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Irrelevant objects of expertise compete with faces during visual search

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Abstract

Prior work suggests that non-face objects of expertise can interfere with the perception of faces when the two categories are alternately presented, suggesting competition for shared perceptual resources. Here we ask whether task-irrelevant distractors from a category of expertise compete when faces are presented in a standard visual search task. Participants searched for a target (face or sofa) in an array containing both relevant and irrelevant distractors. The number of distractors from the target category (face or sofa) remained constant, while the number of distractors from the irrelevant category (cars) varied. Search slopes, calculated as a function of the number of irrelevant cars, were correlated with car expertise. The effect was not due to car distractors grabbing attention because they did not compete with sofa targets. Objects of expertise interfere with face perception even when they are task irrelevant, visually distinct and separated in space from faces.

The perceptual expertise account of specialization for faces suggests that behavioral and neural hallmarks of face perception arise because most adults have had considerable experience discriminating faces at the individual level (Diamond & Carey, 1986; Gauthier & Tarr, 1997; Wong, Palmeri & Gauthier, 2009). Studies of visual expertise show that nonface objects of expertise such as birds, dogs, body parts, cars, handwriting, x-rays, and even novel, computer-generated objects such as Greebles and Ziggerins can exhibit many characteristic behavioral and neurological markers of face perception (e.g., Busey & Vanderkolk, 2005; Diamond & Carey, 1986; Gauthier et al., 2000a; Gauthier & Tarr, 1997; Harley et al., 2009; Stekelenburg & de Gelder, 2004; Wong et al., 2009). Objects of expertise can also recruit face-selective regions in the mid-fusiform gyrus (Gauthier et al., 2000a; Harley et al., 2009; Xu, 2005) and lead to early physiological responses typically evoked by faces over occipitotemporal cortex (Busey & Vanderkolk, 2005; Gauthier et al., 2003; Rossion et al., 2002; Tanaka & Curran, 2001).

If faces and objects of expertise recruit similar processing mechanisms mediated by overlapping neural representations, objects from these domains may compete when they must be processed concurrently. Indeed, there is evidence of competition between faces and nonface objects of expertise on the face-selective N170 ERP component typically recorded at occipito-temporal electrodes at about 170 ms post stimulus onset (Gauthier et al., 2003; Rossion et al., 2007; Rossion, Kung, & Tarr, 2004). In one study, ERPs were measured while subjects viewed an alternating sequence of face and car composites, judging whether the bottom half of an image was the same as the bottom half of the previous image. Holistic effects were estimated by the extent to which the task-irrelevant top of the images

influenced judgments on the bottom of the images. Holistic processing of faces was reduced when car experts had to process the interleaved cars in a holistic manner, and this interference effect was correlated with the amplitude of the face-evoked N170 (Gauthier et al., 2003). Two other studies reported that the N170 response to faces was attenuated when observers concurrently fixated a nonface object from both a category for which participants had acquired expertise in the laboratory (Greebles; Rossion et al., 2004) or through long term experience outside of the laboratory (cars; Rossion et al., 2007). Importantly, the effect of neural suppression significantly correlated with a behavioral index of visual expertise. Competition was also suggested in a training study in which a visual agnostic patient with an inferotemporal lesion participated in a training regimen that required learning to individuate novel objects called Greebles (Behrmann et al., 2005). For this patient, small improvements in performance with Greebles during the long training program were associated with behavioral costs in face perception, and Greeble-evoked increases in activity in the fusiform gyrus were associated with decreases in response to faces. Overall, these results suggest that faces and objects of expertise may compete in a variety of situations.

With the exception of the single case study by Behrmann et al (2005), previous work has been limited to neural measures of competition, without providing direct evidence that perceptual processing of faces is actually impacted by competing objects of expertise. This was the case because either the behavioral task used was exceptionally easy (Rossion et al., 2004; 2007), or the task required selective attention to an image's parts, thereby favoring novices (Gauthier et al., 2003). Thus, it remains to be determined whether neural measures of competition will necessarily translate into reduced behavioral performance. The relationship between neural markers of face selectivity and face perception is not clear. For instance, fMRI activity for non-face objects in the fusiform face area (FFA) correlates with behavioral expertise measures (Behrmann et al., 2007; Gauthier et al., 2005; Xu, 2005) but, paradoxically, FFA responses to faces can also be found in patients incapable of recognizing faces (Marotta, Genovese & Behrmann, 2001; Rossion et al., 2003). A normal face-selective M170 potential (the MEG analog of the N170) has also been reported in developmental prosopagnosics (Harris et al., 2005).

To address this issue, one study directly measured perceptual thresholds for discriminating faces in a RSVP stream of faces alternating with task-irrelevant cars (McKeeff, McGugin, Tong & Gauthier, submitted). Car experts were slower than novices at identifying faces among task-irrelevant cars. However, in a control condition when subjects searched for watches amongst car distractors, the same car experts were faster than novices at identifying studied watches, suggesting that objects of expertise do not simply grab attention. Rather, these results demonstrate how the perception of faces can be influenced by competing objects from another domain of expertise.

In most prior cases of competition between faces and objects of expertise, objects from the two categories alternated. In some cases, objects of expertise were held in visual short-term memory while an effect was observed during face processing (e.g., Gauthier et al., 2003). While in that study, competition could have taken place at a perceptual level and/or in working memory, there are reasons to believe that the locus of competition was only perceptual. Indeed, interference between items in working memory obeys different principles governed by limitations in the encoding and/or maintenance of similar representations, rather than by expertise (Cheung & Gauthier, 2010). This suggests that we should be able to detect competition between domains of expertise in any task that taps into an expertise-specific perceptual bottleneck.

Here, we investigated whether task-irrelevant distractors from a category of expertise can also compete in the context of a visual search task where stimuli are distributed in space

rather than in time. If competition among categories of expertise is governed by perceptual factors, this suggests it should influence performance during visual search, a task that is affected by perceptual factors (Duncan, 2006; Duncan & Humphreys, 1989; Raymond, Shapiro & Arnell, 1992; Treisman & Gelade, 1980; Wolfe et al., 1989). In McKeeff et al. (submitted), the threshold for detecting a face in a RSVP stream varied as a function of one's expertise for the irrelevant cars. To what extent was competition observed because cars were presented at fixation and at a rate at which attention could not be disengaged fast enough to ignore them? The visual search paradigm is one of the most useful paradigms for examining the deployment of attention. We measure competition in a spatial search to assess whether the locus of competition is early enough in processing that it disrupts selective attention to faces when peripheral task-irrelevant distractors could, in theory, be filtered out via top-down attentional mechanisms (Wolfe, 1994).

The efficiency of visual search can be influenced by the familiarity of the target, but also by the familiarity of the distractors. On the one hand, the literature supports a search asymmetry in which the detection of an unfamiliar target amongst familiar distractors is easier/faster than the reverse search (e.g., Malinowski & Hubner, 2001; Rauschenberger & Chu, 2006; Shen & Reingold, 2001; Wang et al., 1994). For example, visual search experiments have demonstrated superior search efficiency for letters or objects in their canonical orientation, including search for mirror-reversed Ns or Zs among canonically-oriented Ns and Zs (Wang et al., 1994), inverted As among upright As (Wolfe, 2001), or inverted animals among upright ones (Wolfe, 2001). Another line of visual search studies has explored the effect of stimulus familiarity when stimuli are kept constant. Rather than rendering objects less familiar by rotation or inversion, some of this work compared performance across American and Chinese subjects searching for meaningful or non-meaningful Chinese characters (Rauschenberger & Chu, 2006; Shen & Reingold, 2001), German and Slavic subjects searching for meaningful or nonmeaningful Latin or Cyrillic alphabet units (Malinowski & Hubner, 2001), subjects searching for unfamiliar faces when the distractors were one's own face (Tong & Nakayama, 1999), and white subjects searching for cross-race faces (faces of a different race than the subject) among same-race faces (Levin, 1996; Levin & Angelone, 2001). Across domains, search was most efficient for unfamiliar targets among familiar distractors.

The studies described above used relatively homogeneous targets and distractors. Other studies using more heterogeneous distractor displays with complex objects have demonstrated the importance of target familiarity in addition to distractor familiarity, showing that targets may actually become more salient than novel targets (Hershler & Hochstein, 2009; Mruczek & Sheinberg, 2005). When the task was to detect the presence of a car, a face or a bird (at the category level) in displays with objects of various categories, faces as well as objects of expertise were found more rapidly (Hershler & Hochstein, 2009).

In the present study, we combine a search for a specific target among homogeneous distractors with the presence of a variable number of objects from a visually dissimilar category. Car experts and car novices searched for a target (face or sofa) in a display of distractors from two different categories. In face-target conditions, the distractors were either faces and cars or faces and sofas, while in sofa-target conditions the distractors were either sofas and cars or sofas and faces. The number of distractors from the target category remained constant (5), while the number of distractors from the task-irrelevant category varied (2, 4 or 8). Only the number of task-irrelevant distractors (rather than targets) was manipulated to assess how expertise with distractors differently affected the efficiency of search for another object of expertise (face) or for a common object (sofa).

We predicted that car expertise would impede search for a target face among car distractors, such that visual search slopes would be correlated with an observer's level of expertise with cars. As the number of task-irrelevant car distractors increases, the detection of a target face should become more difficult. However, we expected no such influence of car expertise during search for a sofa target among car distractors. If this is found, it would suggest a bottleneck for domains of expertise, rather than a general attentional effect for distractors of expertise.

Methods

Participants

Thirty-one individuals participated (19 males, mean age 23 years). While our main prediction focuses on car expertise as a continuous measure, we also divided participants into car "novices" or "experts" based on a median split on scores from an independent test that compared car identification to bird identification. Bird identification was intended to serve as a baseline of novice-level performance across individuals, thus three participants were excluded based on bird identification scores that were more than two standard deviations from the mean. The data are from the remaining twenty-eight participants, fourteen car "experts" and fourteen car "novices". All participants had normal or corrected-to-normal visual acuity. The experiment was approved by the Institutional Review Board at Vanderbilt University, and all participants provided written informed consent.

Stimuli and Design

Stimuli were digitized grayscale images (30 faces (75 x 75 pixels, 2.62 degrees of visual angle), 30 cars (85 x 50 pixels, 2.96 x 1.74 degrees of visual angle), and 30 sofas (75 x 75 pixels, 2.62 degrees visual angle)) presented on a 21-inch, CRT monitor (refresh rate = 100 Hz) using a Macintosh G3 computer using Matlab and Psychophysics Toolbox extension (Brainard, 1997; Pelli, 1997).

On each trial, participants searched for previewed targets in an array of distractors. Target and distractor stimuli were randomized across trials and participants. Thus, a target image on one trial could appear as a distractor image in a subsequent trial. Stimuli were presented in four conditions: face targets among face and car distractors (F/FC), face targets among face and sofa distractors (F/FS), sofa targets among sofa and face distractors (S/SF), and sofa targets among sofa and car distractors (S/FC).

In each condition, a trial began with the simultaneous presentation of two targets from a given category, either two faces or two sofas, for as long as needed by the participants to encode. They then pressed a key to proceed. A brief fixation and search array followed. The search array consisted of 8, 10 or 14 stimuli: 1 target, 5 distractors from the target category, and either 2, 4, or 8 task-irrelevant distractors from another category (see Figure 1). For each trial, stimuli were randomly assigned a position from 16 available locations created by a 4 by 4 matrix. Images were randomly jittered by a maximum of 50 pixels up/down and 50 pixels left/right about their central location. Jittering avoided a grid-like display and discouraged a line-by-line search. Participants were instructed to search the display until they found a target, at which point they indicated which of the two studied targets was found by pressing a right or a left key.

Participants first completed eight practice trials, four sampled randomly from a block of face-target trials and four sampled randomly from a block of sofa-target trials. For the actual experiment, 60 F/FC trials and 60 F/FS trials were randomly presented within one face-target block, while 60 S/SF trials and 60 S/SC trials were randomly presented within one

sofa-target block. The two blocks of 120 trials were each repeated once. Thus, the complete design consisted of 4 blocks and a total of 480 trials.

In a separate task, car expertise was quantified using a sequential matching paradigm as in prior work (Gauthier et al., 2000b; 2005; McGugin & Gauthier, in press; Rossion et al., 2004; Xu, 2005). Participants made same/different judgments about car images (at the level of make and model, regardless of year) and bird images (at the level of species). For each of 112 car trials and 112 bird trials, the first stimulus appeared for 1,000 ms, followed by a 500 ms mask. A second stimulus then appeared and remained visible until a same/different response was specified or until 5 s elapsed with no activity. The results from this task yielded a separate sensitivity score for cars (Car d') and birds (Bird d'). The difference between these measures (Car $d' - \text{Bird } d'$) yields a Car Expertise Index for each participant. According to prior work, participants were classified as car “experts” when their self-report as an expert matched a Car Expertise Index score of greater than 1.

Results

Measure of expertise

For a coarse analysis of expertise effects and to graph performance for groups of participants that differ on car expertise we first split the participants into two groups. The 14 participants who had a Car Expertise Index greater than 1 were also self-reported car experts, the remaining 14 participants were classified as novices. Figure 2 shows the range of Car d' scores (0.23 to 3.71) and more limited range of corresponding Bird d' scores (0.46 to 1.25). Car d' was higher for self-reported car experts ($d' = 2.70$) than for self-reported car novices ($d' = 0.71$; $F(1, 27) = 109.71, p < 0.0001$) while no group difference was found in the bird task ($F(1, 27) < 1, n.s.$). The Car Expertise Index was also higher for self-reported car experts (delta $d' = 1.91$) than novices (delta $d' = -0.14$; $F(1, 27) = 116.91, p < 0.0001$). For all subjects, subsequent statistical analyses performed on Car Expertise Index scores yielded qualitatively and statistically similar results to those obtained using the simple Car d' as a measure of expertise. In other words, our results were not produced by variability in performance on the bird task.

Visual Search Task

Mean response times (RT) for correct responses and mean accuracy scores are reported separately for car experts and novices in each condition in Table 1. We were primarily interested in search times but we will also consider accuracy to rule out the possibility of tradeoffs. In general, mean response times were fairly long, as expected in a difficult search for a target among visually similar distractors from the same category (see Figure 3).

For each individual and each condition, we computed the slope of search as a function of set size using linear regression. This was done for correct RT and accuracy separately. In general, search times were fairly long, as expected given that the search was made difficult by similar distractors of the same category. However, only the number of distractors from the other category was varied and so the slope was calculated as a function of the number of distractors from the task-irrelevant category. Because search efficiency decreases as the similarity between target and distractors increases (Duncan & Humphreys, 1989), we expected that in most conditions, search slopes as a function of the number of visually dissimilar objects should be fairly shallow, which is what we observed. Negative search slopes (as a function of the number of irrelevant distractors) may occur because when there are only two distractors, they may pop out and grab attention, while this effect would be reduced when the target and distractor categories are more numerically balanced in the display.

While Figure 3 suggests that car experts may be slower than car novices overall at searching for faces (the error bars reflect the within-subjects variability), there was no main effect of expertise for the F/FS search ($F_{1,26} = 1.22, p = .28$) or the F/FC search ($F_{1,26} < 1$). Even expertise as a continuous variable does not correlate with search rate collapsing across set size (F/FS: $r = .12, n.s.$; F/FC: $r = .08, n.s.$).

We conducted an ANOVA on the slopes for RT functions with Target category (face/sofa) and Distractor category (car/non-car) as within-subjects factors and Expertise group (car novices/experts) as a between-subjects factor. Note that the factor “Distractor” aligns faces and sofas as “non-car” categories, which is meaningful because the same prediction – no competition – is expected with both non-car distractors. This analysis revealed a significant main effect of Target category ($F_{1,26} = 5.921, MSE = 11304.8, p = .02$), with steeper slopes for the sofa than face targets, and a significant 3-way interaction between Group, Target category and Distractor Category ($F_{1,26} = 5.540, MSE = 14538.1, p = .03$). Scheffé post-hoc tests revealed a steeper slope for car experts than novices in the search for faces among car distractors ($p < .05$), whereas there was no effect of expertise for the 3 other search conditions (all $ps > .24$).

The same ANOVA conducted on the accuracy data did not yield any significant effect, including the critical 3-way interaction ($F_{1,26} < 1$). Thus, there was no evidence for a speed-accuracy tradeoff.

Our prediction was that car expertise would reduce the efficiency of a face search in the presence of car distractors. Because the distinction between car novices and experts is arbitrary, we correlated visual search RT slopes with the quantitative measure of car expertise obtained from the sequential matching task. F/FC was the only condition that revealed a positive correlation between Car Expertise Index scores and visual search slope ($r = 0.43, p = 0.03$; Figure 4). Crucially, this effect does not seem to arise because cars are simply harder to ignore by car experts, as there was no effect of car expertise in a search for sofas with car distractors (nor in the F/FS or S/SF conditions, all $rs < 0.17, n.s.$). To ensure that the few novices with especially negative search slopes in the F/FC condition could not account for the observed effect, we recalculated correlations for all conditions while excluding the two participants with the most negative search slopes in the F/FC search condition. The results were qualitatively identical (F/FC: $r = 0.39, p = 0.05$; all other conditions non-significant).

Car Expertise Index scores and car d' scores yielded equivalent results in all analyses. We conclude that task-irrelevant car distractors interfere with face perception as a function of car expertise.

Discussion

We found that objects of expertise interfere with concurrent face processing, even when they are entirely task irrelevant, visually distinct from faces, and separated in space from faces. This result converges with earlier neural evidence of competition between the concurrent processing of faces and objects of expertise (Gauthier et al., 2003; Rossion et al., 2004; 2007), while strengthening the hypothesis that this interference can have significant behavioral costs as well.

There has been debate in the literature over how best to characterize the contribution of top-down and bottom-up processes in guiding saccadic search behaviors (Barton et al., 2006; Chen & Zelinsky, 2006). Competing hypotheses propose that visual search is either a bottom-up mechanism driven by low-level image characteristics and feature contrast in a scene or, alternatively, a top-down process under voluntary control of the searcher and high-

level demands of the task (Hershler & Hochstein, 2009; Newell, Brown & Findlay, 2004; Tatler, Baddeley, & Gilchrist, 2005). Our findings support the idea that visual search is, at least in part, a goal-driven process in which interference from distractors depends not only on our experience with them but on whether distractors and targets are objects of expertise recruiting a similar perceptual strategy. Prior work shows that some types of expertise recruit a holistic processing strategy typically observed for faces only (Wong et al., 2009; Busey & Vanderkolk, 2005; Curby & Gauthier, 2009). Moreover, one study specifically studied competition between holistic processing of faces and cars in sequential presentation and observed increasing competition with car expertise (Gauthier et al., 2003). Together, these results suggest that holistic processing is the functional locus of the interference effects we observed. Studies also suggest the possibility of a localized neural bottleneck to account for the competition: at least one area in extrastriate cortex, the FFA, is selective for both faces and objects of expertise (Gauthier et al., 1999; 2000a; Harley et al., 2009; Moore, Cohen & Ranganath, 2006; Xu, 2005).

Nonetheless, our results do not allow us to determine exactly how the presence of car distractors influenced the search for a face. For instance, are car experts more likely to foveate a car than novices, or is their decision slowed down by information present only in the peripheral visual field (Rajashekar, Bovik & Cormack, 2006)? Future research using eye movement recordings may help resolve this issue¹. Importantly, whatever car experts did differently as a function of the number of car distractors, they did so only when searching for a face. This allows us to rule out the possibility that observers are simply more likely to look at objects of expertise, because they would have done so in *all* car distractor conditions. Unless car experts were engaged in a search for faces, no behavioral cost of car distractor was observed. This suggests that expert perceptual skills are both top-down – processing cars differently depending on whether targets were faces or objects *and* relatively automatic, since irrelevant cars interfered once a certain mode of processing was engaged. Of course, our behavioral paradigm does not allow us to determine whether neural competition would also arise when faces and cars are both presented but neither is task relevant. This question would be more easily addressed with neuroimaging.

Interestingly, competition in the present paradigm suggests that interference between domains of expertise may arise in a wide range of situations, well beyond dual task paradigms that are tested in the laboratory. In everyday living, observers are rarely forced to make a judgment about one object while fixating another object (Rossion et al., 2004, 2007), when objects from the two different categories occur in very rapid succession at the fovea (McKeeff et al., submitted; Wong et al., submitted), or where judgments for objects from two categories must be made in alternation (Gauthier et al., 2003). However, top-down attention is often directed to objects from one category in the presence of distractors from another category in the peripheral visual field. For instance, an airport security screener could experience competition between task-relevant objects on the screen and irrelevant faces in the surrounding environment. Whether or not this happens, we would argue, depends on whether the expert skills rely on processing strategies that are common with those elicited by faces, or rather those that are used for generic object recognition.

References

- Barton JJ, Radcliffe N, Cherkasova MV, Edelman J, Intriligator J. Information processing during face recognition: The effects of familiarity, inversion, and morphing on scanning fixations. *Perception* 2006;35:1089–1105. [PubMed: 17076068]

¹Pilot results suggest the mere knowledge that one's eye movements are being monitored may influence performance in our search task and that unobtrusive methods may be important.

- Behrmann M, Avidan G, Gao F, Black S. Structural imaging reveals anatomical alterations in inferotemporal cortex in congenital prosopagnosia. *Cerebral Cortex* 2007;17:2354–2363. [PubMed: 17218483]
- Behrmann M, Marotta J, Gauthier I, Tarr MJ, McKeef T. Behavioral change and its neural correlates in visual agnosia after expertise training. *J Cogn Neurosci* 2005;17:554–568. [PubMed: 15829077]
- Brainard DH. The Psychophysics Toolbox. *Spatial Vision* 1997;10:433–436. [PubMed: 9176952]
- Busey TA, Vanderkolk JR. Behavioral and electrophysiological evidence for configural processing in fingerprint experts. *Vision Research* 2005;45:431–448. [PubMed: 15610748]
- Chen X, Zelinsky GJ. Real-world visual search is dominated by top-down guidance. *Vision Research* 2006;46:4118–4133. [PubMed: 17005231]
- Cheung OS, Gauthier I. Selective Interference on the holistic processing of faces in working memory. *Journal of Experimental Psychology: Human Perception and Performance* 2010;36(2):448–461. [PubMed: 20364929]
- Diamond R, Carey S. Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General* 1986;115:107–117. [PubMed: 2940312]
- Duncan J. EPS mid-career award 2004: brain mechanisms of attention. *Quarterly Journal of Experimental Psychology (Colchester)* 2006;59:2–27.
- Duncan J, Humphrey GW. Visual search and stimulus similarity. *Psychological Review* 1989;96:433–458. [PubMed: 2756067]
- Gauthier I, Curby KM, Skudlarski P, Epstein RA. Individual difference in FFA activity suggest independent processing at different spatial scales. *Cognitive Affective Behavioral Neuroscience* 2005;5:222–234.
- Gauthier I, Curran T, Curby KM, Collins D. Perceptual interference supports a non-modular account of face processing. *Nature Neuroscience* 2003;6(4):428–432.
- Gauthier I, Skudlarski P, Gore JC, Anderson AW. Expertise for cars and birds recruits brain areas involved in face recognition. *Nature Neuroscience* 2000a;3:191–197.
- Gauthier I, Tarr MJ. Becoming a “Greeble” expert: Exploring mechanisms for face recognition. (1996). *Vision Research* 1997;37:1682–1682.
- Gauthier I, Tarr MJ, Anderson AW, Skudlarski P, Gore JC. Activation in the middle fusiform ‘face area’ increases with expertise in recognizing novel objects. *Nature* 1999;2:568–573.
- Gauthier I, Tarr MJ, Moylan J, Skudlarski P, Gore JC, Anderson AW. The fusiform “face area” is part of a network that processes faces at the individual level. *Journal of Cognitive Neuroscience* 2000b;12:495–504. [PubMed: 10931774]
- Harley EM, Pope WB, Villablanca JP, Mumford J, Suh R, Mazziotta JC, Enzmann D, Engel SA. Engagement of the fusiform cortex and disengagement of lateral occipital cortex in the acquisition of radiological expertise. *Cerebral Cortex* 2009;19:2746–2754. [PubMed: 19321653]
- Hershler O, Hochstein S. The importance of being expert: Top-down attentional control in visual search with photographs. *Attention, Perception & Psychophysics* 2009;71:1478–1486.
- Levin DT. Classifying faces by race: The structure of face categories. *Journal of Experimental Psychology: Learning, Memory & Cognition* 1996;22:1364–1382.
- Levin DT, Angelone BL. Visual search for a socially defined feature: What causes the search asymmetry favoring cross-race faces? *Perception & Psychophysics* 2001;63:423–435. [PubMed: 11414130]
- Malinowski P, Hubner R. The effect of familiarity on visual-search performance: Evidence for learned basic features. *Perception & Psychophysics* 2001;63:458–463. [PubMed: 11414133]
- Marotta JJ, Genovese CR, Behrmann M. A functional MRI study of face recognition in patients with prosopagnosia. *Cognitive Neuroscience* 2001;12:1–7.
- McGugin RW, Gauthier I. Perceptual expertise with objects predicts another hallmark of face perception. *Journal of Vision*. in press.
- McKeef T, McGugin RW, Tong F, Gauthier I. Expertise reduces the functional cerebral distance between face and object perception. in prep.
- Moore CD, Cohen MX, Ranganath C. Neural mechanisms of expert skills in visual working memory. *Journal of Neuroscience* 2006;26:11187–11196. [PubMed: 17065458]

- Mruczek REB, Sheinberg DL. Distractor familiarity leads to more efficient visual search for complex stimuli. *Perception and Psychophysics* 2005;67:1016–1031. [PubMed: 16396010]
- Newell FN, Brown V, Findlay JM. Is object search mediated by object based or image-based representations. *Spatial Vision* 2004;17:511–541. [PubMed: 15559117]
- Pelli DG. The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial Vision* 1997;10:437–442. [PubMed: 9176953]
- Rajashekar U, Bovik AC, Cormack LK. Visual search in noise: Revealing the influence of structural cues by gaze-contingent classification image analysis. *Journal of Vision* 2006;6:379–386. [PubMed: 16889476]
- Rauschenberger R, Chu H. The effects of stimulus rotation and familiarity in visual search. *Perception & Psychophysics* 2006;68:770–775. [PubMed: 17076345]
- Raymond JE, Shapiro KL, Arnell KM. Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance* 1992;18:849–860. [PubMed: 1500880]
- Rossion B, Caldara R, Seghier M, Schuller AM, Lazeyras F, Mayer E. A network of occipito-temporal face-sensitive areas besides the right middle fusiform gyrus is necessary for normal face processing. *Brain* 2003;126:2381–2395. [PubMed: 12876150]
- Rossion B, Collins D, Goffaux V, Curran T. Long-term expertise with artificial objects increases visual competition with early face categorization processes. *Journal of Cognitive Neuroscience* 2007;19(3):543–555. [PubMed: 17335400]
- Rossion B, Gauthier I, Goffaux V, Tarr MJ, Crommelinck M. Expertise training with novel objects leads to left lateralized face-like electrophysiological responses. *Psychological Science* 2002;13(3):250–257. [PubMed: 12009046]
- Rossion B, Kung CC, Tarr MJ. Visual expertise with nonface objects leads to competition with the early perceptual processing of faces in the human occipitotemporal cortex. *Proc Natl Acad Sci U S A* 2004;101(40):14521–14526. [PubMed: 15448209]
- Shen J, Reingold EM. Visual search asymmetry: The influence of stimulus familiarity and low-level features. *Perception & Psychophysics* 2001;63:464–475. [PubMed: 11414134]
- Stekelenburg JJ, de Gelder B. The neural correlates of perceiving human bodies: an ERP study on the body-inversion effect. *NeuroReport: Cognitive Neuroscience and Neuropsychology* 2004;15:777–780.
- Tanaka JW, Curran T. A neural basis for expert object recognition. *Psychol Sci* 2001;12(1):43–47. [PubMed: 11294227]
- Tatler BW, Baddeley RJ, Gilchrist ID. Visual correlates of fixation selection: effects of scale and time. *Vision Research* 2005;45:643–659. [PubMed: 15621181]
- Tong F, Nakayama K. Robust representations for face: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance* 1999;25:1016–1035. [PubMed: 10464943]
- Treisman A, Gelade G. A feature-integration theory of attention. *Cognitive Psychology* 1980;12:97–136. [PubMed: 7351125]
- Wang Q, Cavanagh P, Green M. Familiarity and pop-out in visual search. *Perception & Psychophysics* 1994;56:495–500. [PubMed: 7991347]
- Wolfe J. Guided Search 2.0: A revised model of visual search. *Psychonomic Bulletin and Review* 1994;2:202–238.
- Wolfe J. Asymmetries in visual search: An introduction. *Perception & Psychophysics* 2001;63:381–389. [PubMed: 11414127]
- Wolfe JM, Cave KR, Franzel SL. Guided search: An alternative to the feature integration model for visual search. *Journal of Experimental Psychology: Human Perception and Performance* 1989;15I:419–433. [PubMed: 2527952]
- Wong AC-N, Qu Z, McGugin RW, Gauthier I. Perceptual interference between processing of characters from alphabetic and non-alphabetic writing systems. submitted.
- Wong ACN, Palmeri T, Gauthier I. Conditions for face-like expertise with objects: Becoming a Ziggerin expert – but which type? *Psychological Science* 2009;20:1108–1117. [PubMed: 19694980]

Xu Y. Revisiting the role of the fusiform face area in visual expertise. *Cerebral Cortex* 2005;15:1234–1242. [PubMed: 15677350]

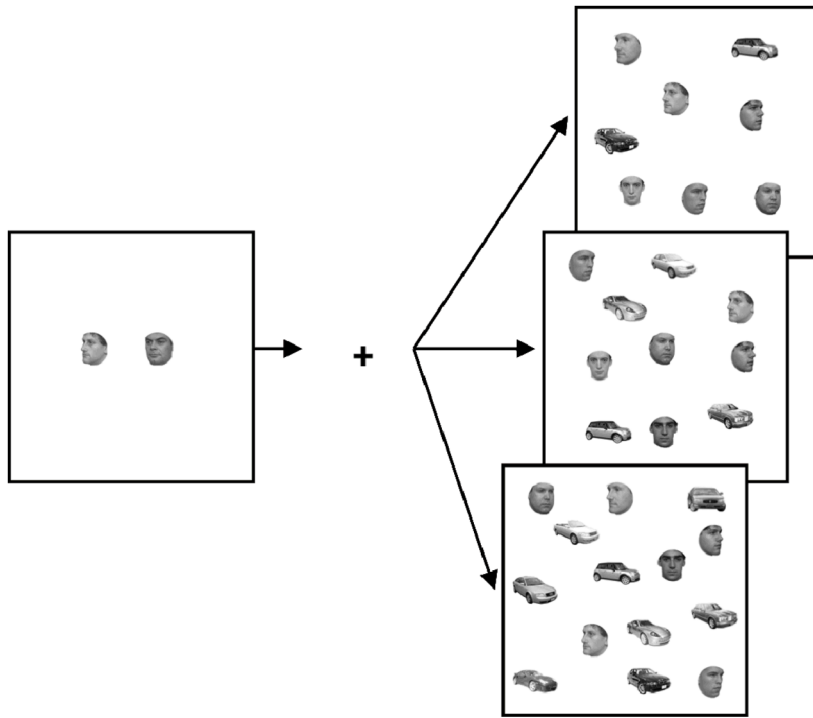


Figure 1. Trial sequence for the F/FC condition. Each trial began with the presentation of two faces followed by a fixation cross. With the onset of the search display, participants searched for one of the two studied faces, responding as quickly and accurately as possible. Search displays always contained one studied image, 5 images from the same category as the studied images, and either 2, 4 or 8 non-target distractors.

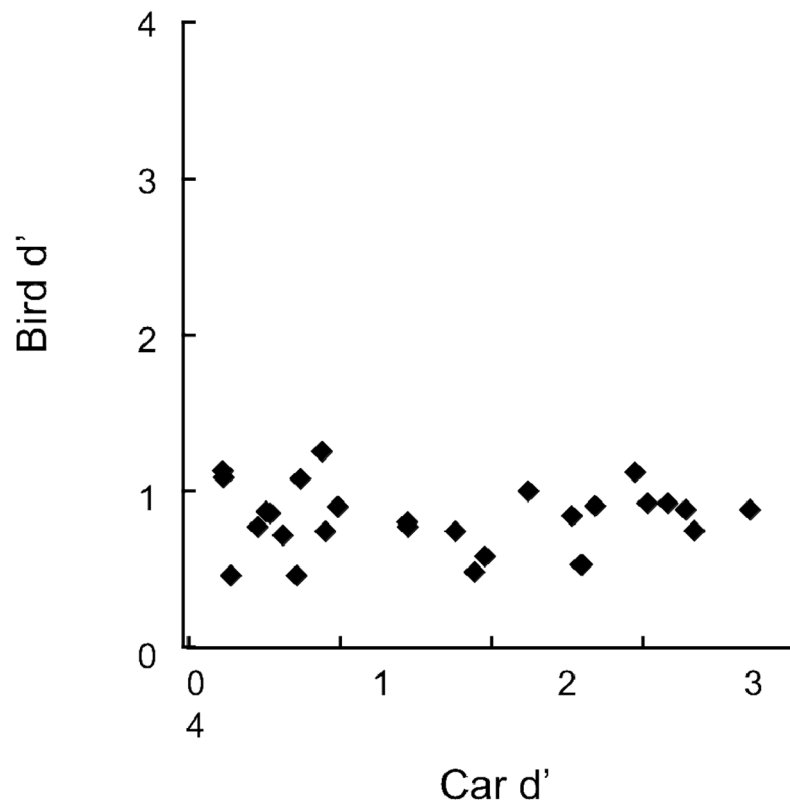


Figure 2. Scatterplot showing the distributions of Car d' and Bird d' scores from the car expertise test.

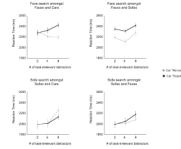


Figure 3. Response time (ms) as a function of the number of task-irrelevant distractors (2, 4, 8) for car experts (n=14) and car novices (n=14) who searched for face targets amongst face and car distractors, face targets among face and sofa distractors, sofa targets among sofa and car distractors, and sofa targets among sofa and face distractors. Error bars represent the standard error of the mean.

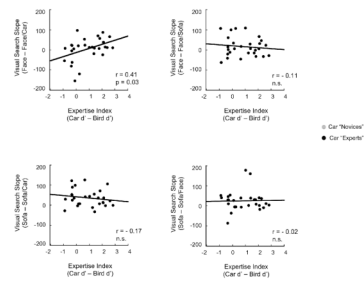


Figure 4. Correlations between Car Expertise Index values (Car d' - Bird d') and visual search slope (reaction time as a function of the number of task-irrelevant distractors) for faces among faces and cars (F/FC; $r = 0.41$, $p = 0.03$), faces among faces and sofas (F/FS; $r = -0.11$, n.s.), sofas among sofas and cars (S/SC; $r = -0.17$, n.s.), and sofas among sofas and faces (S/SF; $r = -0.02$, n.s.).

Mean response times (ms) for correct trials and mean accuracy rates for each condition and set size separately for car experts and car novices.

Table 1

Condition	# Task-Irrelevant Distractors	Mean Response Time (ms)		Mean Accuracy	
		Experts	Novices	Experts	Novices
<i>Face/Car</i>	2	2279.85	2309.2	0.738	0.692
	4	2331.47	2211.98	0.770	0.741
	8	2431.18	2200.27	0.766	0.691
<i>Face/Sofa</i>	2	2355.75	2194	0.752	0.703
	4	2315.97	2111.34	0.733	0.705
	8	2424.88	2284.14	0.758	0.694
<i>Sofa/Car</i>	2	1993.01	1991.3	0.764	0.726
	4	2010.98	2018.74	0.741	0.664
	8	2137.45	2257.72	0.761	0.668
<i>Sofa/Face</i>	2	1992.15	2003.22	0.765	0.698
	4	2048.45	2009.79	0.739	0.661
	8	2185.35	2081.2	0.714	0.656