face perception: a chimeric face made from two left half faces from the viewer's perspective is usually judged more similar to the original face than one made from two right half faces [5,20]. This left side bias effect has been argued to be the behavioral indicator of the right hemisphere lateralization in face processing [20]. Face stimuli can be replaced with other stimuli to test for the lateralization of these stimuli (e.g., [29]).

The holistic processing effect has been linked in fMRI studies to right hemisphere lateralization in face selective areas [22,48]. For example, Schiltz et al. [48] showed that when participants match two top identical halves of aligned composite faces presented sequentially, there is a release of adaptation of BOLD signal in the right FFA when the two task-irrelevant bottoms are different compared with when they are the same. This release of adaptation is absent for misaligned faces. This result indicates that populations of neurons in the right FFA involved in selective attention to a face part are influenced by changes in other face parts only when the face is aligned, i.e., presented as a whole.

Gauthier and Tarr [18] trained participants to become experts in the recognition of a novel object type, Greebles. By the end of the training, participants demonstrated an increase in holistic processing of Greebles. The holistic processing measured for Greebles behaviorally for five participants was positively correlated with the activity of the fMRI signal in the right middle fusiform area captured in a previous study from the same participants performing a Greeble recognition task. Gauthier and Tarr suggested that increased holistic processing is a marker of expertise and goes with right hemisphere lateralization in the FFA. This result, although limited to Greeble recognition, is consistent with the hemispheric asymmetry literature that posits a holistic/analytic preferential dichotomy between right hemisphere and left hemisphere processing [4], and suggests that holistic processing and right hemisphere lateralization effects go together.

Nevertheless, a counterexample was recently found: Chinese character recognition experts have reduced holistic processing and increased right hemisphere lateralization in processing Chinese characters compared with novices [29]. Put simply, Chinese characters are made of strokes fit in a squared shape. Featural information (i.e., the strokes) is critical to Chinese character recognition, but configural information (e.g., the spacing between the strokes) is not [19,37], in contrast to face recognition. A Chinese expert reader can recognize between 3000 and 4000 characters, a number of comparable magnitude to the number of faces adults can recognize [38]. Hsiao and Cottrell [29] adapted the complete composite task with Chinese character stimuli, and the chimeric face judgment task with chimeric mirror-symmetric Chinese characters (created in the same fashion as chimeric faces). Novices showed the congruency effect indicative of holistic processing of Chinese characters, but experts did not. Chinese experts engage in better selective attention on character parts compared with novices. In the chimeric Chinese character judgment task, only experts showed a preference for left-chimeric characters, and novices had no preference. This result suggests that experts engage the right hemisphere more than novices in processing Chinese characters. Hsiao and Cottrell [29] thus suggested that increased left side bias and reduced holistic processing are the markers of expertise in Chinese character recognition. In contrast to the previous results with faces and Greebles [18,48], the left side bias for Chinese characters is associated with reduced holistic processing instead of increased holistic processing. This suggests that holistic processing (as measured in the complete composite