Brief article

When is the right hemisphere holistic and when is it not? The case of Chinese character recognition

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ABSTRACT

Holistic processing (HP) has long been considered a characteristic of right hemisphere (RH) processing. Indeed, holistic face processing is typically associated with left visual field (LVF)/RH processing advantages. Nevertheless, expert Chinese character recognition involves reduced HP and increased RH lateralization, presenting a counterexample. Recent modeling research suggests that RH processing may be associated with an increase or decrease in HP, depending on whether spacing or component information was used respectively. Since expert Chinese character recognition involves increasing sensitivity to components while deemphasizing spacing information, RH processing in experts may be associated with weaker HP than novices. Consistent with this hypothesis, in a divided visual field paradigm, novices exhibited HP only in the LVF/RH, whereas experts showed no HP in either visual field. This result suggests that the RH may flexibly switch between part-based and holistic representations, consistent with recent fMRI findings. The RH's advantage in global/low spatial frequency processing is suggested to be relative to the task relevant frequency range. Thus, its use of holistic and part-based representations may depend on how attention is allocated for task relevant information. This study provides the first behavioral evidence showing how type of information used for processing modulates perceptual representations in the RH.

1. Introduction

Holistic processing (HP), a term that originates from the Gestalt view of visual perception, is commonly defined as the processing of sensory wholes that are qualitatively different to the sum of their individual parts (see Piepers & Robbins, 2012, for a review). HP has long been considered a property of right hemisphere (RH) processing (e.g., Bradshaw & Nettleton, 1981). Consistent with this view, in visual object processing, HP is frequently found to be associated with RH lateralization. For example, both RH lateralization and HP have been consistently reported in face recognition. The fusiform face area (FFA) is reported to have larger activation in the RH than the left hemisphere (LH) (Kanwisher, McDermott, & Chun, 1997). Holistic face processing is demonstrated consistently with different paradigms including the part-whole (Tanaka & Farah, 1993) and composite paradigms (Rossion, 2013). Ramon and Rossion (2012) further found that holistic face processing was observed when faces were presented in the left visual field (LVF)/RH but not in the right visual field (RVF)/LH. Also, right FFA responses to faces were found to be consistent with behavioral HP effects (Schiltz & Rossion, 2006). Similarly in object recognition, increase in HP was correlated with increased activation in the right

occipitotemporal regions (Gauthier & Tarr, 2002).

Nevertheless, some recent findings have challenged this claim. For instance, Hsiao and Cottrell (2009) found that expert Chinese readers showed reduced HP and increased left side bias (an indication of RH lateralization) in Chinese character perception as compared with novices, suggesting that HP and RH lateralization do not always go together (Tso, Au, & Hsiao, 2014). It was speculated that the difference between face/object recognition and Chinese character recognition may be in the importance of information about spacing among components: while small changes in spacing typically change the identity of faces/objects, it does not change the identity of Chinese characters. Consistent with this speculation, spacing information is shown to be important for face recognition (e.g., Farah, Wilson, Drain, & Tanaka, 1998), whereas sensitivity to components (radicals) at specific positions within a character facilitates Chinese character recognition (Ho, Ng, & Ng, 2003). Thus, the relationship between HP and RH lateralization may depend on whether spacing information is used during visual object processing.

To test this hypothesis, Hsiao and Galmar (2016) conducted a computational modeling study and showed that when a face recognition task relied purely on spacing information (i.e., all faces had the
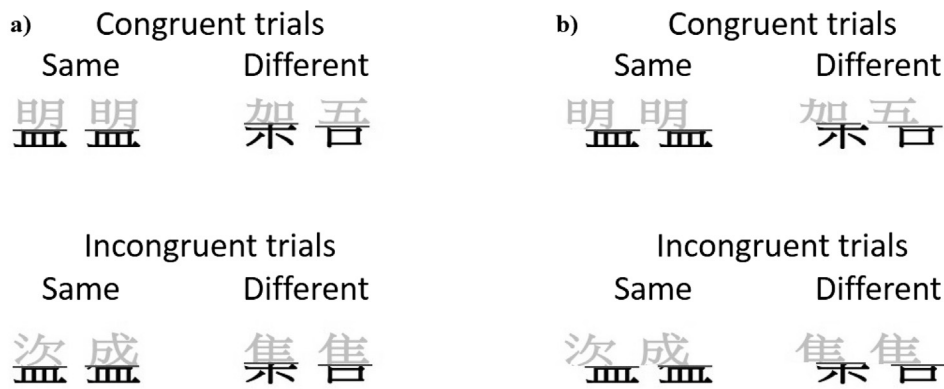
Fig. 1. Illustration of the stimulus pairs. The halves to be judged are shown in black for illustration purposes; this example illustrates attending to bottom trials. (a) Aligned trials. (b) Misaligned trials. In congruent trials, the attended and irrelevant halves elicit identical responses (i.e., both lead to "same" responses or both lead to "different" responses). In incongruent trials, the attended and irrelevant halves elicit conflicting responses (e.g., the attended halves lead to a "same" response while the irrelevant halves lead to a "different" response).

same features but differed in spacing among them), there was a positive correlation between HP and RH lateralization. In contrast, a negative correlation between HP and RH lateralization was found when the task relied purely on featural information (i.e., all faces had the same spacing among features but differed in the features). Similar results were found in an earlier modeling study, in which artificial symbols each consisting of three English letters forming a triangular configuration were used as the stimuli (Hsiao & Cheung, 2011). Thus, whether the RH engages HP may depend on the type of information being used for recognition. Consistent with this finding, a recent fMRI study showed that neural populations in the right FFA were capable of encoding both part-based (i.e., tuned to changes to one feature) and holistic (i.e., tuned conjointly to changes to two features) face representations (Harris & Aguirre, 2010).

Here we aim to test the hypothesis that whether the RH engages HP depends on the type of information being used during visual object processing using Chinese character stimuli through a divided visual field design. Although unilateral stimulation used in the divided visual field paradigm does not preclude information transfer via the corpus callosum, it has been shown to be an effective and efficient means of investigating functional hemispheric asymmetries behaviorally (Banich, 2003; Bourne, 2006). Ramon and Rossion (2012) used this paradigm to show that HP for faces was observed in the LVF/RH but not in the RVF/LH. In contrast to faces, Chinese characters offer a unique opportunity to test the use of spacing or featural information with the same stimuli: since exact spacing among components is not important for identifying Chinese characters, expert readers may be less sensitive to spacing information and more sensitive to component features than novices. Accordingly, experts' HP in the LVF/RH may be reduced as compared with novices. Thus, we predict that HP will be observed in the LVF/RH in novices but not in experts.

Note that in the literature, HP has been conceptualized through different paradigms, with each focusing on slightly different aspects of holistic perception (Behrmann, Richler, Avidan, Kimchi, & Wagemans, 2015). For example, the part-whole paradigm assesses the "all of a piece" account of HP, assuming holistic perception as an undifferentiated whole that involves minimal part decomposition. In contrast, the composite paradigm assesses the "automatized attentional" account, conceptualizing HP as failure of selective attention to parts (Gauthier & Bukach, 2007). Since the automatized attentional account has been more commonly used, especially for studies examining the relationship between HP and RH processing in visual object processing (e.g., Gauthier & Tarr, 2002; Hsiao & Galmar, 2016; Ramon & Rossion, 2012), here we focus our discussion on this account.

2. Experiment 1: Chinese character processing

2.1. Participants

Twenty-four expert Chinese readers (18 females, 6 males) and 24 non-Chinese readers (novices; 19 females, 5 males) were recruited at the University of Hong Kong.[1] All experts were native Chinese speakers/readers; they had passed public examinations in Chinese Language and obtained grade E or above. All novices reported no experience in learning Chinese. The two groups were matched in age (experts: $M = 19.33$, $SE = 0.437$; novices: $M = 20.63$, $SE = 0.567$; $t(46) = 1.804$, *n.s.*). All participants were right-handed according to the Edinburgh Handedness Inventory (i.e., above 0 in EHI score, $M = 0.853$, $SD = 0.198$; Oldfield, 1971), and had normal or corrected-to-normal vision.

2.2. Materials

We used the complete composite paradigm to assess HP (Gauthier & Bukach, 2007). The stimuli consisted of 192 pairs of Chinese characters. In each trial, participants were presented with a stimulus pair and were asked to judge whether the top (or bottom) halves of the two stimuli were the same or different. All characters had a top-bottom configuration that could be horizontally separated into two halves. The pairs were equally distributed into the four conditions illustrated in Fig. 1a, with each pair of attended halves appearing in one congruent and one incongruent trial. In congruent trials, the attended and irrelevant halves elicit identical responses, whereas in incongruent trials, they elicit conflicting responses. HP is indicated by the interference from irrelevant halves when matching the attended halves, and can be assessed as the performance difference between congruent and incongruent trials. Since this congruency effect due to HP should be reduced when the top and bottom halves of the stimuli are spatially misaligned to make perceptual grouping difficult (Fig. 1b), HP can also be measured as the interaction between congruency and alignment. Here we used this measure since it is shown to be particularly sensitive to expertise driven and perceptually focused HP (Richler, Cheung, & Gauthier, 2011; Rossion, 2013).[2]

A 3-pixel wide red line was added in the middle of each character to avoid ambiguity in defining the top and bottom halves. All characters were existing characters within a medium to high frequency range (Ho & Kwan, 2001). The frequency and number of strokes were matched between congruent trials and incongruent trials. Characters were displayed in Ming font, with 1.5° of visual angle in width (viewing distance: 60 cm). To avoid ceiling effects, the contrast level of the characters was adjusted using Adobe Photoshop CS6 (lightness adjusted to 90). For the misaligned conditions, the unattended half of each character was moved half character width to the right or left (Fig. 1b).

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[1] The sample size was determined based on previous and pilot studies

[2] An alternative paradigm contains only incongruent same and congruent different trials (partial composite paradigm; e.g., Ramon & Rossion, 2012), and HP is measured as the performance difference between the aligned and misaligned trials in incongruent trials. This paradigm has been shown to be susceptible to the influence of response bias (Gauthier & Bukach, 2007).