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Perceptual Expertise as a Shift from Strategic Interference to Automatic Holistic Processing

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Abstract

Holistic processing was initially characterized a unique hallmark of face perception (e.g., Young et al., 1987) and later argued a domain-general marker of perceptual expertise (e.g., Gauthier et al., 1998). More recently, evidence for holistic processing - measured by interference from task-irrelevant parts - was obtained in novices, raising questions for its usefulness as a test of expertise. Indeed, recent studies use the same task to make opposite claims: Hsiao & Cottrell (2009) found more interference in novices than experts for Chinese characters, while Wong, Palmeri & Gauthier (2009) found more interference in experts than novices with objects. Offering a resolution to this paradox, our work on the perception of musical notation (Wong & Gauthier, in press) suggests that expert and novice interference effects represent two ends of a continuum: interference is initially strategic and contextual, but becomes more automatic as holistic processing develops with the acquisition of perceptual expertise.

Holistic processing – the tendency to process separate features as a single unified whole – can help us discriminate between objects within a category. Holistic processing provides information about spatial relations that goes beyond the shape of individual parts or their coarse configuration. For example, holistic processing is useful for face recognition because faces share the same features (e.g., eyes, nose, mouth) in the same general arrangement (e.g., eyes above nose, nose above mouth). Indeed, holistic processing was initially argued to be a unique hallmark of face perception (Young et al., 1987; Farah et al., 1998). However, evidence for holistic processing is also observed for non-face objects of expertise in both real-world (Bukach et al., in press; Busey & Vanderwolk, 2005) and lab-trained (Gauthier et al., 1998; Wong et al., 2009) experts. The same task demands - individuation of highly similar objects – that makes holistic processing beneficial in face recognition promote holistic processing for other object categories (e.g., cars, fingerprints, novel objects)

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Recommended Reading

For details of the studies that test interference effects in novices and experts, see:

Hsiao, J.H., & Cottrell, G.W. (2009). Not all visual expertise is holistic, but it may be leftist: The case of Chinese character recognition. *Psychological Science, 20*, 455–463.

Wong, A.C.-N., Palmeri, T.J., & Gauthier, I. (2009). Conditions for face-like expertise with objects: Becoming a Ziggerin expert – but which type? *Psychological Science, 20*, 1108–1117.

For details of the studies reporting interference effects in novices that are modulated by context and strategy, see:

Richler, J.J., Bukach, C.M., & Gauthier, I. (2009). Context influences holistic processing of non-face objects in the composite task. *Attention, Perception & Psychophysics, 71*, 530–540.

Wong, Y.K., & Gauthier, I. (in press). Holistic processing of musical notation: Dissociating failures of selective attention in experts and novices. *Cognitive and Affective Behavioral Neuroscience.*

following extensive individuation experience. Such results have led to the proposal that holistic processing is not face-specific, but rather is a marker for expertise in domains where individuation is required (Diamond & Carey, 1986; Gauthier et al., 1998; Gauthier & Tarr, 2002; but see Robbins & McKone, 2007). In this context, rather than simply using holistic processing as an all-or-none hallmark of a special ability, it becomes interesting to ask what promotes the acquisition of this perceptual strategy and what its antecedents may be in novice perception.

One interesting consequence of holistic processing is that, while it is beneficial for identification and discrimination at the object level, it can be disadvantageous when attempting to selectively attend to a single part or feature. For example, when asked to judge whether a face half (e.g., top) is the same or different between two sequentially presented faces (composite task; Figure 1), the same-different status of the irrelevant, to-be-ignored half (e.g., bottom) interferes with performance – selective attention to the target half fails because faces are processed as wholes. Thus, interference due to an inability to selectively attend is indicative of holistic processing, and this is the operational definition we focus on in this article.

Certainly, failures of selective attention are not unique to the composite task, and they can occur at different levels of processing. For instance, in the classic Stroop paradigm, an automatic reading response interferes with a response to ink color, and interference can occur at either the level of response selection and execution or at a perceptual level (MacLeod, 1991). In contrast, failures of selective attention due to holistic processing, at least in the case of expert face perception, produce only perceptual interference (Richler, Cheung, Wong & Gauthier, 2009), consistent with the view that holistic processing reflects a perceptual tendency to process faces (or expert objects) as wholes. Even when perceptual interference contributes to Stroop effects, this is not attributed to parts being processed together in an obligatory manner. Therefore, while holistic processing can lead to perceptual interference due to an inability to selectively attend, not all failures of selective attention result from holistic processing.

In fact, a recent paper calls into question the validity of associating failures of selective attention in the composite task with perceptual expertise. In this study, individuals who did not read Chinese – novices – showed interference from task-irrelevant parts in the composite task, while expert readers of Chinese did not (Hsiao & Cottrell, 2009). This is surprising and inconsistent with an expertise account of holistic processing. While the absence of an interference effect in expert Chinese readers may be explained by recent work clarifying the conditions of expertise that promote holistic processing (Wong, Palmeri & Gauthier, 2009), this does not explain why interference would be observed in novices.

If failures of selective attention can arise in different tasks for different reasons, how can we distinguish interference that is indicative of holistic processing due to perceptual expertise (*expert interference*) from failures of selective attention that can sometimes be observed in novices (*novice interference*)? Our recent work sheds light on this issue. Because expertise results from the fine-tuning of strategies and representations that promote fast and efficient decisions, we propose that interference due to holistic processing is relatively automatic and stable across various task conditions. In contrast, novice interference is strategic, depending on specific task contexts and constraints.

TASK CONTEXT CAN INDUCE INTERFERENCE IN NOVICES

The idea that interference from task-irrelevant parts can be observed in novices in the composite task under certain task conditions was first suggested by Richler, Bukach & Gauthier (2009). In this study, participants completed the composite task with novel objects

(Greebles; see Figure 1). For one group, the study Greeble was presented in an aligned format, and for another group the study object was misaligned (e.g., the edge of the top part fell on the center of the bottom part, see Figure 1). Test format (aligned/misaligned) was manipulated for both groups. Because participants had no previous experience with these objects, an expertise account of holistic processing predicts that no interference should be observed. But surprisingly, the group of participants who studied Greebles in a misaligned format showed an interference effect.

Richler et al. (2009a) suggested that interference observed when the study item is misaligned may be a consequence of the strategic deployment of attention. When the study object is misaligned, attending to both halves requires a larger attentional window than when an aligned object is studied. If this larger attentional window carries over to the test stimulus, this puts the irrelevant object part within the scope of attention, causing interference. In a second experiment, this strategic attentional account was further tested by randomizing the study-aligned trials and study-misaligned trials, which encourages the use of a wider attentional window throughout the experiment. Consistent with this hypothesis, interference was obtained for novel objects in novices for both study-aligned and study-misaligned trials under randomization, suggesting that novice interference is strategy-based and depends on the specific context of the task.

Importantly, novice interference as observed in Richler et al. (2009a) differs in several ways from interference attributed to holistic processing in experts (see Figure 2). In novices, interference depends on object alignment at *study*, but not on the configuration of parts at test. In contrast, alignment at *test* influences the magnitude of expert interference (Richler et al. 2008; Wong et al., 2009), while alignment at study has no effect (Richler et al., 2008). Furthermore, novice interference can spread from one to all conditions when study alignment is randomized (Richler et al., 2009a), but expert interference is not modulated by such a contextual manipulation (Richler et al., 2008). These differences suggest that novice interference depends on strategic adjustments to the requirements of the task, while expert interference reveals an inability to “turn off” a holistic perceptual strategy.

MANIPULATING CONTEXT IN EXPERTS AND NOVICES

Richler et al. (2009a) suggested that novice interference depends on task factors that can influence the strategic deployment of attention. This was directly tested by Wong & Gauthier (in press) where both expert and novice music readers performed a composite task with short sequences of notes. In this version of the composite task, four-note sequences were presented visually and participants judged whether a cued target note in the second sequence was the same or different from the equivalent note in the first sequence (Figure 1). Critically, target position (central or peripheral in the sequence) and target distribution (mostly at center, mostly in periphery, or evenly distributed) were manipulated, such that focusing attentional resources on certain note positions would be an advantageous strategy. In particular, if novice interference effects are strategic in nature, they should be modulated by task demands that promote the use of different strategies, and interference should be largest when novices are asked to ignore notes in locations that are strategically prioritized. In contrast, in experts, more efficient holistic encoding acquired through hours of practice comes at a cost, which is that it cannot be turned off easily to follow instructions or to adopt an advantageous strategy given the current context. If expert interference reflects an automatic perceptual tendency, then interference should not be influenced by manipulations of target position or distribution.

In Experiment 1, the target appeared in a central position (2^{nd} or 3^{rd} note) on 75% of trials and in a peripheral position (1^{st} or 4^{th} note) on only 25% of trials. As predicted by a strategic account of novice interference, interference for novices was larger for peripheral trials than central trials. In other words, there was less interference for novices in the more frequently probed central location, consistent with a strategy of devoting more attention to more frequently probed locations; interference was larger when the target appeared in a less frequently probed location because the distractors were in the central, relatively more attended location. Critically, while interference was also observed for experts, in their case it was not modulated by target location.

These results were extended in Experiment 2, where three different target distributions were used (mostly central, mostly peripheral, or evenly distributed). This time, participants were explicitly informed of the target distribution before each block, encouraging all participants to deploy attentional strategies. But as in Experiment 1, while novice interference was influenced by whether the target was in an expected location, expert interference was unaffected by target likelihood, consistent with the notion that holistic processing is automatic and not cognitively penetrable.

Finally, Wong & Gauthier (in press) found that perceptual fluency for musical notation (how fast participants could encode music sequences) showed a U-shape relation with interference (see Figure 3). That is, in the range of performance occupied by people without any real experience reading music, interference decreased as perceptual fluency increased, but within the group of experts, an increase in perceptual fluency translated into stronger interference effects. This provides additional support for a strategic account of novice interference: The strategy of only attending to the more frequently probed locations was more beneficial for novices who processed music sequences more slowly; when participants encoded all the notes in the study sequence slowly, focusing attention on the more frequently probed location was the most effective way to perform the task. Ironically, these results suggest that interference in novices is caused by *higher* selective attention to part of the object, instead of a *failure* of selective attention as a result of holistic processing in experts (Richler et al., 2008).

IMPLICATIONS

Our recent findings resolve an interesting paradox: interference from task-irrelevant parts in the composite task is generally found to increase with perceptual expertise due to holistic processing (Gauthier & Tarr, 2002; Wong et al., 2009) but has also been observed in novices (Hsiao & Cottrell, 2009). Our recent work demonstrates that simply observing a failure of selective attention in the composite task is not sufficient evidence for holistic processing. Indeed, context-dependent interference effects in novices were shown to be quite different from the more automatic interference effects observed in experts, both in terms of their sensitivity to configural manipulations of parts (aligned/misaligned) at study or test (Richler et al., 2008 vs. Richler et al., 2009a), and their malleability under different task contexts that promote different attentional strategies (Wong & Gauthier, in press).

Distinguishing interference indicative of holistic processing from interference effects in novices is critical if we are to understand the mechanisms that are modified by practice, such as when strategically-induced interference is replaced by more automatic, holistic processing. In addition, this distinction can be useful in understanding how perception differs in disorders where expert skills are lost or, in some cases, never quite develop. For example, Gauthier et al. (2009) reported that adolescents with Autism processed faces holistically in the composite paradigm. At first glance, this finding is incompatible with the known face-processing deficits for this group. However, although interference was observed, it was unaffected by test face alignment. Given that study-misaligned and study-aligned trials were randomized, the pattern of results was more similar to the strategy-based interference observed in novices (Richler et al., 2009a) than what is typically observed for faces in experts (Richler et al., 2008; see Figure 2). Therefore, face perception in adolescents with Autism may be similar to the way in which typical participants approach a demanding part-matching task with material they are not familiar with. Indeed, Gauthier et al. (2009) concluded that despite demonstrating some failures of selective attention for faces in the composite task, individuals with Autism are not "face experts".

Expert and novice interference effects appear qualitatively different. Holistic processing in experts is relatively automatic, resulting in stable interference effects, while interference in novices is modulated by task constraints, task context and strategy. Instead of abandoning holistic processing as a characteristic of expertise altogether as recently advocated (Hsiao & Cottrell, 2009), studying the failures of selective attention in novices may provide a window into the antecedents of holistic processing in experts. Indeed, expert and novice interference effects may simply reflect two ends of a continuum: interference is initially strategic and contextual, but becomes more automatic with increased individuation experience and the development of expertise. Consistent with this view is the finding that holistic processing of faces can be lost in a graded fashion in acquired prosopagnosia, a face-recognition deficit attributed to brain damage (Bukach et al., 2006). In fact, this continuum could even play out in the variability of face recognition skills in the normal population (Duchaine & Nakayama, 2006). Holistic processing has been a cornerstone of research in face recognition, but until recently there was no evidence it predicted face recognition abilities (Konar et al., 2010). This link was recently demonstrated: individuals who process faces more holistically are better face recognizers (Richler, Cheung & Gauthier, submitted). The framework we have presented here leads to the prediction that interference in the best face recognizers would be stable across various conditions, while under some contextual manipulations, it is poor face recognizers that could show the most interference, as they would be more susceptible to strategic failures of selective attention.

Acknowledgments

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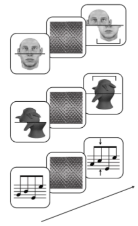

Figure 1.
Example of composite task trials with faces (top), Greebles (middle) and note sequences (bottom). On each trial, a study object is presented, followed by a mask, followed by a test object. Participants are instructed to judge whether the cued portion of the test image (object half indicated by a square bracket for faces and Greebles or note indicated by two arrows for note sequences) is the same or different from the same part of the study object. Note that participants do not know which half of the study object will be the target half until the test item is presented, so all parts of the study object must be attended. For faces and Greebles the study and test objects can be either aligned or misaligned.

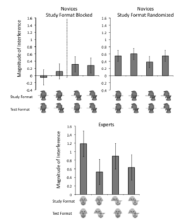

Figure 2.
Magnitude of interference for novices with novel objects (top row; data from Richler et al., 2009b) and for experts with faces (bottom; data from Richler et al., 2008) based on study format (aligned or misaligned) and test format (aligned or misaligned). For novices (with Greebles), interference is only observed for study-misaligned trials when study format is blocked, and for all trial types if study-misaligned and study-aligned trials are randomized. For experts (with faces), interference is larger when the test face is aligned vs. misaligned. For novices, test format does not influence the amount of interference, while in experts, study format has no effect.

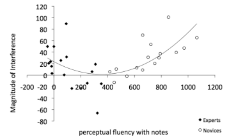

Figure 3.

Magnitude of interference as function of perceptual fluency with note sequences for experts and novices. Smaller values indicate greater perceptual fluency. For experts, individuals who process notes more fluently show larger interference effects. In contrast, novices who process notes more fluently show smaller interference effects.