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Degrees of Expertise

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INTRODUCTION

Visual object recognition and categorization are fundamental abilities required for successful negotiation of the visual world. Humans effortlessly classify and recognize objects and faces within busy scenes, thousands of times a day. Thus, understanding how perceptual categorization and learning occur and how such seemingly complicated computations are implemented in brain processes is an important goal in cognitive psychology and cognitive neuroscience. One way of furthering our understanding of category learning is to examine how differences in experience with specific classes of objects (e.g., dogs, cars, faces) influence the speed and level at which these objects are categorized.

Object categorization is arbitrary in the sense that a single object can be classified at multiple levels of abstraction. For instance, the same American Tree Sparrow can be classified as an "animal" at a general or superordinate level, a "bird" at the basic level, and an "American Tree Sparrow" at a specific or subordinate level. In contrast to object categorization, object *recognition* is not arbitrary in that most objects are identified at the same level of abstraction—the so-called basic level (Jolicoeur, Gluck, & Kosslyn, 1984; Murphy & Smith, 1982; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Seminal work by Rosch and colleagues demonstrated that the basic level is the optimum level of abstraction at which category members are perceptually most similar to one another and are maximally distinct from other category members. Given its structural advantage, the basic level is the preferred level in initial object recognition.

However, the basic level is typically not the preferred level for experts where recognition often demands a more specific, subordinate level of identification (Johnson & Mervis, 1997; Tanaka, 2001; but see Wong & Gauthier, in press, and Chapter 10, for descriptions of basic-level expertise). For example, face processing is thought to be a universally expert skill where faces are differentiated at the level of the individual (e.g., Bob, Susan) (Tanaka, 2001). Similarly, given the demands of expertise, expert bird watchers and car enthusiasts identify birds or cars at a more subordinate level (e.g., Bachman warbler, BMW Z1) compared to nonexperts (Tanaka & Taylor, 1991). Tanaka & Taylor (1991) suggested that category specificity arises when the demands of expertise require that exemplars within a category be differentiated from one another (as we do with faces). Furthermore, different recognition strategies may be best supported by different parts of

the visual system (Scott, Tanaka, Sheinberg, & Curran, 2006). According to this view, face perception and expert perceptual processing differ from nonexpert object perception with respect to the cognitive strategies and neural substrates that are recruited to support subordinate-level recognition. Subordinate-level categorization of vehicles and animals in nonexperts has been found to rely on predominately high–spatial frequency information, whereas basic-level categorization relies on low–spatial frequency information (Collin & McMullen, 2005). However, in face categorization there is a greater reliance on low–spatial frequency information for subordinate-level categorization of faces relative to objects (Harel & Bentin, in press). Thus, the perceptual information used for visual face and object categorization appears to be flexible and dependent on previous experience and whether fine-grained and detailed visual analyses are needed.

Understanding the processes and mechanisms involved in the acquisition of expert object recognition will not only inform the study of perceptual expertise but will also aid in our understanding of how experience influences object perception. Full appreciation of how humans learn to categorize necessarily involves an understanding of expert perceptual processing. This includes the conditions necessary for category learning and perception to occur as well as the neural mechanisms mediating these processes. However, this also includes understanding why and when learning does not occur as well as when perceptual processing is disrupted.

The present chapter will examine perceptual category learning and expertise from a variety of perspectives. First, we consider the naturally occurring perceptual expertise of face recognition and examine specialization involved in the recognition of one's own species, own race, or own face. Second, we will describe work investigating the abilities of real-world experts and draw parallels and contrasts between the acquired forms of expertise and the naturally occurring form of face recognition. Third, we will discuss studies that examine the training of expertise and learning conditions, which promote the acquisition of expert recognition.

EXPERIENCE-DEPENDENT BIASES IN FACE PROCESSING

Humans rely on face processing abilities to accomplish a variety of everyday activities, including identifying and discriminating individuals, emotions, gender, race, attractiveness, and age. Face processing research spans the fields of cognitive, social, clinical, and developmental psychology, as well as the fields of cognitive, affective, and computational neuroscience. Thus, the importance of understanding face processing abilities in humans is reflected in the large number of empirical articles investigating this phenomenon. The purpose of this review is not to discuss the whole of the face processing literature, but to review the research that has looked at increasing levels of subspecialization *within* the domain of face processing, including the recognition of faces from other species, faces from other races, and the recognition of one's own face.

Recognition of Own and Other Species' Faces.

The other-species effect (OSE) is the phenomenon in which subjects exhibit superior recognition of members of their own species (i.e., conspecifics) relative to recognition of members from other species. The OSE has been studied by comparing recognition of primate faces (e.g., monkeys and humans) to nonprimates faces (e.g., sheep and cows) (Campbell, Pascalis, Coleman, Wallace, & Benson, 1997; Pascalis, Demont, de Haan, & Campbell, 2001) and by comparing the recognition of human and nonhuman primate monkey faces (Dufour, Pascalis, & Petit, 2006; Pascalis & Bachevalier, 1998; Pascalis, de Haan, & Nelson, 2002; Pascalis et al., 2005; Scott, Shannon, & Nelson, 2005, 2006). Assuming that human infants and adults have little perceptual experience with nonhuman primate faces relative to human faces, the OSE suggests that perceptual experience plays a role in shaping face perception abilities.

In human recognition, a perceptual advantage is found for recognition of primate faces compared to nonprimate faces. For example, in human adults recognition is disproportionately impaired for human and monkey faces as compared to sheep faces (Pascalis & Bachevalier, 1998), the so-called face inversion effect (Yin, 1969). Although the exact source of the inversion effect is controversial (Freire, Lee, & Symons, 2000; Riesenhuber, Jarudi, Gilad, & Sinha, 2004), this effect has been used as a benchmark to gauge the extent to which other stimuli are processed like human faces.

Developmental studies have shown that young (5 years) and older (8 years) children recognized human faces better than monkey faces which, in turn, were better recognized than sheep faces (Pascalis et al., 2001). Critically, similar to adults, children displayed an inversion effect for the primate human and monkey faces, but not for recognition of sheep faces. Pascalis and colleagues suggest that the human face processing system may be tuned to the character-istics of primate (human and monkey) faces by 5 years of age and that subsequent experience with own-species faces tunes this system to better dis-criminate faces with which we have experience. Although there appears to be an advantage for the recognition of primate faces over nonprimate faces in humans, several studies have found that among primates, there is a preference for faces from one's own species. For example, using looking time measures to infer human and monkey's ability to discriminate same and other species' faces, Pascalis and Bachevalier (1998) found that monkeys looked longer at novel monkey faces than novel human faces whereas humans showed the reverse pattern of looking. These findings suggest better discrimination for own-species compared to other-species faces.

In addition to the behavioral investigations described above, studies using event-related potentials (ERPs) have also reported differential responses while humans recognize and differentiate human versus nonhuman primate faces. ERPs represent the summation of electromagnetic activity generated from synchronously active neurons in the brain, resulting in a series of positive and negative voltage deflections over time. These deflections,

referred to as components, are thought to reflect the activity of underlying neural processes. ERP studies have found a negatively peaked component occurring around 170 ms after stimulus onset (called the "N170") that differentiates faces and objects (e.g., Carmel & Bentin, 2002) and is delayed (e.g., Bentin, Allison, Puce, Perez, & McCarthy, 1996) and enhanced (e.g., Rossion et al., 1999) to inverted faces compared to upright faces. In adults, the N170 ERP component has been found to be longer in latency (Carmel & Bentin, 2002) and less susceptible to inversion effects (de Haan, Pascalis, & Johnson, 2002) while participants view monkey faces compared to human faces. Furthermore, a recent investigation of the time course of human and monkey face processing, using both behavioral and ERP measures, suggests that human adults more readily learn and subsequently recognize human compared to monkey faces (Scott, Shannon & Nelson, 2005). More specifically, adult humans are not only better at recognizing human compared to monkey faces but, given the same amount of familiarization to both types of faces, can generalize recognition of frontal familiarized faces to profile views of these same faces for human but not for monkey faces. Importantly, the amplitude of the VPP component, which is thought to arise from the same neural source(s) as the N170 component (Joyce & Rossion, 2005; Rossion, Joyce, Cottrell, & Tarr, 2003), was also found to positively correlate with measures of accuracy for the human but not the monkey faces (See Figure 4.1). Thus, the amplitude of the VPP increased as accuracy increased for the human but not the monkey faces task (even when accuracy to the monkey faces was well above chance). These data support the hypothesis that previous experience with certain types of faces influences subsequent behavioral and neural processing and that this experience generalizes to the recognition of nonhuman primate faces.

One question related to studies of the OSE is whether or not these perceptual biases are genetically determined or whether they can be accounted for solely by experiential factors. As in all of the questions related to the nature or nurture of cognitive or perceptual abilities, these perceptual biases likely reflect a combination of influences including both genetic and experiential factors. However, several recent investigations have begun to elucidate the mechanisms of the development of face processing in the first year of life using human and monkey faces (Pascalis et al., 2002, 2005; Scott & Monesson, 2009). Six-month-old infants have been found to discriminate monkey faces that 9-month-olds and adults do not, suggesting that younger infants exhibit a more broadly tuned face processing system than older infants and adults (Pascalis et al., 2002). Furthermore, 6-month-old infants who were given 3 months of perceptual experience with monkey faces, by sending them home with books of images individually labeled monkey faces, maintain the ability to discriminate monkey faces at 9-months-of age (Pascalis et al., 2005; Scott & Monesson, 2009). These data suggest that, during the first 9 months of life, infants may be particularly sensitive to perceptual differences between different types of faces, and this sensitivity is subsequently decreased for faces not present in their environment.
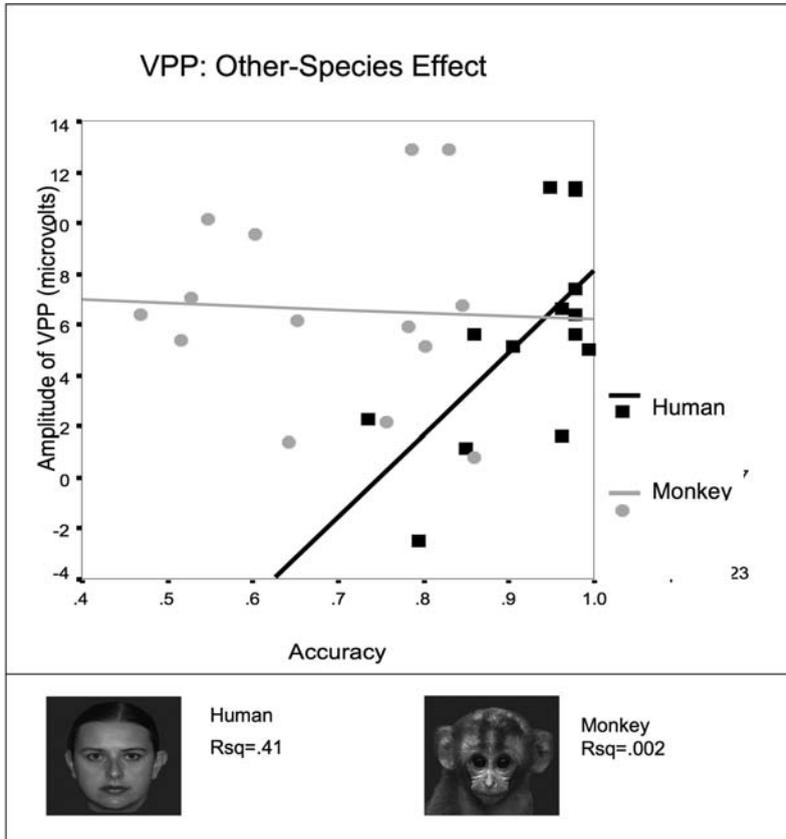
VPP: Other-Species Effect

Figure 4.1 Behavioral measures of percent correct for the monkey and human task (Scott, Shannon, & Nelson, 2005) plotted against the maximum amplitude for the VPP component. Responses to monkey faces are shown in gray; responses to human faces are shown in black. Used with permission from the Psychonomic Society/ Journal of Cognitive, Affective, and Behavioral Neuroscience, Copyright 2005.

The electrophysiological time course of human and monkey face processing has also been investigated within the first year of life (de Haan et al., 2002; Halit, de Haan, & Johnson, 2003; Scott & Nelson, 2006; Scott, Shannon, & Nelson, 2006). de Haan et al. (2002) first reported two components (the N290 and the P400) in the 6-month-old infant ERP that both appear to be developmental precursers to the adult N170 component (see also: de Haan et al., 2002; Halit et al., 2003; Scott & Nelson, 2006; Scott, Shannon, & Nelson 2006). During the first year of life, differences between upright and inverted faces and between face and nonface objects are spread across both the infant N290 and P400. However, by 12 months of age, the N290 appears to be functionally equivalent to the adult N170 (Halit et al., 2003). Differences between human and monkey face processing have been

recently investigated in 9-month-old infants (Scott, Shannon, & Nelson, 2006). In this study, ERPs were collected while 9-month-olds were presented with pictures of familiar and unfamiliar monkey or human faces in two different orientations. Earlier in processing (the infant N290), there was evidence for electrophysiological differentiation of familiar compared to unfamiliar faces, regardless of orientation or species. In contrast, later in processing (the infant P400) the response became more specific for human faces compared to monkey faces. Whereas the P400 to human faces differentiated the orientation of both familiar and unfamiliar faces, the P400 to monkey faces only differentiated at the level of familiarity. These results suggest more specific processing of human compared to monkey faces in 9-month-old humans. However, recall the above-described behavioral results, which suggest that without perceptual experience, 9-month-olds lose the ability to discriminate monkey faces (Pascalis et al, 2002, 2005). Unlike the behavioral results, ERP data suggest a residual ability, in the brain, to differentiate monkey faces in 9-month-olds.

Face expertise has also been investigated by manipulating the spacing of facial features in both human and monkey faces (Mondloch, Maurer, & Ahola, 2006). In this study adults and 8- year-olds performed a sequential, same–different discrimination task for human and monkey faces. Spacing changes were made to both types of faces. Results reveal that although adults performed better overall, both 8-year-olds and adults were better at detecting changes for human faces compared to monkey faces. This suggests that any advantage adults have over children is due to general, rather than domain-specific, cognitive and perceptual improvements such as spatial integration. The authors conclude that face-specific improvements cannot be accounted for by increased experience with faces after 8 years of age.

Recognition of Own and Other-Race Faces

The other-race effect (ORE), also called the own-race effect/bias or cross-race effect/bias, is a commonly reported phenomenon in which people have more difficultly differentiating and remembering faces of another race compared to faces within their own race (Chance, Turner, & Goldstein, 1982; Meissner & Brigham, 2001; O'Toole, Deffenbacher, Valentin, & Abdi, 1994). The ORE is assumed to reflect differential experience with own- and other-race faces. However, it is currently unclear *how* race-specific information and experience influences face processing abilities. Several developmental and adult investigations have focused on understanding what aspects of face processing are influenced by race information.

The ORE has been shown as early as 3 months of age using both visual preference tasks and visual paired comparison tasks (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005; Sangrigoli & De Schonen, 2004). Although partially present in 3-month-olds, the ORE is not seen in newborns (Kelly et al., 2005) and does not seem to be fully present until 9 months of age (Kelly, Quinn, Slater, Lee, Ge, & Pascalis, 2007). Furthermore, preferences for own-

race faces in 3-month-olds have been found to be dependent on the amount of exposure to same- versus other-race faces (Bar-Haim et al., 2006).

Similarly, investigators studying this effect in adults have historically attributed the ORE to greater exposure with faces of one's own race compared to other races (Brigham & Mallpass, 1985; Malpass & Kravitz, 1969). Investigations showing that training with other-race faces can reduce this effect also support the notion that the ORE is experience dependent (Elliott, Willis, & Goldstein, 1973; Lavrakas, Buri, & Mayzner, 1976; Malpass, Lavigueur, & Weldon, 1973). Just 1 hour of visual training significantly reduced the other-race effect, whereas visual training with one's own race did not improve performance (Malpass et al., 1973). Paired-associate training with other-race faces significantly improved later discrimination of other-race faces compared to no training or training with own-race faces (Elliott et al., 1973), but this reduction of the ORE through training does not appear to be long lasting (Lavrakas et al., 1976).

Recent training studies suggests that perceptual exposure by itself might not be sufficient to reduce the other-race effect (Tanaka & Droucker, submitted; Tanaka & Pierce, 2009). In the first phase of this experiment, Caucasian participants who had relatively little experience with non-Caucasian people were given an old/new recognition test comprised of African-American and Hispanic faces as a baseline measure. Next, participants received 2 weeks of training in which they were required to individuate African-American (or Hispanic) faces and categorize Hispanic (or African-American) (See Figure 4.2). Critically, the African-American and Hispanic faces were presented an equal number of times during training, so the faces did not differ with respect to their absolute amount of perceptual exposure.
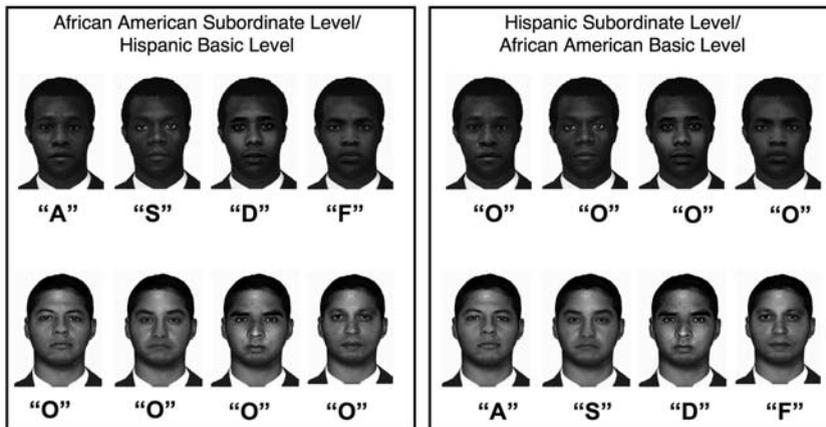

Figure 4.2 Examples of face images used in the other-race training study. Half of the Caucasian subjects completed training with African-American faces at the subordinate or individual level and Hispanic faces at the basic or category level (left box), and the other half did the opposite (right box).

After training, the participants completed an old/new recognition test with a novel set of African-American and Hispanic faces. The central finding was that recognition improved for faces from the racial group that was in the individuating condition, but there were no gains in recognition for faces in the race categorization condition (See Figure 3). These results suggest that the ORE is not mediated by amount of absolute exposure to faces from another race, but by the level at which these faces are categorized. Individuation of people from unfamiliar racial groups can help ameliorate the ORE whereas racial categorization serves to perpetuate racial differences in recognition—no matter how many times one sees faces from an other race (Tanaka & Droucker, submitted; Tanaka & Pierce, 2009).

Although it appears that the level of experience with faces helps determine the magnitude of the ORE, these studies do not address *how* race-specific visual experience influences the cognitive mechanisms of the face processing. Other studies suggest that the development of holistic or configural processing is disrupted when viewing other-race faces, leading to a decrement in recognition abilities (Fallshore & Schooler, 1995; Rhodes, Tan, Brake, & Taylor, 1989; Tanaka, Kiefer, & Bukach, 2004). The inversion of faces causes considerable decrements in recognition accuracy and reaction time compared to the inversion of objects (Yin, 1969). Presumably, inverting faces leads a disruption in configural over featural processing (Freire, Lee, & Symons, 2000). The inversion effect has been found to be greater for own compared to other-race faces, suggesting that the strategies for recognizing and discriminating other-race compared to own-race faces may depend on more feature-based processing (Fallshore & Schooler, 1995; Rhodes et al., 1989).

Using the parts and wholes task, Tanaka et al. (2004) examined the relative importance of featural and configural information in the recognition of own versus other-race faces. In this task, participants study an intact face and are then tested for their recognition of face parts presented in the whole face or in isolation. Recognition of the face part is typically superior in the whole-face condition than in the isolated condition because the whole face provides a better match with the underlying holistic face representation. When shown Caucasian and Asian faces, Caucasian participants were better at recognizing the Caucasian faces when the whole face was presented compared to just the features. However, there was no advantage for holistically presented faces when Caucasians viewed Asian faces. Furthermore, Asian participants were better at identifying the correct face when presented holistically compared to featurally for both Asian and Caucasian faces. Interestingly, Caucasians reported significantly more exposure to Caucasian compared to Asian faces, whereas Asians reported equal exposure to both.

A similar recent investigation also found differences in holistic processing, using composite faces, between own- and other-race faces (Michel, Rossion, Han, Chung, & Caldara, 2006). In the composite paradigm, the top half of a well-known person is paired with the bottom half of another well-known person (Young, Hellawell, & Hay, 1987). When participants are asked to report the identity of the cued top or bottom portion of the
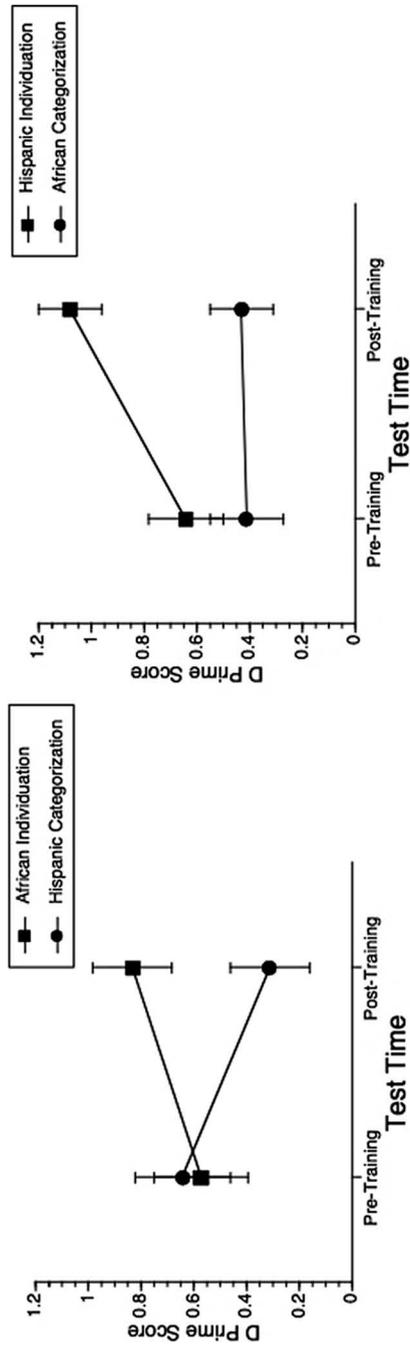
Figure 4.3 Mean d' scores on pre- and postmemory tasks for participants who completed subordinate training with African-American faces (left) and those who completed subordinate level training with Hispanic faces (right).

face, recognition accuracy is impaired when the face halves are aligned relative to when they are misaligned or when the composite face is inverted. In the aligned face condition, the to-be-ignored half of the face interferes with judgments of the to-be-attended cued portion, suggesting that the features of a face are not perceived independently of one another but are integrated in a unitary, holistic representation. Using this paradigm with Chinese and Caucasian faces, Michel and colleagues (2006) found that participants were faster to identify the top part of an aligned face if the face halves were not from the participant's race. That is, Asian participants demonstrated less configural interference for Caucasian faces whereas the Caucasian participants showed less interference for the Asian faces. These findings are consistent with evidence suggesting that the ORE may be due to a deficit in holistic relative to featural face processing when presented with other-race faces (Michel et al., 2006; Tanaka et al., 2004). However, one recent report found evidence for deficits in both featural and configural face processing in Caucasian and Chinese adults (Hayward, Rhodes, & Schwaninger, 2008). More research is needed to reconcile whether the ORE is due to specific deficits in holistic processing of other-race faces or whether there is a general face processing deficit including both featural and configural processing.

A somewhat overlapping perspective of the ORE suggests that impaired processing of other-race faces may be due to the way in which other-race faces are represented and retrieved from memory. For example, Valentine (1991) proposed a model that holds that faces are represented in a hypothetical multidimensional face space. Within this space, faces are stored based on various relevant dimensions, such as features or sets of features. Experience with faces, including learning the conditional probabilities of the feature dimensions of incoming faces, mediates the ability to encode and process various faces. Thus, the ORE results from repeated exposure to own-race faces as well as learning the invariant features, which are diagnostic to recognition and discrimination for own but not other-race faces. Once formed, this representation does not easily generalize to faces of another race (Chiroro & Valentine, 1995; Tollefson, Luxenberg, Valentine, Dunsmore, & Tollefson, 1991).

Alternately, the race-feature hypothesis holds that race information masks processing of faces when viewing other-race faces (Levin, 2000). In other words, race information is explicitly encoded for other- but not own-race faces. This processing specifies race information first, prior to recognition, which then masks processing of other individuating information used in own-race identification. Support for this theory comes from an investigation that improved other-race face recognition by informing participants of the ORE, prior to completion of a study–test recognition paradigm, and instructing them to individuate other-race faces by paying close attention to what differentiates one particular face from another of the same race (Hugenberg, Miller, & Claypool, 2007). Participants without such instructions showed a decreased discrimination of other- compared to same-race faces.

Recently, the multidimensional face space and the race-feature hypotheses were tested using both similarity ratings and identification accuracy of same- and other-race faces (Byatt & Rhodes, 2004). The results suggest that participants are more accurate and rate faces as more dissimilar for same- compared to other-race faces. Byatt and Rhodes (2004) also found that although race is an important feature in identification, it is equally important for same- and other-race faces. These data support the multidimensional face space hypothesis and suggest that same- and other-race faces form distinct clusters within face space and that other-race faces are more densely clustered within this space.

Theories of the ORE have been tested using computational models (Furl, Phillips, & O'Toole, 2002). This investigation analyzed the performance of several recognition algorithms to determine conditions in which an ORE can be generated. Results of this modeling suggest that a simple exposure–based algorithm actually leads to a recognition advantage for other- compared to own-race faces. The authors explain that this occurs because in an exposure-only system, other-race faces are seen as more distinctive and therefore more easily recognized. Thus, in order to computationally replicate the ORE, Furl and colleagues implemented a two-stage model of face learning that goes beyond the simple exposure–based algorithm and combines both a feature extraction stage and an identity classification stage. During the classification stage, the perceptual space is warped to emphasize distinctions between exemplars. This, combined with greater experience with own-race faces, leads to an increased ability to discriminate own- versus other-races faces. Thus, results of this modeling are consistent with the "developmental contact" hypothesis and suggest that behavioral differences between own and other-race faces are due to differential experience encoding distinctions between exemplars of own- versus other-race faces (Furl et al., 2002).

Work in neuroimaging has explored the neural substrates of own- and other-race face perception. The fusiform face area is a region of temporal cortex that responds more strongly to faces than to other objects using measures of functional brain activity (fMRI) (Haxby, Hoffman, & Gobbini, 2000; Kanwisher, McDermott, & Chun, 1997; Kanwisher, Stanley, & Harris, 1999; McCarthy, Puce, Gore, & Allison, 1997). This region also exhibits a greater response when experts view objects of expertise (Gauthier, Skudlarski, Gore, & Anderson, 2000; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Gauthier, Tarr, et al., 2000). Studies have found differential responses to same- versus other-race faces in regions of the fusiform gyrus (Golby, Gabrieli, Chiao, & Eberhardt, 2001; Kim et al., 2006). More specifically, Golby et al. (2001) found superior recognition memory for same- compared to other-race faces, and the difference in performance between these two types of faces correlated with increased activation to own- compared to other-race faces in the left fusiform as well as regions of the hippocampus and parahippocampal gyrus. Additionally, face familiarity appears to modulate the ORE in the fusiform area (Kim et al., 2006). In this study, Korean participants completed a familiarity judgment task while being

presented with familiar and unfamiliar Korean and Caucasian faces. Greater activation in the fusiform was found for same-race compared to other-race unfamiliar faces. This differential activation was not found for familiar faces. These data suggest that the ORE can be found using both behavioral and neuroimaging methods. Furthermore, the ORE is more robust for unfamiliar compared to familiar faces, suggesting an interaction between familiarity at the level of the race and familiarity at the level of the individual. This interaction is supported by work suggesting that training with other-race faces reduces the ORE and increases holistic processing of other-race faces (McKone, Brewer, MacPherson, Rhodes, & Hayward, 2007).

Studies using ERPs have also reported differential responses to own and other-race faces (Caldara, Rossion, Bovet, & Hauert, 2004; Caldara et al., 2003; Ito & Urland, 2005b; James, Johnstone, & Hayward, 2001). Caldara and colleagues (2003, 2004) investigated the sensitivity of the N170 to race information in faces. In both of these investigations, the N170 did not differentiate same- versus other-race faces, but modulation of race was seen for a positive component around 240 milliseconds after stimulus onset (Caldara et al., 2004). However, another recent study found the N170 to be sensitive to the race of a face (Ito & Urland, 2005). Tanaka and Pierce (2009) also found that a later ERP component is responsive to the level at which other-race faces are learned. In their study, Caucasian participants were trained to identify African-American or Hispanic faces at either the level of the individual (e.g., Bob, Joe, Frank) or race (African-American, Hispanic). Although faces from both races were presented an equal number of times during training, only faces from the individuated race elicited an enhanced N250, suggesting that this component is sensitive to the level at which other-race faces are categorized and not necessarily the amount of perceptual exposure. More work investigating the role of task context, experience, and the N170 and N250's sensitivity to same- versus other-race faces should further our understanding of the electrophysiological correlates of the ORE.

The above review suggests expertise effects within the study of face recognition and reveals a processing advantage for own- compared to other-race faces. This effect is replicable across a variety of studies and is apparent using behavioral, neuroimaging, computational modeling, and electrophysiological techniques. Furthermore, although the mechanisms responsible for this effect are still debated, differential exposure, differential experience individuating other-race faces at the subordinate level, differences in configural processing, and the early processing of race-specifying information during face perception have all been found to influence this face processing bias.

Self Recognition

In previous sections, we discussed expert recognition of human faces relative to other nonhuman species and other-race faces. The different lines of

research suggest that face expertise cuts across many levels of category distinctions and occurs at different scales of perceptual analysis. Here we examine a very narrowly defined kind of face expertise involving the recognition of a single face; namely, the recognition of one's own face. Of all the faces that we see and recognize, none are as familiar to us as our own face. From the moment of birth to the time of death, our own image is an enduring presence and a tangible manifestation of our self-identity (Gallup, 1970).

Tong and Nakayama (1999) demonstrated the special status of the own face representation in a visual search study where the target was either the subject's own face or an unfamiliar face. The subject's task was to locate the target item displayed among an array of unfamiliar distracter faces. The main finding was that search times were reliably faster by 58 ms to 77 ms when the own face was the target compared to the unfamiliar face targets. The own-face advantage was reliable over hundreds of testing trials and across different views (frontal, three-quarter, and profile) and orientations (upright, inverted) of the own face. These findings suggest that own-face representations possess a "robust" quality that differentiates them from other-face and object representations. According to Tong and Nakayama, robust representations: (a) mediate rapid visual analysis, (b) require extensive visual experience, (c) contain view-invariant information, (d) facilitate a variety of visual and decisional processes across tasks and contexts, and (e) demand fewer attentional resources. Tong and Nakayama's criteria of robustness is an apt description of expert processes where specialized perceptual routines are conferred upon the object of expertise, facilitating its fast and accurate recognition. The authors left open the question as to whether robustness can be extended to other overlearned faces (e.g., spouse, sibling) or objects (birds, cars). However, the case of own-face recognition qualifies as the narrowest form of perceptual expertise where privileged access is restricted to the recognition of a single, albeit important, face exemplar.

Other work in own-face recognition has investigated the neural substrates mediating self-recognition. Kircher and colleagues (2001) found interesting differences between the hemodynamic response to the subject's own face versus the face of their partner. Relative to when participants viewed images of their partners, images of the self led to enhanced blood oxygenation in the right limbic, left prefrontal cortex and superior temporal cortex. Viewing images of the partner, but not the self, led to right insula activiation. Thus, the subject's own-face stimulus elicits greater brain activation than even a face of someone who is highly familiar to them and with whom they have formed strong emotional associations. These results suggest that unique affective and semantic processes are triggered by the image of one's self.

The neuroimaging evidence suggests that specific neural substrates are specialized for the recognition of self, and presumably, if these structures are compromised, selective deficits or biases in own-face recognition might occur. Although there are no known cases of selective prosopagnosia for recognition of self, a study by Keenan, Nelson, O'Connor, & Pascual-Leone

(2001) examined the effects of anesthesia of the cerebral hemispheres on the perception of self and others. While undergoing an anaesthetization procedure to evaluate their epilepsy condition, patients were shown a photograph that was a 50/50 morph of their own face and the face of a famous person. After recovery, when asked to recall the photograph, patients whose left hemisphere had been anaesthetized recalled the "self" as the face that had been presented. In contrast, patients receiving right hemisphere anaesthetization were biased toward recalling the famous face. It has also been reported that patients with a right frontotemporal lesion experience a sense of detachment or estrangement from themselves (Sperry, Zaidel, & Zaidel, 1979). Other patients with right hemisphere damage misidentify those own body parts as belonging to others, a condition known as "asomatopagnosia" (Meador, Loring, Feinberg, Lee, & Nichols, 2000). These results indicate that structures in the right hemisphere play a larger role in the "expert" recognition of self.

The neural correlates of own-face effects have also been examined with ERPs. In an early study, Ninomiya, Onitsuka, Chen, Sato, & Tashiro (1998) found that when participants were monitoring a display for a famous face, their own face elicited a larger P3a (or "novelty P3") response than other nontarget stimuli (e.g., red square, unfamiliar face). The P3a is typically observed for salient, low-probability nontarget stimuli (Goldstein, Spencer, & Donchin, 2002). Thus, given the presence of other low-probability nontargets, the stronger P3a to the subject's own face probably reflects its greater salience. Similarly, a greater P300 has been found in response to the self-face in comparison with another familiar face, such as that of a friend (Scott, Luciana, Wewerka, & Nelson, 2005). Interestingly, this effect was not found in 4-year-old children. In 4-year-olds, the ERP response to the self-face is not differentiated from the mother's face, but both are both differentiated from unfamiliar faces (Scott, Luciana, et al., 2005).

Further evidence demonstrating the automaticity of own-face processing was found using the Joe/No Joe task (Tanaka, Curran, Porterfield, & Collins, 2006). In this task, participants completed a familiarization phase during which they studied a target "Joe" face ("Jane" for female subjects). They were then presented with a series of probe faces and indicated whether each probe face was "Joe" or "not Joe." The faces included the subject's own face, a same-sex "Joe" (Jane) face, and several same-sex "other" faces. Despite the fact that subjects were monitoring for Joe's face, their own face elicited an enhanced negative deflection (N250) over right posterior regions of the scalp—an ERP component associated with subordinate-level processing of faces and objects of expertise (Schweinberger, Huddy, & Burton, 2004; Schweinberger, Pickering, Burton, & Kaufmann, 2002; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002; Scott, Tanaka, Sheinberg, & Curran, 2006; 2008). The results from the "Joe/No Joe" study show that presentation of the own-face stimulus is sufficient to activate a corresponding face representation even when the own face was not directly task relevant. Although the N250 to the subject's own face was enhanced relative to Joe's face and other
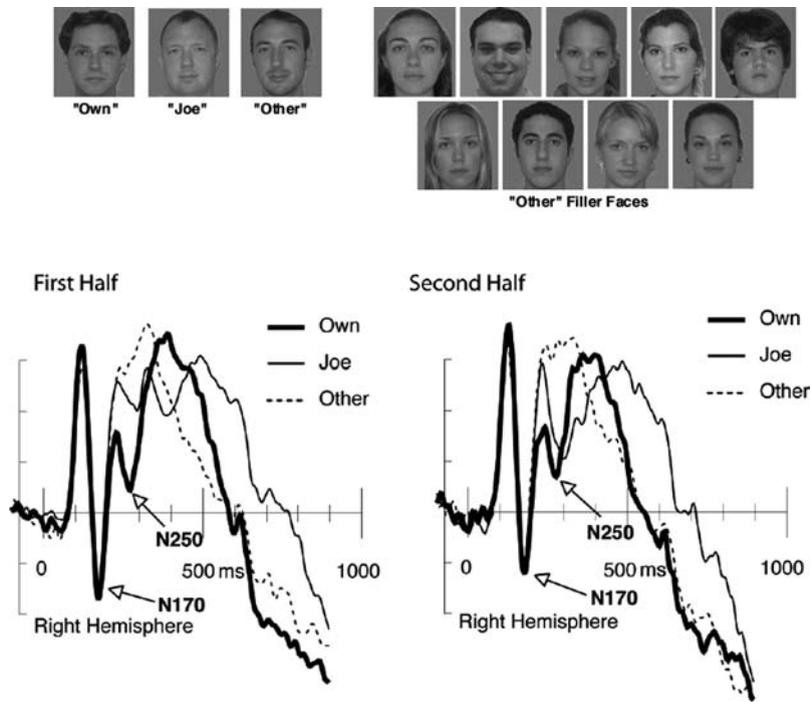
Figure 4.4 Top pictures are examples of face images used during the Joe/No-Joe task. The bottom shows the N170 and N250 response during the first and second halves of the experiment. Note that by the second half of the experiment, the N250 response to Joe's faces is equivalent in amplitude to the N250 response to the participant's own face.

nontarget faces in the first half of the experiment, Joe's face became suffi-ciently familiar over the course of the experiment to elicit an N250 that was equivalent to the own face in the second half of the experiment (See Figure 4.4). Thus, the N250 response was not specific to the subject's own face but seemed to index the familiarity of individual faces and other objects. In contrast to these findings, the N170 appears to be sensitive to the familiarity of basic-level categories (as documented below) in a fashion that does not typically discriminate objects at the individual or subordinate level (Bentin & Deouell, 2000; Eimer, 2000; Scott, Tanaka et al., 2006, 2008). However, using a continuous presentation adaptation paradigm, Jacques and Rossion (2006) report that the N170 can show sensitivity to differences in individual faces. This type of presentation may remove activation from low-level visual properties that might mask identity-level effects on the N170 using a single stimulus design.

In variations of the "Joe/No Joe" experiment, particpants monitored for either Joe's dog or Joe's car intermixed with pictures of their own dog, own

car, other unfamiliar dogs, and other unfamiliar cars (Tanaka, Curran, Boddington, & Droucker, 2005). The main finding of these experiments was that images of the subject's own dog and own car stimuli elicited an enhanced N250 component that was similar in magnitude to the ERP produced by their own face. These findings suggest that the N250 is not necessarily restricted to one's own face but can be extended to other highly familiar, self-relevant objects.

Overall, self-recognition seems to represent an extremely specific form of experience-dependent expertise that preferentially engages our core face/object identification mechanisms and also involves other processes that may be integral to processing self-identity. Just as differential experience with our own species or own race facilitates perception of faces falling within these categories, high levels of experience with individual objects such as our own face, own car, or own dog facilitates perception of these particular objects. Later, we will argue that well-controlled training studies suggest that separate neural mechanisms may support recognition at different levels of abstraction (e.g., basic versus subordinate-level) (Scott, Tanaka, et al., 2006, 2008).

This review of experience-dependent biases in face recognition examined different degrees of expertise within the domain of face recognition. Results of studies conducted with other-species faces, other-race faces, and subjects' own faces suggest an important role of perceptual exposure and individuation experience in the tuning of the neural mechanisms underlying face recognition. These results further suggest that the processes involved in the recognition of faces may be similarly recruited for objects of expertise. In the next section, we will examine the kind of acquired expertise that people develop for real-world objects, such as car experts who excel at identifying the precise makes and models of automobiles or expert "birders" who are adept at identifying species of birds. An examination of the cognitive and neurophysiological mechanisms mediating acquired expertise provides an informative contrast to the behavioral and biological processes of natural face recognition.

REAL-WORLD OBJECT EXPERTISE

Real-world perceptual expertise represents the endpoint on the continuum of perceptual category learning. Real-world expertise has been investigated across a variety of domains. For example, studies examining the abilities of dog show judges (Diamond & Carey, 1986; Robbins & McKone, 2006; Tanaka & Curran, 2001), bird watchers (Gauthier, Skudlarski, et al., 2000; Johnson & Mervis, 1997; Palmeri & Blalock, 2000; Tanaka & Curran, 2001; Tanaka & Taylor, 1991; Xu, 2005), car experts (Gauthier, Curran, Curby, & Collins, 2003; Gauthier, Skudlarski, et al., 2000; Grill-Spector, Knouf, & Kanwisher, 2004; Rossion, Collins, Goffaux, & Curran, 2007; Xu, Liu, & Kanwisher, 2005), fingerprint examiners (Busey & Vanderkolk, 2005), radiologists (Myles-Worsley, Johnston, & Simons, 1988; Nodine &

Krupinski, 1998; Nodine, Kundel, Lauver, & Toto, 1996; Nodine et al., 1999), expert fisherman (Boster & Johnson, 1989), and tree experts (Lynch, Coley, & Medin, 2000; Proffitt, Coley, & Medin, 2000) have all investigated the categorization abilities of the expert.

As mentioned previously, everyday object recognition typically occurs at the basic level (Rosch et al., 1976). As described above, the basic level for recognition of an American Tree Sparrow is "bird" whereas the subordinate level would be "American Tree Sparrow." Evidence for increased subordinate-level processing in experts comes from work showing that dog show judges and birdwatchers recognized dogs and birds at the subordinate (species) level as fast as at the basic level (Tanaka & Taylor, 1991). This result, now called the "entry-level shift" of processing has become an index of subordinate-level expertise. More specifically, there is a downward shift in reaction time, with subordinate-level training, from identifying objects at the basic level to the subordinate level with increases in expertise.

To investigate how expertise influences basic-level processing, Johnson & Mervis (1997) conducted a series of expertise studies. In these investigations, three levels of bird expertise (novices, intermediate experts, and advanced experts) were tested. These authors conclude that the basic level does not lose its privileged status as expertise increases. However, subordinate level access to objects increases with expertise. Furthermore, in the more advanced experts, subordinate level processing achieves basic-level privileges. The authors further suggest that increases in expertise leads to an increase in the ability to attend to more fine-grained perceptual features, typically associated with subordinate-level processing.

In addition to increases in the ability to process some objects of expertise at the subordinate level (see Chapter 10 for discussion of expertise that affects other levels of categorization), there is also a trend for greater holistic processing of objects of expertise. In a classic investigation, Diamond and Carey (1986) examined the inversion effect, typically found for faces, in expert dog judges and breeders. Results of this study suggest that when dog experts have sufficient knowledge to individuate dogs within a specific breed, inversion of these dogs significantly impairs subsequent memory. This result is consistent with what is found for inverted faces and led these authors to conclude that faces are not a special class of stimuli. Furthermore, they conclude that any class of stimuli that share the same basic configuration can be individuated at the subordinate level, and those in which expertise is obtained are perceived and remembered similarly to faces. In car experts relative to novices, a visual short-term memory advantage is also found for cars (Curby, Glazek, & Gauthier, 2009). This advantage is similar to what is found for faces and correlates with level of car expertise. Rossion and Curran (submitted) found that groups of car experts and novices showed similar car inversion effects, but the magnitude of the inversion effect correlated with degree of expertise within the expert group. This correlation with expertise is similar to what was reported by Curby et al. (2009) and suggests that increased expertise significantly influences perceptual processing of upright

versus inverted objects of expertise. In contrast, Robbins and McKone (2006) found no evidence of facelike holistic processing in dog experts viewing images of dogs as measured by the inversion task, the composite paradigm, and sensitivity to contrast reversal (but see Gauthier and Bukach, 2007, for a critical review of their interpretation of null results).

To more closely examine the acquisition of expertise, researchers have utilized different methods for comparing nonexperts and experts at various stages of training. Johnson and Mervis (1997) found that more advanced experts have greater access to subordinate-level object information compared to less advanced experts and novices. Mammographers with different levels of experience have been tested on their ability to detect malignant lesions (Nodine et al., 1999). Participants included expert mammographers (more than 5 years experience), 2nd-, 3rd-, or 4th-year radiology residents, and radiology technologists (who have experience with mammographic imaging but no reading experience). As radiological expertise increased, false positives decreased. Moreover, simply viewing X-ray images, as in the case of the radiology technologists, did not improve diagnostic skills. In a similar investigation, novice controls, 1st- year radiology residents (less than 1 year of radiological experience), junior staff radiologists (average of 4 years experience), and senior radiologists (average of 22 years of experience) were tested on their memory of normal and abnormal chest X-rays (Myles-Worsley et al., 1988). Recognition memory for abnormal X-rays increased with experience, but recognition memory for *normal* X-rays decreased with radiological experience. These results suggest that expertise in radiology increases the ability to remember clinically relevant abnormal X-rays, but that this increase is associated with a concomitant decrease in memory for normal X-rays.

A question of interest when studying expertise is whether being an expert in one domain leads to increased performance in other domains or increases in general abilities. For example, does being a radiologist increase your abilities on other nonradiological visual search tasks? Nodine and Krupinski (1998) looked at the abilities of radiologists and nonradiological experts in two visual search tasks. Specifically, participants completed "WALDO" (from "Where's Waldo" poster books) and "NINA" (from the hidden detection drawings appearing in theatrical scenes of the *New York Times*) visual search tasks. Results suggest no significant differences between experts and nonexperts in the ability to detect targets across both tasks. However, experts took significantly longer to search the image scenes than nonexperts. Furthermore, using eye tracking, the authors determined that the scanning patterns of the radiologists contained more fixations and covered less of the image compared to nonexperts, who used a more circumferential search pattern. In sum, radiological expertise did not increase abilities in new search tasks, with similar requirements. These results are consistent with what is typically found in perceptual learning studies and suggest that increased performance in perceptual learning tasks does not easily transfer to other related tasks (e.g., Ahissar, Laiwand, Kozminsky, & Hochstein, 1998; Fiorentini & Berardi, 1980; Poggio, Fahle, & Edelman, 1992; Sagi & Tanne,

1994). However, recently Green and Bavelier (2003) found generalization of learning in video game experts and in novices trained on an action video game. In this study, habitual video game players were found to have increased visual attentional capacity, enhanced task-switching abilities, and faster temporal processing of visual information. These researchers also trained novices on a single action video game and determined that similar to habitual video game players, training also increased visual attentional processes. Combined, these data suggest that while perceptual skills do not easily transfer, attentional skills may more readily transfer across tasks.

Recent investigations into the neural correlates of perceptual expertise find that long-term expertise with birds and cars recruits face-selective areas within the ventral temporal cortex (Gauthier, Skudlarski, et al., 2000; Xu, 2005). Furthermore, electrophysiological investigations of real-world expertise provide evidence against the notion that the N170 is a specific marker of face processing and suggest that the N170 may be involved in more domain-general processing of objects of expertise (Gauthier et al., 2003; Rossion, Curran, & Gauthier, 2002; Rossion et al., 2007; Tanaka & Curran, 2001). Tanaka and Curran (2001) established the relation between the N170 ERP component and expert object recognition. In this study, bird and dog experts completed a category verification task. Results revealed a significantly enhanced N170 ERP component when bird and dog experts categorized objects within their domain of expertise relative to objects outside their domain. These results suggest that by 170 ms after stimulus onset, objects of expertise are electrophysiologically differentiated from objects with which expertise has not been obtained.

Other research has similarly shown that the amplitude of the N170 increases with car expertise as measured by a perceptual matching task (Gauthier et al., 2003). In addition, both behavioral and electrophysiological research suggest that being an expert in one domain (e.g., cars) may interfere with perceptual processing within another domain (Gauthier & Curby, 2005; Gauthier et al., 2003; Rossion, Kung, & Tarr, 2004; Rossion et al., 2007). In one study, concurrent presentations of faces and cars reduced the N170 amplitude to faces for car experts but not for novices (Rossion et al., 2007). Another study examined interference related to holistic processing of cars and faces (Gauthier et al., 2003). Behavioral results suggested that car experts process upright cars more holistically than novices, and this interfered with holistic processing of faces. Furthermore, electrophysiological results suggest that the difference between the amplitude of the car and face N170 negatively correlates with car expertise. Thus, the greater expertise with cars (as measured by d'), the smaller the N170 difference between cars and faces. The presence of interference between faces and car expertise suggest shared neural mechanisms for processing these stimuli (see Chapter 8 for more on this topic).

A recent report with fingerprint experts found inversion effects, similar to what is found typically with faces, for images of fingerprints in fingerprint experts compared to novices (Busey & Vanderkolk, 2005). In this study the N170 to inverted fingerprints in fingerprint experts was delayed compared to

upright fingerprints. This difference was not found in fingerprint novices. These data suggest that similar to the results described above, as well as ERP studies with faces, increases in fingerprint expertise is accompanied by an increase in configural processing.

It is important to point out that not all studies of real-world experts have found expertise effects for previously identified neural indices of face processing. The M170 component is thought to be the magnetoencephalography (MEG) equivalent to the N170 ERP component. Using MEG, Xu et al. (2005) did not find expertise differences for the M170. More specifically, there was no difference between the M170 to cars and other objects in car experts or car novices. The M170 was correlated with successful face identification but not the identification of objects of expertise. Xu et al. (2005) criticized prior N170 expertise experiments for not using a localizer approach to show that the same channels showing enhanced responses to faces over objects also show expertise effects. In other words, they argue that expertise effects occurring at the time of the N170 are distinct from face-selective effects. However, the force of this argument is weakened by the fact that Xu et al. did not observe any MEG effects of expertise, even when broadly searching other locations and time points.

The above review suggests that similar to face recognition, increases in individuation or subordinate-level processing are seen in real-world experts. While some of the research suggests that real-world experts process objects of expertise holistically, other studies indicate that there may be multiple pathways to perceptual expertise involving both holistic and featural analysis. The reviewed research also reveals overlap of face and expert object processing mechanisms as evidenced by similar electrophysiological increases with bird, dog, and car expertise. Moreover, reported interference effects (Gauthier et al., 2003; Rossion et al., 2007) further supports overlapping neural resources for face and expert object processing. Although not yet directly investigated, evidence of interference also suggests that there may be somewhat limited resources for object processing, and future research should examine the limitations and trade-offs of perceptual expertise.

TRAINING EXPERTS IN THE LABORATORY

One way to mimic the acquisition of a natural expert system like face processing is to train participants to better discriminate different classes of objects. Researchers using training studies do not expect to equate laboratory-trained expertise to real-world expertise. Real-world expertise occurs on the scale of years, whereas typical laboratory training studies require only hours of training. However, training studies allow for the manipulation of different factors that may contribute to the acquisition of expertise, providing better control over variables influencing this process. Some of the important factors that have been manipulated across the different training studies include: level of categorization, supervised training versus unsupervised exposure learning, and stimulus type. Moreover, training studies have

allowed for a more precise look at generalization of learning, the relation between changes in the brain and changes in behavior, as well as the flexibility and stability of learning effects.

Face processing is thought to differ from nonexpert object processing in two ways. First, we view hundreds of faces everyday, thus it is thought that the amount of exposure to faces is greater than other object categories. Second, as mentioned previously, faces are typically individuated and thus processed at a more subordinate level than nonexpert object processing. These two differences also hold for the processing of expert stimuli. For example, bird experts not only see more birds than nonexperts, but they also individuate birds at a more subordinate (species) level compared to nonexperts (Tanaka & Taylor, 1991). Although the effects of exposure and subordinate-level processing cannot be precisely dissociated in face processing or in real-world experts, training studies allows for this dissociation. Similarly, training studies also allow for the manipulation of feedback in category learning. For example, how does supervised learning, mediated by explicit feedback, differ from unsupervised exposure to stimuli? Furthermore, manipulations of categorization level allow for a better understanding of how increases in basic versus subordinate-level processing are related to category expertise. Finally, generalization of learning occurs when performance improvements with a specific set of trained exemplars generalize or transfer to previously unlearned exemplars. Training studies also allow for better manipulations of the factors that lead to more or less generalization.

The use of training studies to examine the acquisition of perceptual expertise originated with training participants with novel objects called Greebles (Gauthier, Behrmann, & Tarr, 1999; Gauthier & Tarr, 1997, 2002; Gauthier, Tarr, et al., 1999; Gauthier, Williams, Tarr, & Tanaka, 1998). The first of these investigations found that training not only led to faster and more accurate responses, but training also increased the configural (and thus facelike) processing of Greebles (Gauthier & Tarr, 1997), evidenced by increased reaction time to trained Greeble configurations (studied parts, in a studied configuration) compared to transformed Greeble configurations (studied parts, in a different configuration). Tests of generalization of learning after Greeble training suggest that learning generalizes to Greebles that are structurally similar to the training set, but does not generalize to Greebles that are less similar to the training set (Gauthier et al., 1998).

Tanaka, Curran, and Sheinberg (2005) applied the Greeble training protocol to teach bird expertise. In this study, participants learned to classify 10 species of wading birds and 10 species owls at either the subordinate (species, e.g., Snowy Owl) or basic (wading bird) level of abstraction. Participants completed 6 days of training with the amount of training equated for both basic and subordinate-level conditions. Results indicate that participants trained at the subordinate level demonstrated increased discrimination on previously trained wading birds or owls. In addition, an "entry level shift" was observed such that subordinate training led to similar category verification times for basic and subordinate-level judgments. Furthermore,

subordinate- but not basic-level training led to greater generalization to novel exemplars within the trained species and to novel (untrained) species within that family (i.e., owls or wading birds). These data suggest that learning to individuate at the subordinate but not the basic level increases discrimination in experts.

Neuroimaging studies have more closely linked behavioral changes due to training with corresponding changes in brain activity as measured by fMRI and ERP methods (Gauthier, Tarr, et al., 1999, 2000; Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002; Scott, Shannon, & Nelson, 2006; Scott, Tanaka, et al., 2006; Tarr & Gauthier, 2000). Using fMRI, two areas of the brain, the right hemisphere "OFA" and "FFA," previously associated with face processing, have also been found to increase in activation after Greeble training (Gauthier, Tarr, et al., 1999; Gauthier, Tarr, et al., 2000; Tarr & Gauthier, 2000). More specifically, these areas are both recruited when Greeble novices become Greeble experts.

As described above, the N170 component has been found to index face processing. Furthermore, an enhanced N170 is found in real-world experts for objects of expertise compared to other nonexpert objects (Gauthier et al., 2003; Tanaka & Curran, 2001). Recently the N170 has also been investigated using training studies with nonface objects. Following Tanaka, Curran, & Sheinberg (2005), the relative contribution of subordinate- and basic-level category experience in the acquisition of perceptual expertise was investigated with both behavioral and electrophysiological measures (Scott, Tanaka et al., 2006). Behavioral results showed that subordinate- but not basic-level training improved subordinate discrimination of trained exemplars, and that this improvement generalized to novel exemplars of trained species and exemplars from novel species within the subordinate-trained family. We hypothesized that if the N170 were related to expert perceptual processing at the subordinate level, as previous findings with real-world experts suggests, then we should see an increased N170 to subordinate- but not basic-level training. However, ERP results indicated that both basic- and subordinate-level training enhanced the early N170 component, but only subordinate-level training amplified the later N250 component (See figure 4.5). These results suggest that perceptual expertise enhances neural responses to both basic and subordinate processing, with basic-level processing proceeding subordinate-level processing in time. However, this study did not address whether the increases seen for the N170 component are specific to basic-level processing or whether they can be accounted for by increased mere exposure to objects of expertise. Moreover, the processes of generalization and maintenance of learning, and whether these behavioral and electrophysiological effects can be replicated with other classes of stimuli, had yet to be determined.

To address these questions, a follow-up to the above investigation was conducted using different classes of cars as training stimuli (Scott et al., 2008). Antique cars, modern SUVs, and modern sedans served as stimuli classes. For this study ERPs were recorded before, immediately after, and 1 week after each of these classes of cars was trained at either the basic,
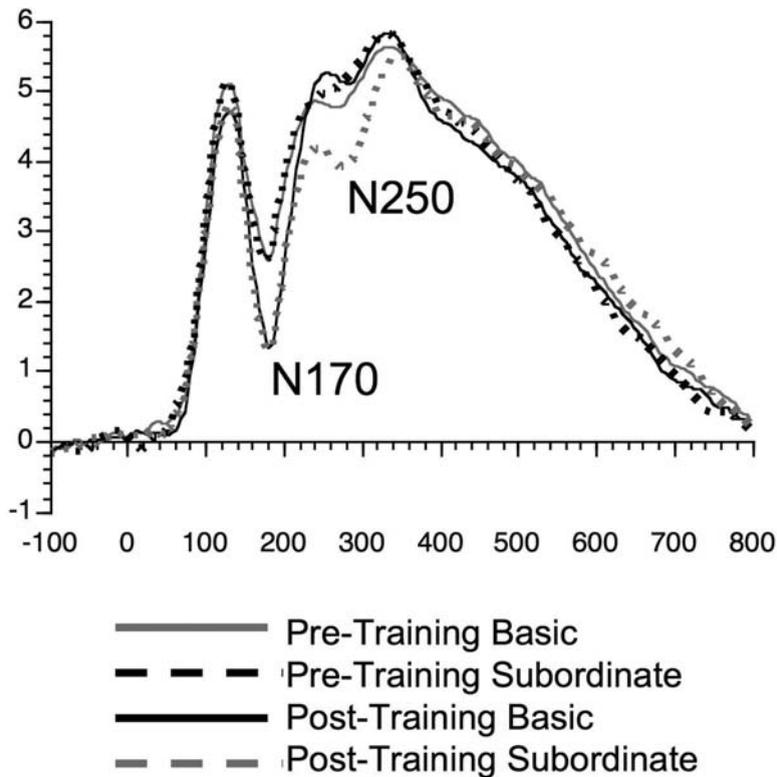
Figure 4.5 This graph pictures the right hemisphere occipital-temporal ERP response during pre and posttraining to birds trained at the subordinate versus the basic level. The N170 increased equally for both types of training, whereas the N250 only increased in response to subordinate-level training.

subordinate, or exposure-only level. Results of this study suggest better behavioral discrimination of cars trained at the subordinate level compared to the basic and exposure-only conditions, and this ability does not degrade after a week without training. Interestingly, basic-level and exposure-only training yields similar later discrimination, both immediately and 1 week later. However, unlike the previous study with birds, there appears to be less generalization of expertise to novel exemplars of trained car models and no generalization to novel car models. Electrophysiologically, the N170 appears to increase equally for all three types of training, but the N250 only increases in response to cars trained at the subordinate level. Similar to the observed behavioral improvements, the increase in N250, but not N170, amplitude continues 1-week posttraining. Overall, these data suggest that expertise training at the subordinate level results in an increased ability to discriminate within-class, trained exemplars and that this change is reflected in increases in the N250 ERP component.

The generalization discrepancy between the bird and car training studies may have important implications for our understanding of general category learning. First, as artifact versus natural kind objects, cars and birds have different features that help specify subordinate-level category membership. For example, color is diagnostic for the subordinate-level categorization for birds, but not diagnostic for subordinate-level categorization of cars. Other features, such as texture and contrast, may also be more diagnostic for categorizing birds compared to cars. Thus, we suggest that the greater the number of features that are diagnostic for subordinate-level category membership, the greater the generalization to unlearned exemplars will be. Identifying how bird expertise differs from car expertise might prove informative for understanding previously reported differences between living and nonliving objects, and natural versus artificial categories. Second, previous verbal experience of participants may differ for cars and birds. It is conceivable that participants' prior verbal knowledge for car labels ("Honda CRV," "Toyota Camry," etc.) is interfering with their ability to learn the new subordinate-level labels we give them during training ("Model A," "Model B," "Model C," etc.). Requiring that participants learn new labels for cars, when they may already have labels for them, might impair performance and generalization. Both of these hypotheses can be tested using novel objects whose features and variability can be manipulated.

The electrophysiological results of the bird (Scott et al., 2006) and car (Scott et al., 2008) training studies suggest that the N170 component indexes unsupervised exposure in category learning because the amplitude of this response increases regardless of the type of training (exposure training, subordinate-level training, or basic-level training). These data suggest that previous reports of the N170, which find increased amplitude to faces and to objects of expertise compared to nonexpert objects, may be due to increased exposure to these object categories. Although subordinate-level training does not appear to differentially modulate the early N170 response, the later N250 is significantly greater for objects trained at the subordinate relative to the basic level and exposure-only training. This N250 response to objects trained at the subordinate level is consistent with previous studies investigating the N250 in response to faces (Schweinberger et al., 2004; Schweinberger, Pickering, Burton, et al., 2002). These studies find a larger N250 to repeated and familiar faces compared to novel or unfamiliar faces.

The relative timing of the N170 and N250 responses is consistent with a hierarchical, simple-to-complex view of visual processing whereby later processing become increasingly more stimulus specific (Jiang et al., 2006). This account is supported by studies of face processing, studies using the Joe/No Joe task with the own face, car, and dog, and now results from training studies. Furthermore, this hypothesis is also consistent with a recent neuro-computational model of basic- and subordinate-level training (Nguyen & Cottrell, 2005). Nguyen and Cottrell were able to model the results from the bird training studies (Scott et al., 2006; Tanaka, Curran, & Sheinberg, 2005) with a two-component model of perceptual expertise. Following a common

series of lower-level visual processing stages, the model contains two separate modules that simultaneously learn basic- and subordinate-level classification tasks. Thus, similar to the electrophysiological data described above, this model depended upon a combination of supervised (back propagation) and unsupervised (autoencoder) mechanisms.

The above-described research highlights similarities between laboratory-trained experts and real-world experts. Research suggests that holistic processing increases with perceptual training (Gauthier & Tarr, 1997; Gauthier et al., 1998). In addition, similar to what is seen in real-world experts (Gauthier et al., 2003), there is also evidence of interference between faces and expert object processing in laboratory-trained experts (Rossion, Gauthier, et al., 2002). For example, Rossion, Kung, and Tarr (2004) trained participants with Greebles and found that, similar to face/car interference effects reported with real-world car experts (Rossion et al., 2007), the N170 to faces viewed concurrently with Greebles was significantly attenuated compared to the N170 to faces viewed concurrently with nonexpert objects of similar complexity. These results imply that car and Greeble expertise compete for the same holistic resources that mediate everyday face recognition.

Results of training studies have further clarified the importance of individuation training as well as unsupervised exposure in the formation of expert perceptual abilities. For example, studies looking at electrophysiological and behavioral changes over time (Scott, Tanaka, et al., 2006, 2008), have refined our understanding of the N170 component and suggest that increases in the N170 are due to increased exposure to object categories (such as faces or objects of expertise). Furthermore, the N250 component appears to be involved in subordinate-level processing of objects and faces. Overall, training studies provide a powerful tool for elucidating the mechanisms involved in the acquisition of perceptual expertise, and the use of these studies for further understanding what makes an expert "expert" is invaluable.

GENERAL CONCLUSIONS

This review was intended to give the reader a general overview of the different types of perceptual expertise currently being investigated. It was meant to underscore the differences and similarities across many different studies, examining face processing and the other-species, other-race, and self-face effects, and expert object recognition in both real-world and laboratory trained experts. Across all of these areas, the role of experience-dependent learning in shaping perceptual abilities has been examined. Results suggest that both unsupervised exposure and supervised, feedback-mediated learning at the subordinate level interact to produce recognition biases, such as the OSE and the ORE. Evidence for these different mechanisms comes from studies utilizing both behavioral and neuroscientific methods. Issues of generalization of learning were reviewed in each of the subsections

of this chapter, and although there is evidence of generalization of learning across several studies, there do appear to be limitations to generalization, which are currently not completely understood. Interference effects between objects of expertise and faces have been found in both real-world and laboratory-trained experts—suggesting shared resources for face and expert object processing. Finally, one important avenue for future research is to understand further the multiple pathways to expert perceptual processing.

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AQ3

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Chapter 4

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