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Brief article

# Expertise increases the functional overlap between face and object perception

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ABSTRACT

Recent studies indicate that expertise with objects can interfere with face processing. Although competition occurs between faces and objects of expertise, it remains unclear whether this reflects an expertise-specific bottleneck or the fact that objects of expertise grab attention and thereby consume more central resources. We investigated the perceptual costs of expertise by measuring visual thresholds for identifying targets embedded within RSVP sequences presented at varying temporal rates. Car experts and novices searched for face targets among face and car distractors, or watch targets among watch and car distractors. Remarkably, car experts were slower than novices at identifying faces among task-irrelevant cars, yet faster than novices at identifying watches among cars. This suggests that car expertise leads to greater functional overlap between cars and faces while reducing the functional overlap between cars and objects, a result incompatible with the notion of an encapsulated module for exclusive processing of faces.



## 1. Introduction

Much has been written about whether faces and objects recruit distinct perceptual systems. Expertise at individuating objects from a visually similar category is thought to recruit similar processing strategies as face perception (Busey & Vanderkolk, 2005; Diamond & Carey, 1986; Gauthier & Tarr, 1997). Although faces and objects of expertise can elicit similar neural responses (Gauthier, Skudlarski, Gore, & Anderson, 2000; Xu, 2005), such similarities cannot exclude a domain-specific, information-encapsulated face processing module. For example, faces and objects of expertise might be represented by neighboring but independent cortical regions. Recent studies have provided stronger evidence against modularity by showing that objects of expertise interfere with face processing (Gauthier, Curran, Curby, & Collins, 2003; Rossion, Collins, Goffaux, & Curran, 2007; Rossion, Kung, & Tarr, 2004). However, such interference could arise in dual-task situations because participants favor attending to objects of expertise over other stimuli. Even when objects of expertise are task-irrelevant, they could compete with concurrent face perception simply because they grab attention (Awh et al., 2004; Ro, Russell, & Lavie, 2001; Vuilleumier, 2000) and thus would be expected to interfere with concurrent processing of any other object, rather than faces specifically. Alternatively, Gauthier et al. (2003) proposed a more specific bottleneck rooted in the holistic processes typically engaged by faces but not other objects (Farah, Wilson, Drain, & Tanaka, 1998; Tanaka & Sengco, 1997). This hypothesis suggests that *objects of expertise should interfere with face processing but not with general object processing* – a prediction tested here for the first time.[1]

This study addressed whether competition occurs specifically between faces and objects of expertise, by having

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[1] Note that a follow-up study to the present experiment, extending the results to a spatial visual search task, was recently accepted for publication (McGugin, McKeeff, Tong, & Gauthier, in press).

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car experts and novices search for face targets of a particular identity among face and car distractors, or watch targets among watch and car distractors. We predicted that car experts would be selectively impaired at distinguishing faces in the presence of task-irrelevant cars, but as good as or better than novices at distinguishing other objects (e.g., watches) in the presence of car distractors. Items were shown at varying temporal rates using rapid serial visual presentation (RSVP) to determine presentation rate thresholds for target identification. Thus, we targeted perceptual processes that can be maintained at rapid presentation rates (McKeeff, Remus, & Tong, 2007; Potter & Levy, 1969). We reasoned that if perceptual thresholds were systematically affected by expertise for task-irrelevant items, then this would provide strong evidence of *perceptual competition* between faces and objects of expertise.

## 2. Method

### 2.1. Participants

Eleven car experts (mean age 25 years, 2 females) and eleven car novices (mean age 26 years, 3 females) participated, all right-handed with normal or corrected-to-normal visual acuity. The study was approved by the Vanderbilt University Institutional Review Board. All participants provided written informed consent.

### 2.2. Stimuli and design

Participants performed a two-alternative forced-choice discrimination task, which required discriminating which of two possible targets appeared within each RSVP sequence. Presentation rate was adjusted adaptively on each trial to estimate the threshold rate at which participants could discriminate the target identity at 82% accuracy, with faster temporal thresholds indicating superior discrimination performance. There were four conditions: face targets with face and car distractors (F/FC), face targets with face and watch distractors (F/FW), watch targets with watch and face distractors (W/WF) and watch targets with watch and car distractors (W/WC). It was important to include distractors from both the target category and competing category for this experimental design. The inclusion of distractors from the target category minimized the likelihood that participants could rely on low-level cues to detect the target item, while the inclusion of distractor items from the second category allowed us to assess the degree to which they interfered with processing of the items from the target category. Stimuli included grayscale images of 30 faces, 30 cars, and 30 watches ($15.5° \times 15.5°$ of visual angle). To avoid salient diagnostic features, we removed hair from faces and text from watches. Images were presented on a 21-in., CRT monitor (refresh rate, 75 Hz) with a Macintosh G3 computer using Matlab and Psychtoolbox.

Participants completed 30 practice trials for each of the four target-distractor conditions, followed by 16 experimental blocks (four of each condition) with 30 trials in each block. Block order was counterbalanced across subjects. Each block began with a pair of randomly selected face targets (or watch targets), which participants could study for as long as needed. Each trial began with a fixation cross for 4000 ms, followed by an RSVP sequence of 20 images alternating between the two distractor categories. Images were presented successively at the same central location, with no interstimulus interval. For each sequence, a randomization procedure was used to determine the sequence of distractor images to be shown, the serial position of the target (anywhere but the first or last positions) and which of the two targets would appear at that position. After each sequence, participants indicated which target appeared by pressing one of two keys. Within each block, the presentation rate started at 7.075 items/s, and was varied subsequently using an adaptive staircase procedure to converge at 82% discrimination accuracy (Watson & Pelli, 1983). Thresholds for each participant and condition were based on the average of estimates over the four blocks.

Car expertise was quantified using a sequential matching task in which participants matched car images at the level of model, regardless of year (Gauthier, Curby, Skudlarski, & Epstein, 2005; Gauthier et al., 2000; Rossion et al., 2004; Xu, 2005). The same task, involving bird images of different species, provided a baseline for motivation and general perceptual skill. Participants performed 112 trials in each task. Results yielded sensitivity ($d'$) scores for cars and for birds. A *Car Expertise index* was defined as the difference between car and bird performance (Car $d'$ – Bird $d'$) (Gauthier et al., 2000a; Gauthier et al., 2003). We were unable to collect any matching scores from three novices and bird matching scores from two car experts. Nonetheless, excluding these participants led to no reliable differences in the pattern of results.

## 3. Results

Our performance-based index of car expertise revealed superior performance by self-reported car experts ($\Delta d' = 1.98$) relative to novices ($\Delta d' = 0.19$; $F(1, 15) = 84.08$, $p < .0001$). Self-reported car experts performed better than novices when matching cars ($d' = 2.69$, $SD = 0.54$ and $d' = 0.95$, $SD = 0.61$ respectively), ($F(1, 17) = 43.10$, $p < .0001$), but comparably when matching birds ($d' = 0.77$, $SD = 0.43$ and $d' = 0.76$, $SD = 0.22$ respectively), ($F(1, 15) < 1$, n.s.). All self-reported car experts had a $\Delta d'$ greater than 1.4 whereas no novice performed better than 0.7.

In the main experiment, we determined the threshold presentation rate at which subjects could still accurately discriminate which of two face targets (or two watch targets) had appeared among the set of distractors for that experimental condition. Performance for the face and watch searches in the presence of various task-irrelevant distractors was quantified using mean presentation rate threshold (Fig. 1). Although our visual task differed in difficulty across experiment conditions (as evidence by variations in novice performance), of greater relevance was how expertise led to changes in performance relative to that of novices, our baseline comparison Group. While car experts and novices obtained similar thresholds when looking for

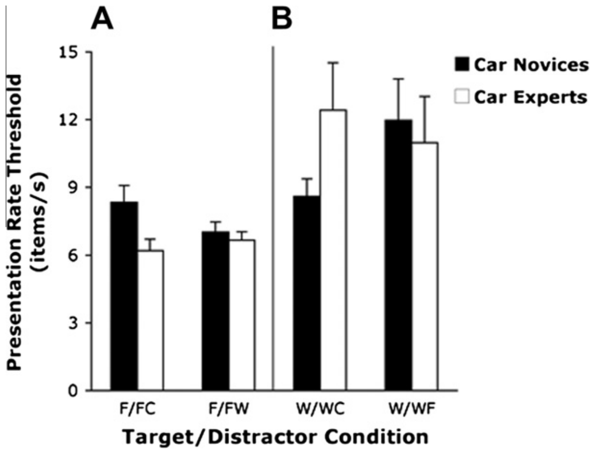


**Fig. 1.** Presentation rate thresholds for car novices and car experts who searched for (A) face targets among face and car distractors (F/FC), or face targets among face and watch distractors (F/FW), and (B) watch targets among watch and car distractors (W/WC), or watch targets among watch and face distractors (W/WF).

face targets among watches, car experts were relatively slower than novices when searching for faces among cars (Fig. 1A). This cannot be attributed to irrelevant cars grabbing the attention of car experts, because experts were faster than novices at identifying watch targets among irrelevant cars, while the two groups were comparable when searching for watches among irrelevant faces.

These observations were supported by statistical analyses. The mean threshold for each participant and condition was submitted to a three-way ANOVA with Target (face vs. watch) and Distractor Category (car vs. watch/face) as within-subject factors, and Group (expert vs. novice) as a between-subject factor. The three-way interaction was significant ($F(1,20) = 12.06$, $p < .01$) and two-way ANOVAs were performed for each target condition to investigate this interaction.

With a face target, there was a trend for a differential effect of Distractor Category on performance between car experts and novices ($F(1,20) = 3.69$, $p = .07$), Fig. 1A). Car experts required slower presentation rates than novices to identify faces among cars ($F(1,20) = 4.17$, $p < .04$). In contrast, there was no threshold difference between groups for face targets among watch distractors ($p = .62$).

It is important to note that absolute search rates are influenced by category homogeneity (e.g., better search rate for F/FW than W/WF) and that car and watch distractor conditions should not be compared directly because faces may be more visually similar to watches than to car profiles. More meaningful is the relative difficulty of target conditions as a function of expertise. We performed a more powerful continuous analysis (Preacher, Rucker, MacCallum, & Nicewander, 2005) in which an *interference index* was defined as the difference in threshold for the two irrelevant distractor categories, divided by the sum of these thresholds (F/FW − F/FC)/(F/FC + F/FW). Car expertise was directly related to this interference index ($r = .69$, $p < .001$; Fig. 2A). Thus, task-irrelevant car distractors interfered with face perception as a function of car expertise.

For watch targets, we also observed an interaction between Distractor Category (cars vs. faces) and Group ($F(1,20) = 6.11$, $p < .05$; Fig. 1B). There was a trend for car experts to identify watch targets at higher presentation rates than novices when distractors were cars ($F(1,20) = 2.61$, $p = .12$). As expected, no difference in threshold was observed between groups when searching for watches among faces ($p = .64$). Here, there was a significant *negative* correlation between interference index [(W/WF − W/WC)/(W/WC + W/WF)] and car expertise index ($r = -.55$, $p < .02$; Fig. 2B). Task-irrelevant cars interfered with watch perception as a function of car expertise, but in this case expertise makes it *easier* to ignore task-irrelevant cars.

## 4. Discussion

The present study provides novel evidence that expertise can alter perceptual thresholds systematically and that competition between faces and objects of expertise has a

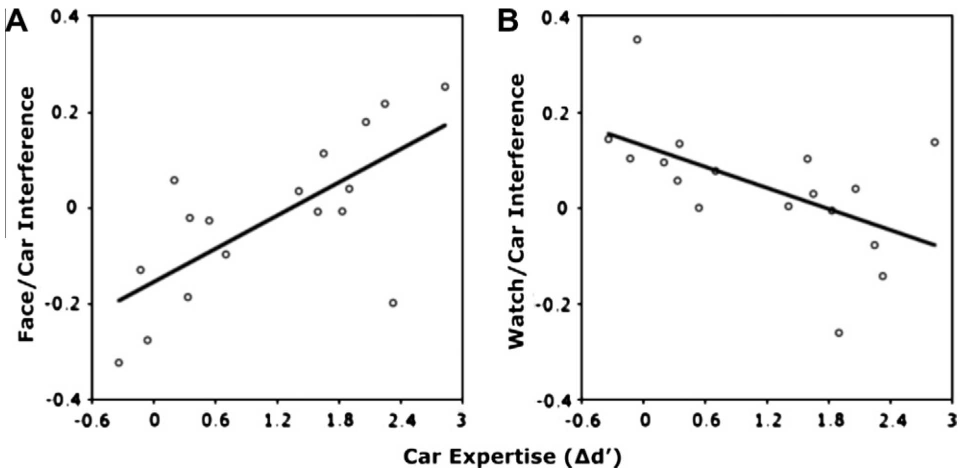


**Fig. 2.** Correlation between car expertise index and (A) an index of interference between faces and cars [(F/FW − F/FC)/(F/FC + F/FW)] or (B) an index of interference between cars and watches [(W/WF − W/WC)/(W/WC + W/WF)].

category-specific, rather than central, locus. Specifically, car experts required *more* time than novices to find faces among cars, yet required *less* time than novices to discriminate watches among car distractors. This crossover interaction between expertise and target-type rules out many accounts. Competition between faces and objects of expertise does not arise simply because expertise leads to obligatory capture of attention or depletion of central resources (Awh et al., 2004; Ro et al., 2001; Vuilleumier, 2000), otherwise car distractors should have interfered with experts' watch discrimination. Moreover, familiarity or expertise does not merely result in more efficient processing of distractors (Mruczek & Sheinberg, 2005; Tong & Nakayama, 1999; Wang, Cavanagh, & Green, 1994), since cars were easier for car experts to ignore only when searching for objects, not for faces. Rather, our results suggest that the presence of car distractors raises or lowers perceptual thresholds in experts depending on the perceptual strategy required to discriminate the target category. When car experts rely on holistic processing to search for faces (Farah et al., 1998), this strategy, well suited for expert car perception, leads to interference from car distractors. However, when the same expert searches for a watch, she uses part-based processing, making cars easier to ignore. It has been suggested that face processing does not depend on general capacity limits, but on face-specific capacity limits (Lavie, Ro, & Russell, 2003) – our results suggest that these limits are better described as process-specific.

The results suggest that perceptual competition was an important contributor in previous studies of interference between faces and objects. EEG studies have reported that the N170 face-selective potential (Bentin, McCarthy, Perez, Puce, & Allison, 1996; Rossion et al., 2000) is attenuated when faces are presented concurrently with objects of expertise (Rossion et al., 2004, 2007). This could result from direct perceptual competition or from decreased attention to faces in the presence of other interesting objects. Another study found that holistic face processing is impaired when car experts maintain cars in working memory (Gauthier et al., 2003). Again, this might be attributed to competition between the visual representations resulting from immediate perception and those maintained in working memory, or to how experts allocate central resources to each task. A recent study suggests that the source of this competition does not have its locus in working memory (Cheung & Gauthier, 2010). The crossover interaction found in the present study indicates that the competition between faces and objects of expertise is relatively peripheral, and likely perceptual in nature. If task-irrelevant cars depleted only central attentional resources, then experts should have shown impairments in both face and object processing, rather than a benefit in object processing.

While the idea that experts process non-face objects holistically has been controversial (McKone, Kanwisher, & Duchaine, 2007), recent work suggests that experience individuating non-face objects can produce this hallmark of face processing (Wong, Palmeri, & Gauthier, 2009). Therefore, the notion that expertise leads to greater holistic processing remains the best candidate to account for the similarity of face and car processing in car experts (Gauthier et al., 2003). Although we believe the source of the competition observed here has a perceptual locus, we acknowledge that the locus of holistic processing itself (perceptual vs. decisional) remains debated (Mack, Richler, Gauthier, & Palmeri, in press; Richler, Gauthier, Wenger, & Palmeri, 2008; Wenger & Ingvalson, 2002).

While it is intriguing to ask whether face distractors would selectively impact car identification by car experts, multiple factors could affect performance when expertise for targets is manipulated and the results would be more difficult to interpret. For instance, car processing should be less perceptually taxing (and more motivating) for car experts than novices, potentially allowing attentional resources to spill over to irrelevant items regardless of category (Lavie, 1995).

The fact that expertise with an object category leads to both greater perceptual competition with face processing and decreased competition with object processing suggests that the acquisition of expertise represents a shift from one type of strategy (or representation, Dicarlo & Cox, 2007) in favor of another. Our results can be discussed within a framework proposed by Kinsbourne and Hicks (1978) in which the degree of interference between any two processes or representations depends on their "cerebral functional distance" (CFD). This framework emphasizes that the brain is a highly linked network in which activation spreads and decays as a function of distance. An increase in competition between two tasks with expertise reflects a decrease in CFD. An interesting prediction of the CFD framework is that expertise should affect not only holistic face processing but also affect object processing in the opposite direction, as was found here.

What changes might be occurring at a neural level to account for perceptual competition due to expertise? The nature of neural object representations is controversial, with some proposing that face representations are especially focal (Kanwisher, McDermott, & Chun, 1997; Spiridon & Kanwisher, 2002; Tsao, Freiwald, Tootell, & Livingstone, 2006) and others favoring distributed, overlapping representations for faces and objects (Haxby et al., 2001; O'Toole, Jiang, Abdi, & Haxby, 2005). Of relevance here, object representations can be altered by experience. Expertise with objects is associated with greater activation in and nearby face-selective regions of the ventral visual pathway (Gauthier et al., 2000, 2005; Moore, Cohen, & Ranganath, 2006; Wong, Palmeri, Rogers, Gore, & Gauthier, 2009; Wong et al., 2009; Xu, 2005) which suggests greater overlap with the neural representation of faces. Alternatively, neuronal populations for faces and trained objects could remain separate while inhibitory connections between these networks become more extensive. According to the CFD framework, both the degree of neuronal overlap and the strength of inhibitory connections could alter the effective functional distance between visual representations. Recent studies have focused primarily on neural overlap between object representations (Gauthier et al., 2000; Grill-Spector, Knouf, & Kanwisher, 2004; Tong, Nakayama, Moscovitch, Weinrib, & Kanwisher, 2000; Tsao et al., 2006), and though some overlap is typically found, it remains difficult to predict *how much* overlap would be necessary to translate into perceptual competition. An advantage of the CFD framework is its focus on the functional impact of overlap between processes or representations. Even if two separate neuronal populations represent different objects, functional overlap could still be high due to mutually competitive interactions. In this case, neither neuronal population would be "functionally encapsulated" and the performance of one would fail to operate independently of the other. In that sense, regardless of their neural underpinnings, our results are inconsistent with the notion of a domain-specific module for face perception that operates independently from the processing of stimuli outside this domain. Future modeling efforts, combined with neurophysiological recordings, will be key in unraveling the mechanisms underlying competition effects.

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