The neural plasticity of other-race face recognition

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Abstract

Although it is well established that people are better at recognizing own-race than other-race faces, the neural mechanisms mediating this advantage are not well understood. In this study, Caucasian participants were trained to differentiate African (or Hispanic) faces at the individual level (e.g., Joe, Bob) and categorize Hispanic (or African) faces at the basic level of race (e.g., Hispanic, African). Behaviorally, subordinate level individuation training led to improved performance on a post-training recognition test than basic level training. As measured by event-related potentials (ERPs), subordinate and basic level training had relatively little effect on the face N170 component. However, compared to basic level training, subordinate level training elicited an increased response in the posterior expert N250 component. These results demonstrate that learning to discriminate other-race faces at the subordinate level of the individual leads to improved recognition and enhanced activation of the expert N250 component.

The neural plasticity of other-race face recognition

Although virtually everyone is an expert in face recognition, people demonstrate an even more specialized form of face expertise for the recognition of own-race faces. That is, a well established finding in the face processing literature is that people are better at recognizing faces from their own race than faces from other races (Bothwell, Brigham, & Malpass, 1989; Meissner & Brigham, 2001). The Own Race Effect (ORE) is independent of the race of the participant and race of the face. For example, Caucasian participants show an advantage for the recognition of Caucasian faces over the recognition of Asian faces whereas Asian participants show a reverse recognition advantage for Asian faces over Caucasian faces (O'Toole, Deffenbacher, Valentin, & Abdi, 1994; Walker & Tanaka, 2003). The dissociation of the ORE provides compelling evidence that the own race advantage is determined by the perceptual experiences of the observer and not by the facial geometry of the racial group (Chiroro & Valentine, 1995; Furl, Phillips, & O'Toole, 2002; Goldstone, 2003; Meissner & Brigham, 2001; Slone, Brigham, & Meissner, 2000; Valentine, 1991; Wright, Boyd, & Tredoux, 2001). However, it is less clear whether it is the quantity or the quality of the own- versus other-race face experience that influences the magnitude of the ORE.

Several studies have shown that the amount of exposure to other-race individuals can ameliorate the ORE. For instance, Caucasian individuals who live in a multi-racial neighborhood (Chiroro & Valentine, 1995) or watch sporting events played by African American athletes (MacLin, Van Sickler, MacLin, & Li, 2004) exhibit a reduced ORE compared to race-matched control participants. However, other studies have shown that substantial inter-racial contact does not necessarily ensure that other-race face recognition will improve. Caucasian participants with extensive inter-racial contact with Chinese individuals (Ng & Lindsay, 1994) do not show an improved ability to recognize faces from the other race. Developmental studies similarly show that African American children reared in a multi-cultural environment show the same level of recognition of Caucasian faces as children reared in a mono-cultural African American environment (Cross, Cross, & Daly, 1971). Meta-analysis of the ORE studies revealed that self-report measures of other-race contact accounted for less than 3% of the total variance found in the ORE (Meissner and Brigham, 2001). The equivocal findings from the social contact studies indicate that other factors beyond pure exposure to other race faces modulate the magnitude of the ORE.

Beyond experience, it has been suggested that the own-race face advantage is a consequence of categorization processes. That is, people tend to categorize members of their own race at the subordinate level of the individual (e.g., Bob, Joe) and categorize other-race members at the basic level of race (e.g., Caucasian, African American, Hispanic). Levin (2000) has argued that as a consequence of categorization processes, race defining information is abstracted from the other-race face at the cost of individuating information. Whereas basic level categorization of other-race faces produces a deficit in a recognition task, it can result in a benefit for other types of tasks. For example, in a visual search task, it was found that Caucasian participants were faster to detect an African American face target amongst Caucasian face distracters than a Caucasian target amongst African American distracters (Levin, 2000). Hence, when the relevant level of discrimination is race, participants demonstrate an other-race *advantage.*

The different levels at which own- and other-race faces are categorized is similar to the differences that distinguish experts and novices. Studies have shown that whereas experts tend to categorize objects in their domain of expertise at the specific, subordinate level of abstraction (e.g., a bird expert will identify a bird as “robin” or “sparrow”), novices will categorize the same object at the generic, basic level (e.g., a novice will categorize the same “robin” or “sparrow” as a “bird”) (Johnson & Mervis, 1997; Tanaka & Taylor, 1991). Recent training studies have shown that participants who learn to categorize owls or wading birds at the subordinate level of species (e.g., ‘‘great blue crown heron,” “eastern screech owl”) demonstrate improved discrimination of novel bird exemplars from learned and related species. In contrast, participants who learned to categorize the same birds at the basic level showed no evidence of perceptual transfer (Scott, Tanaka, Sheinberg, & Curran, 2006; Tanaka, Curran, & Sheinberg, 2005). These studies indicate that training in subordinate level categorization induces a finer grain of perceptual analysis that is not afforded by basic level learning.

To what degree can other-race face recognition be improved through subordinate level training? In a previous training study, participants were trained to categorize African American (or Hispanic) and Hispanic (or African American) faces at either the subordinate level of the individual or basic level of race (Tanaka & Droucker; submitted). After five training sessions, participants who received subordinate level training demonstrated improved recognition of novel other-race faces, whereas basic level training produced no change or impaired performance. These results suggest that, like other forms of perceptual expertise, recognition of other-race faces can be ameliorated through subordinate level training.

ERPs and own- versus other-race face recognition

Studies employing event-related potentials (ERPs) have shown that approximately 170 ms after stimulus onset, faces elicit a greater negative brain potential (N170) in right posterior electrodes relative to non-face stimuli (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Rossion, Joyce, Cottrell, & Tarr, 2003). It has been speculated that the face N170 indexes the global properties shared by all faces rather than the individuating properties of a particular face (Bentin & Deouell, 2000; Eimer, 2000). Consistent with this interpretation, studies have found that the race of the face has little effect on the latency or the amplitude of the face N170 response (Caldara et al., 2003; Caldara et al., 2004; James et al., 2001) or its related positive-going front-central Vertex Positive Potential (VPP) (Ito et al., 2004). These results suggest that the N170 is not to be sensitive to differences in racial structure of faces nor differences in people's experience to race (but see Ito and Urland 2005, for an exception).

Differences in processing of own- and other-races faces emerge around 200 ms or later. For example, the N200 component recorded from front-central midline sites is greater to own- than to other-race faces (Ito et al., 2004; James et al., 2001; Ito & Urland, 2003; 2005) whereas the P200 component, recorded from parietal sites, shows the opposite effect with greater activity to other-race black faces than own-race white faces (Ito & Urland, 2003; 2005). At the posterior occipital electrode (POZ), a positive deflection was found in response to other-race Asian faces occurring approximately 200 ms post-stimulus onset (Caldara et al., 2004). The N400 component has been shown to be larger to own-race faces in some cases (Correll, Urland, & Ito, 2006) and other-race faces in others (James et al., 2001). The varied, and sometimes conflicting, response of the post-N170 ERP components indicate that they are sensitive to the context and task demands of the experiment, tapping more into the semantics associated with own- and other-race faces rather than their perception (Ito & Urland, 2005).

Whereas the above studies have focused on individuals who are already own-race face experts, little is known about how one acquires the ability to recognize other-race faces and the neurophysiological changes that accompany enhanced other-race recognition. ERP studies in object recognition have shown that expert training promotes greater bilateral activity in two posterior components: the N170 and a later negative going N250. It is hypothesized that the N170 provides an index of the expert's category experience where experts are more frequently exposed to objects from their domain of expertise than novices (Scott, Tanaka, Sheinberg, & Curran, 2006; Tanaka & Curran, 2001). In contrast, the N250 is a marker of category specificity in which objects (Scott et al., 2006, in press) or faces (Tanaka, Curran, Porterfield, & Collins, 2006; Kaufmann & Schweingerger, 2008) that are differentiated at the subordinate level produce a greater N250 negativity relative to objects that are categorized at the basic level. Similar results were reported in repetition priming studies where repeated exposures of familiar faces elicit a larger negative brainwave (N250r) at inferior temporal sites compared to repetitions of unfamiliar faces (Schweinberger, Huddy & Burton, 2004; Schweinberger, Pickering, Jentzsch, Burton & Kaufmann, 2002). Collectively, these results indicate that the N250 component indexes an individual face representation rather than a general representation of the face category (Bentin & Deouell, 2000; Eimer, 2000).

In the current study, participants were trained to individuate other-race African American (or Hispanic) faces as individuals and to categorize Hispanic (or African

American) faces in terms of race. The number of learning trials were equated such that African American and Hispanic faces were presented an equal number of times during training and differed only in the level at which they were classified. Event-related potentials were recorded to the African American and Hispanic faces during a recognition test administered prior to and after training. Behaviorally, we predicted that the ORE would be diminished for faces trained at the subordinate level of the individual relative to faces trained at basic level of race. With respect to ERP components, there were two primary predictions under test: First, given that participants have previous and pervasive experience to faces, basic and subordinate level training should have little effect on the N170 component. Second, as a marker of subordinate level differentiation, an enhanced N250 should be produced after subordinate level training as opposed to basic level training.

Method

Participants

Twenty-four University of Victoria undergraduate students participated in this experiment, ages 18-29 (Mean = 21.0). All had normal or corrected to normal vision, were right handed, and had no history of brain injury or trauma. Participants received course credit plus $20.00 for their participation. One participant was excluded due to a technical problem with one of her data files.

Participants completed a background questionnaire regarding their experience with members from other racial groups. Nineteen participants (83%) identified themselves as Caucasian, while four participants (17%) identified themselves as belonging to other racial groups (Korean, First Nations Aboriginal, Turkish, and Thai).

Two participants (9%) reported daily, and four (17%) reported weekly contact with someone from a racial group other than Caucasian (Chinese, Japanese, Korean, East Indian). None of the participants reported having daily experience with Hispanic or African American individuals.

Stimuli

Six hundred original photographs of African American and Hispanic faces were obtained from the Department of Corrections face databases from the states of Florida, Arkansas, Georgia and Kansas. Adobe PhotoShop was used to create 440 gray-scaled images with these faces. All faces displayed neutral expressions and were males of either Hispanic or African American ethnicity between the ages of 20-35 years. Internal face features were digitally placed in a standard face template with identical hairstyle, face contour, and clothing (see Figure 1a). External cues (e.g., hairstyle, clothing) were kept constant in order to promote recognition strategies based on the facial features rather non-face strategies based on incidental cues (Bonner, Burton, & Bruce, 2003; O'Donnell & Bruce, 2001). Luminance was controlled within each racial group (African American = 121 mean luminance, Hispanic = 151 mean luminance). Images were formatted as 225 x 311 pixel bitmaps and were presented on a computer monitor (LG monitor, 1024 x 768 pixel screen resolution) positioned 60 cm from the participant. Visual stimuli subtended a visual angle of approximately 6.65 degrees and 7.59 degrees in the vertical and horizontal dimensions, respectively.

Procedure

Pre-Training Face Recognition Test. Prior to training, participants performed an old/new face recognition test. During the study phase of the test, participants viewed 12 Hispanic and 12 African American faces that were randomly presented on a computer screen. Each study trial began with a fixation cross presented for 250 ms, followed by the study face appearing for 2 seconds. The study face was followed by a blank screen and an inter-trial interval of 1 sec.

A recognition test was administered immediately following the study phase. Participants were told that they would see a series of faces and that they were to indicate whether the face appeared in the study phase. Their task was to press the key labeled "old" on the response box if the face appeared in the study phase and the key labeled "new" if it was not. Each trial began with a fixation cross that was shown for 250 ms, followed by a test face appearing on the screen for 3 sec. Participants could respond while the face was on the screen or during an additional 2 sec blank screen interval. Following the participant's response, there was a 1 sec inter-trial interval. During the test phase, 24 Hispanic faces (12 old and 12 new) and 24 African American faces (12 old and 12 new) were randomly presented. The old/new recognition test was repeated three times with a new set of 24 Hispanic and 24 African American faces. Thus, the entire recognition test was comprised of a total of 144 trials (72 Hispanic faces, 72 African American faces).

During the recognition phase of the pre-training test, the electroencephalogram was recorded from 41 electrode sites using Brain Vision Recorder software (Version 1.3, Brainproducts, GmbH, Munich, Germany). Electrodes were set in an Easy Cap and referenced to a common ground. Eye movements were recorded from electrodes set on the left and right temples, and beneath the right eye. Electrode impedances were maintained below 10 kΩ. EEG data were sampled at 250 Hz, amplified (Quick Amp, BrainProducts, GmbH, Munich, Germany), and filtered through a bandpass of 0.017 Hz – 67.5 Hz. After recording, the EEG data were filtered (0.1 Hz – 20 Hz passband), re-referenced to unlinked earlobes and ocular correction was performed (Gratton, Coles and Donchin, 1983). Subsequent artifact rejection removed trials in which the change in voltage was 35 uV or greater. All of the participants had a minimum of 68 artifact-free trials in the Hispanic and African American conditions. The ERPs were segmented into a 800 ms epoch surrounding stimulus presentation and baseline-corrected with respect to a 200-ms pre-stimulus recording interval which included the offset of the fixation cross. The offset generated a pre-stimulus negative deflection that elevated the overall positivity of the waveforms when included in the baseline correction. However, this had no effect on the comparisons between the training conditions (basic vs. subordinate) or test times (pre-training vs. post-training).

Behavioural Training. Behavioural training consisted of five 45-minute sessions on consecutive days following the pre-training assessment. Participants were randomly assigned to either the “African American individuation/Hispanic categorization” or the “Hispanic Individuation/African American categorization” training condition. Training involved a learning task, a naming task, and a timed-response task, designed so that participants would learn to individuate eight novel faces of Hispanic or African American ethnicity per day, while categorizing the converse. Importantly, none of the faces employed for training were used in the recognition test.

Learning Task. At the beginning of the first training block, participants were shown two Hispanic and two African American faces with corresponding labels underneath. Subsequent training blocks presented one new face from each race, until eight faces from each race were learned. Faces belonging to the individuation condition were presented with labels of either “A”, “S”, “D”, “F”, “G”, “H”, “J”, or “K”. Faces in the categorization condition were always presented with the letter “O”. Each face was introduced twice in this way, and participants were to press the key corresponding to the label. Stimuli remained on the screen until the participant’s response was made. A feedback screen for 750 ms with corrective information for incorrect responses followed each response. There was a 1000 ms interval between presentations.

Naming Task. Each block of the learning task was followed by a naming task. During the naming task the stimuli from the learning task were presented, in random order, with no label until a response was made. Participants were required to press the button corresponding to the identity that was previously associated with the face. Following their response participants were provided with feedback for 1000 ms to indicate whether they were correct or incorrect on each trial. On incorrect trials, the correct label was provided. Participants were required to correctly label the faces with 100% accuracy before continuing on to the next block. If they failed to do so they repeated the block until successful. This proceeded until participants had learned to individuate or categorize eight faces from each racial group.

Timed-Response Task. Following seven blocks of learning and accurate naming of the eight individuated and eight categorized faces, a timed-response task was performed for three blocks. During this task participants were again required to respond to the same stimuli presented throughout the session with the assigned keys, but this time under a response deadline of 3000 ms for the first block, 2500 ms for the second block, and 2000 ms for the final block. Feedback was then presented for 1000 ms for the first block, and 1500 ms for subsequent blocks. Participants were required to complete this task at 100% accuracy, indicating that they had successfully learned to differentiate all faces within the session.

Post-Training Old/New Recognition Test. Following five sessions of behavioural training, participants were given a post-training old/new recognition task. Procedures for the post-training recognition test were identical to those used in the pre-training recognition test. To provide a direct basis of comparison, the same face stimuli employed in the pre-training test were used in the post-training measure.

Results

Behavioural Analysis

To evaluate training effects, performance on the old/new recognition test was submitted to a repeated measures ANOVA with the factors of training (individuation, categorization), test time (pre, post) and response type (hits, correct rejections) (See Table 1). A significant main effect of test time $F(1, 22) = 14.20$, $p < 0.01$, was found showing that overall, recognition was better after training (individuation or categorization) than before training. Although the main effect of training was not reliable, $F(1, 22) = 2.71$, $p > 0.10$, there was a marginally significant training by test time interaction $F(1, 22) = 3.99$, $p = 0.058$, indicating that after training, participants in the individuation condition improved to a greater extent than those in the categorization condition (See Figure 2). Planned comparisons confirmed that the individuation and categorization conditions showed improvement after training as measured by gains in pre- to post-training performance, $p < 0.01$. However, recognition performance in the individuation condition was significantly better after individuation training than basic level training recognition performance in the categorization condition, $p < 0.01$.

A second repeated measures ANOVA was performed on *d'* scores with the main effects of training condition (individuation, categorization) and test time (pre, post). A main effect of test time was found, $F(1, 22) = 16.31$, $p < 0.01$, indicating that overall, recognition improved after training relative to before training. The main effect of training, $F(1, 22) = 1.77$, and the interaction between training condition and test time, $F(1, 22) = 1.34$, were not reliable, $p > 0.10$. Although there was no difference in performance between the individuation and categorization conditions at the time of the pre-training test (Individuation Mean = .51, Categorization Mean = .49), $p > 0.10$, there was a trend towards a recognition advantage after individuation training rather than categorization training (Individuation Mean = .93, Categorization Mean = .79), $p = 0.08$.

To test whether training influenced the response bias of participants, the response bias measure B_r was calculated and a repeated measures ANOVA was performed on the factors of training (individuation, categorization) and test time (pre, post). There was no main effect of training $F(1, 22) = .29$, $p > 0.10$. However, the main effect of test time was reliable, $F(1, 22) = 5.56$, $p < 0.05$, indicating that participants in both conditions responded more conservatively during the pre-training test. Planned comparison analyses revealed that there was no difference in response bias between the individuation and categorization conditions at either pre- or post-training tests, $p > 0.10$.

ERP Analysis

ERP analysis focused on the visual P100, N170, P200 and N250 components at posterior channels PO7 and PO8 where these components showed maximal activity. ERPs were recorded during the test trials (correct and incorrect) of the old/new face recognition test before and after training. The latency and mean amplitudes for each component were submitted to an ANOVA with training (individuation, categorization), test time (pre-training, post-training) and hemisphere (left, right) as within-groups factors.

P100

P100 latency was identified as the maximum positive peak amplitude between a window of 50 and 150 ms post-stimulus onset. A main effect of training was found $F(1, 22) = 5.03$, $p < 0.05$, indicating that the P100 occurred earlier in the individuation condition (106 ms) than the categorization condition (109 ms). No other effects reached significant levels. To compute mean amplitudes, time windows of two standard deviations around the mean latencies for individuation (76 – 135 ms) and categorization (79 – 140 ms) training conditions were selected. A repeated measures ANOVA showed that there were no main effects of training $F(1, 22) = .43$, $p > 0.10$, test time $F(1, 22) = .84$, $p > 0.10$, or hemisphere $F(1, 22) = 2.60$, $p > 0.10$. There was a significant training by hemisphere interaction $F(1, 22) = 5.19$, $p < 0.05$, indicating that the mean amplitude of P100 was smaller in the categorization condition than the individuation condition, but only in the left hemisphere[1] (See Table 2). No other interactions were reliable.

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[1] The main effect of training cannot be interpreted given that the first recognition test was administered before the training manipulation (individuation or categorization) was introduced. Interpretation of the training effect is only meaningful if it interacts with the test time factor (pre-training versus post-training).

N170

The N170 latency was identified as the maximum negative peak amplitude between a window of 120 and 200 ms post-stimulus onset. Although the test time difference was small (pre: $M = 162$ ms, post: $M = 166$ ms), this factor reached reliable levels, $F(1, 22) = 4.60$, $p < 0.05$, indicating an earlier latency after than before training. Given this difference, separate time windows of +/- 2 standard deviations around the mean latency were calculated for the pre-training (141 – 192 ms) and post-training (134-190 ms) conditions (See Table 2). A repeated measures ANOVA for mean activity revealed no main effects of training $F(1, 22) = .089$, $p > 0.10$, test time $F(1, 22) = 1.14$, $p > 0.10$, or hemisphere $F(1, 22) = .386$, $p > 0.10$. However, there was a significant training by hemisphere interaction $F(1, 22) = 7.23$, $p < 0.05$ (but see Footnote 1). No other interactions were reliable.

P200

The P200 latencies were identified as the maximum positive peak in a time window of 150 – 250 ms following stimulus presentation. A repeated measures ANOVA showed no significant latency differences for any of the main factors or their interactions. A mean activity (in uV) was computed using a time window +/- 2 standard deviations around the mean latency (219 ms), leading to an analysis window of 182 – 257 ms. There was a significant effect of hemisphere $F(1, 22) = 9.33$, $p < 0.01$, where overall activity was greater in the right hemisphere than the left hemisphere. There was a reliable training by test time interaction, $F(1, 22) = 7.13$, $p < 0.05$, reflecting higher P200 activity after categorization training than individuation training. The training by hemisphere $F(1, 22) = 5.46$, $p < 0.05$, and time by hemisphere $F(1, 22) = 6.50$, $p < 0.05$, interactions were also significant. (See Table 2). No other interactions were reliable.

N250 Component

The N250 component is identified as the negative going wave immediately following the P200 component, spanning a time window of approximately 100 ms (Schweinberger, Huddy, & Burton, 2004; Scott, Tanaka, Sheinberg, & Curran, 2006; Tanaka, Curran, Porterfield, & Collins, 2006). Based on visual inspection of the data, the N250 component was identified as the mean activity occurring 220 ms to 330 ms post-stimulus onset. A repeated measures ANOVA was performed with the between-group factor of individuated race (African American, Hispanic) in addition to the within-group factors of training, test time, and hemisphere. The variable of individuated race was not reliable nor did it reliably interact with any of the other variables, $p > 0.05$, indicating that there were no differences between the African American and Hispanic faces. Results indicated a main effect of training, $F(1, 22) = 11.92$, $p < 0.01$, and hemisphere $F(1, 22) = 5.81$, $p < 0.05$. There was no main effect of test time $F(1, 22) = .90$, $p > 0.10$. Critically, there was a significant condition by test time interaction, $F(1, 22) = 18.18$, $p < 0.001$, indicating that the individuation training showed a greater increased activity in the N250 component from pre- to post-assessment relative to categorization training (See Figures 4 and 5). No other interactions were reliable.

Planned comparisons confirmed this interpretation where individuation and categorization training conditions were not significantly different at pre-assessment, $p > 0.10$. However, the individuation condition showed significantly greater N250 activity than the categorization condition at post-assessment, $p < 0.001$. Moreover, whereas the difference between the pre- and post-training N250 component was reliable in the individuation condition, $p < 0.001$, the difference was not significant in the categorization condition, $p > 0.10$. (See Figures 4 and 5.)

The change in pre- and post-training recognition of African American faces was reliably correlated with the change in magnitude of the N250 component ($r = -.426$, $p < 0.05$) (as shown in Figure 6). Specifically, as other-race face recognition improved, there was a linear increase in the N250 amplitude. Although this pattern was only observed for recognition of the African American faces, other studies have suggested that enhancement of the N250 component is reliably linked to expert perception. For example, object training studies have shown that as participants gain the perceptual skill to discriminate objects at the subordinate level, there is a significant increase in the N250 component (Scott et al., 2006; Scott, Tanaka, Sheinberg, & Curran, in press). A recent study has also shown that when engaged in a difficult perceptual categorization task, the "high" learners (i.e., participants who successfully met the learning criterion) can be distinguished from the "low" learners (i.e., participants who failed to meet the training criterion) based on the magnitudes of their N250 (Krigolson, Pierce, Holroyd & Tanaka, in press). These results suggest that the N250 reflects the formation of perceptual representations that support the fine grain visual discriminations of the expert.

Discussion

In this study, participants were trained to identify African American and Hispanic faces at either the basic level of race or the subordinate level of the individual. Prior to training, participants did not differ in their ability to recognize African American and Hispanic faces. While recognition of both African American and Hispanic faces was improved after training, recognition of faces from the individuated race (African American or Hispanic) was superior to recognition of faces from the categorized race. This result replicates findings from a previous other-race training study demonstrating that subordinate level learning enhances the recognition of novel, other-race faces (Tanaka & Droucker, submitted).

Other-race training also elicited changes in ERP processing components. After individuation and categorization training, the peak latency of the face N170 component to the African American and Hispanic faces occurred slightly earlier (pre-training: 166 ms, post-training: 162 ms) suggesting that repeated exposure to other-race faces affected the speed at which the face stimuli were accessed. However, the robustness of the latency effect is questionable given that the overall difference of 4 ms was equal to the 250 Hz sampling rate. In contrast, training had no effect on the magnitude of the N170. This finding is consistent with previous results showing that own- versus other-race faces do not elicit differences on the face N170 component (Caldara et al., 2003; Caldara et al., 2004) or the related Vertex Positive Potential (VPP) (Ito et al., 2004). It has been speculated that the magnitude of the N170 provides an index of category experience where experts show a greater N170 to objects in their domain of specialization than novices (Scott, Tanaka, Sheinberg, & Curran, 2006, *in press;* Tanaka & Curran, 2001). Because most people are already "face experts," the modest amount of face experience provided in the face training experiment pales in comparison to the lifetime of experience that people have with faces (Caldara et al., 2003; Caldara et al., 2004).

An unexpected finding was the greater left hemisphere P200 component that was produced after categorization training. It been suggested that this component might reflect the semantic information that is associated with a face (Caldara et al. 2004). Other researchers have hypothesized that the P200 plays a role in combining individual facial features into an integrative whole (Milivojevic, Clapp, Johnson, & Corballis, 2003). However, neither of these interpretations explain why basic level categorization training would enhance semantic processing or induce holistic perception.

Differences between individuation and categorization face training were most prominent in the N250 component. After learning to individuate African American or Hispanic faces, faces from the individuated race elicited a greater N250 component than faces from the categorized race. This result is consistent with previous studies where the N250 is responsive to the identities of familiar people (Herzmann, Schweinberger, Sommer, & Jentzsch, 2004; Schweinberger et al., 2004; Tanaka et al., 2006). The current results show that the N250 component extends beyond previously familiar faces and generalizes to new within-category faces as a consequence of individuation training. It is notable that this difference was recorded during administration of an old/recognition test, where ostensibly, the participant's task is to individuate faces. Yet because only faces from the individuated race, but not the categorized race, produced the heightened N250, this component appears to be influenced by prior training in subordinate level categorization and not by overt task demands.

The other-race N250 finding is analogous to the object training results where participants who learned to differentiate models of cars (Scott et al., in press) or species of birds (Scott et al., 2006) produced an enhanced N250 to novel exemplars from the trained categories. In the current experiment, the N250 to individuated African American faces did not generalize to categorized Hispanic faces (or vice versa). Similarly, in the object training studies, the enhanced N250 did not extend to exemplars from other basic level categories (e.g., antique cars, if trained on subordinate-level sedans or wading birds, if trained with subordinate-level owls). These findings suggest that the level of specificity as coded by the N250 is flexible and determined by categorization training.

This study sheds light on the important differences and similarities between face expertise and object expertise. Most people are face experts to the extent that we are exposed to hundreds of faces on an everyday basis and over the years, have accumulated a vast catalog of experience to faces. Hence, as a neural correlate of face experience, the N170 is less affected by the additional exposure to other-race faces received during the training sessions. In contrast, people have less experience individuating faces from other racial groups. Our results show that training participants to individuate members from another race fostered improved recognition of novel faces and elicited changes in the N250 component - the brain potential identified with expert perception and recognition.

To summarize, the current findings are compatible with a perceptual expertise account of the other-race effect. According to this view, as experts, we differentiate own-race faces at the subordinate level of the individual, and as novices, we classify other-race faces at the basic level of race. As predicted by Levin's Feature-Specific hypothesis

(Levin, 2000), the contrasting levels of categorization influence perceptual processing of own- and other-race faces. Subordinate level individuation promotes a finer level of perceptual encoding emphasizing the unique properties of a face, which in turn enhances the memorability of own-race faces. In contrast, categorization by race accentuates race-specific features (Fiset, Blais, Gosselin, Bub, & Tanaka, 2008) deemphasizing the distinctive aspects of an individual face. Our findings suggest that the recognition of other-race faces is not inflexible and unresponsive to perceptual learning, but is adaptable and receptive to the effects of perceptual training. Here, we show that subordinate level training can improve the recognition of other-race faces, and can produce changes in the ERP component associated with perceptual expertise.

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Table 1 - Behavioural measures (percent correct for hits and correct rejections as well as d′ scores) for pre- vs post-assessment in the individuation and categorization conditions

	Individuation				Categorization			
	Hits	Correct Rejections	*d′*	B_r	Hits	Correct Rejections	*d′*	B_r
Pre	56%	62%	0.51	0.46	58%	60%	0.49	0.49
Post	66%	68%	0.93	0.43	58%	68%	0.79	0.42

Table 2 - Mean latencies and amplitudes for all components for pre- vs post-assessment for the individuation and categorization conditions

		Individuation				Categorization			
		Pre		Post		Pre		Post	
Component	Electrode	Latency (ms)	Amp. (uV)	Latency (ms)	Amp. (uV)	Latency (ms)	Amp. (uV)	Latency (ms)	Amp (uV)
P100	P07	105	8.55	102	9.52	110	8.53	103	8.71
	P08	107	9.35	108	9.84	113	9.73	111	9.65
N170	P07	168	2.56	161	3.42	165	2.34	159	2.81
	P08	168	3.00	166	2.97	165	3.20	163	3.96
P200	P07	224	7.38	215	6.96	221	7.22	220	7.77
	P08	222	8.91	219	9.29	220	9.10	215	10.99
N250	P07	N/A	7.08	N/A	5.24	N/A	7.14	N/A	7.11
	P08	N/A	8.26	N/A	6.92	N/A	8.29	N/A	9.69

Figure Captions

Figure 1. a) In the African American individuation/Hispanic categorization training condition, eight African American faces were assigned a unique letter label (A, S, D, F, G, H, I, K) and eight Hispanic faces were assigned to the same letter label (O). b) During training, participants were randomly presented with either an African American or Hispanic face and asked to respond with appropriate letter label. If the participants responded incorrectly, corrective feedback was provided. In Experiment 1, half of the participants were trained to individuate African American faces and categorize Hispanic faces and other half received the opposite training.

Figure 2. Accuracy (% correct on "old" and "new" trials) from pre- to post-assessment for the individuation and categorization conditions

Figure 3. a) Waveforms from the left hemisphere (P07) for the individuation (left panel) and categorization (right panel) conditions at pre- vs post-assessment, b) Waveforms from the left hemisphere (P08) for the individuation (left panel) and categorization (right panel) conditions at pre- vs post-assessment

Figure 4 - N250 mean activity (uV) from pre- to post-assessment for the individuation and categorization conditions

Figure 5. Topographical maps showing activity at post-assessment for the individuation

and categorization conditions (top panel) and the difference between the conditions at post-assessment (bottom panel)

Figure 6. Correlation between change in *d′* (i.e., post-training recognition – pre-training recognition) and change in N250 mean activity (uV) (i.e., post-training amplitude – pre-training amplitudes) for African American faces

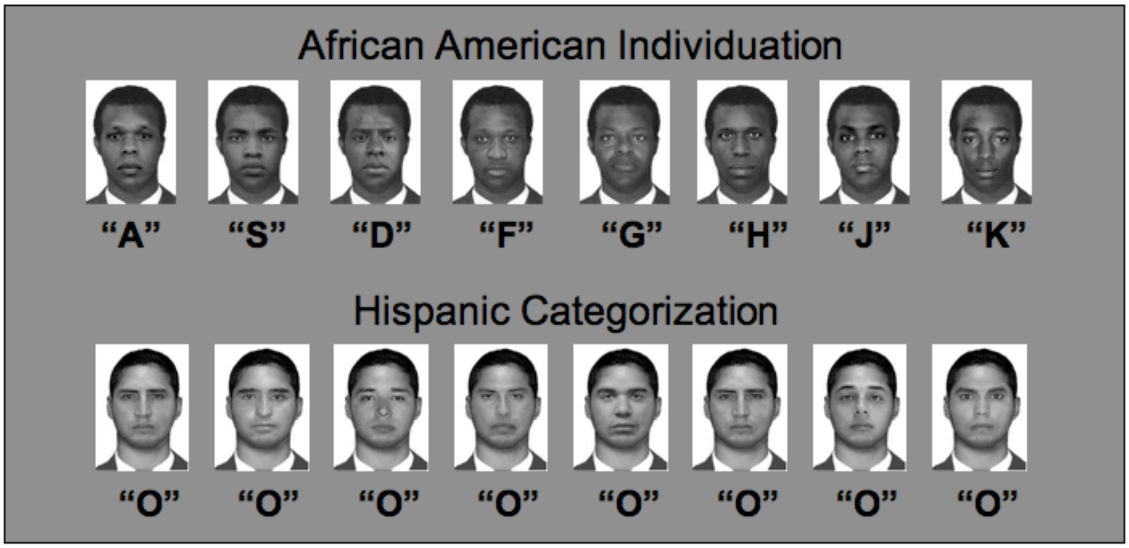

Figure 1a

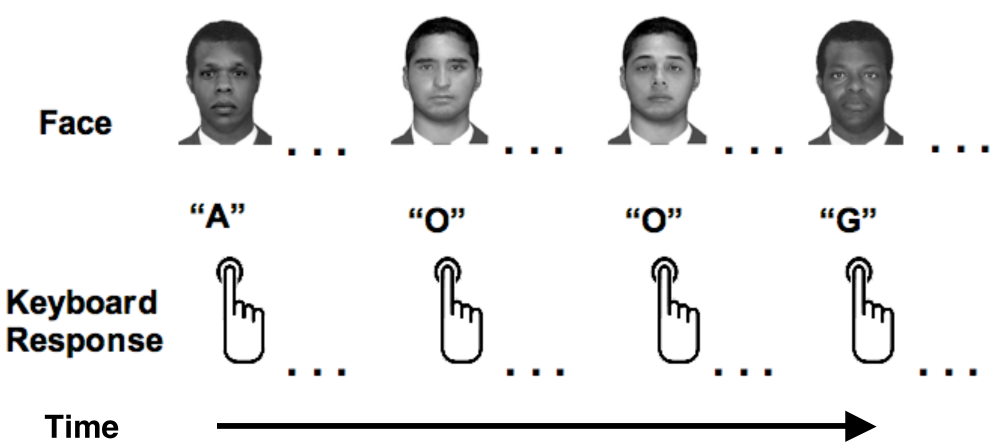

Figure 1b

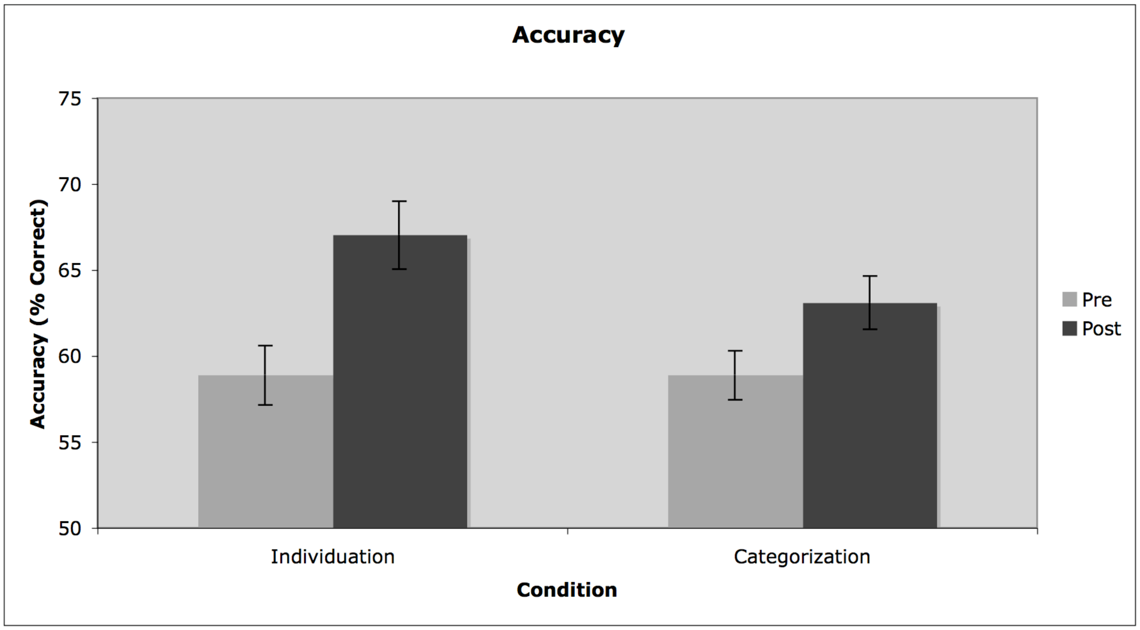
Accuracy
75
70
65
60
55
50
Accuracy (% Correct)
Individuation
Categorization
Condition
Pre
Post

Figure 2

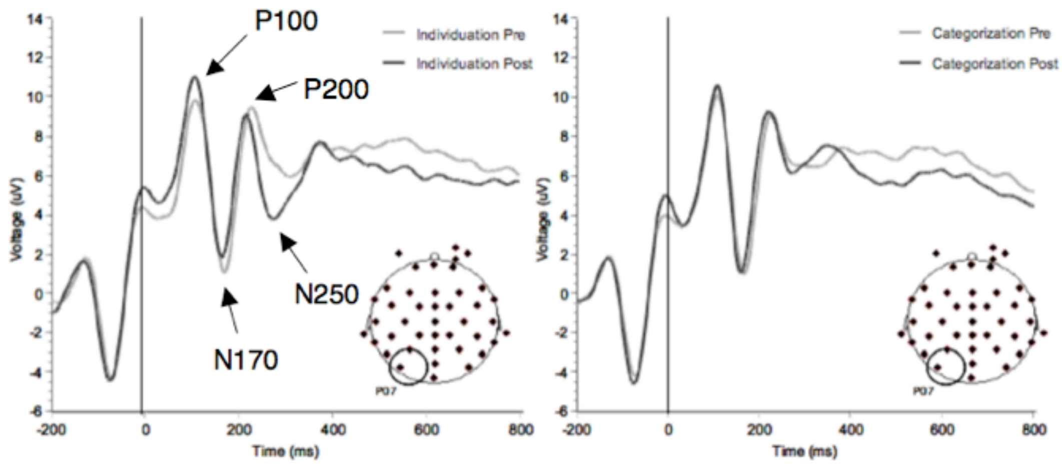

Figure 3a

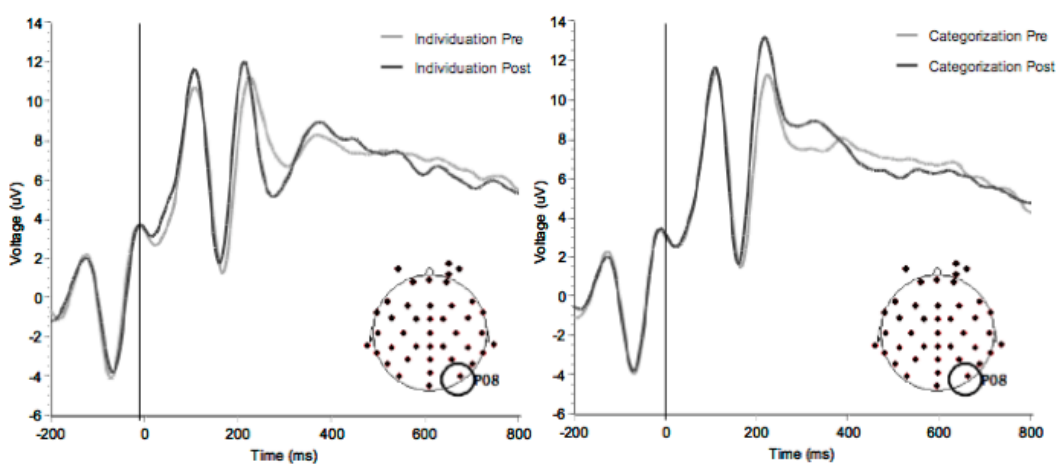

Figure 3b

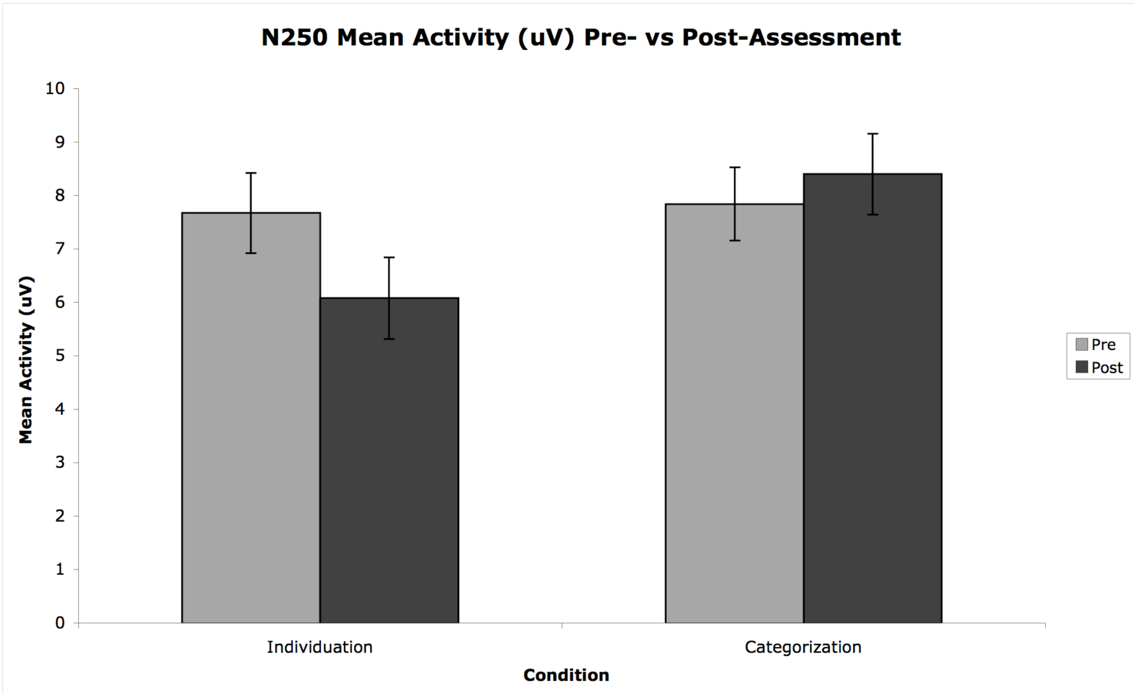
N250 Mean Activity (uV) Pre- vs Post-Assessment
Mean Activity (uV)
10
9
8
7
6
5
4
3
2
1
0
Individuation
Categorization
Condition
Pre
Post

Figure 4

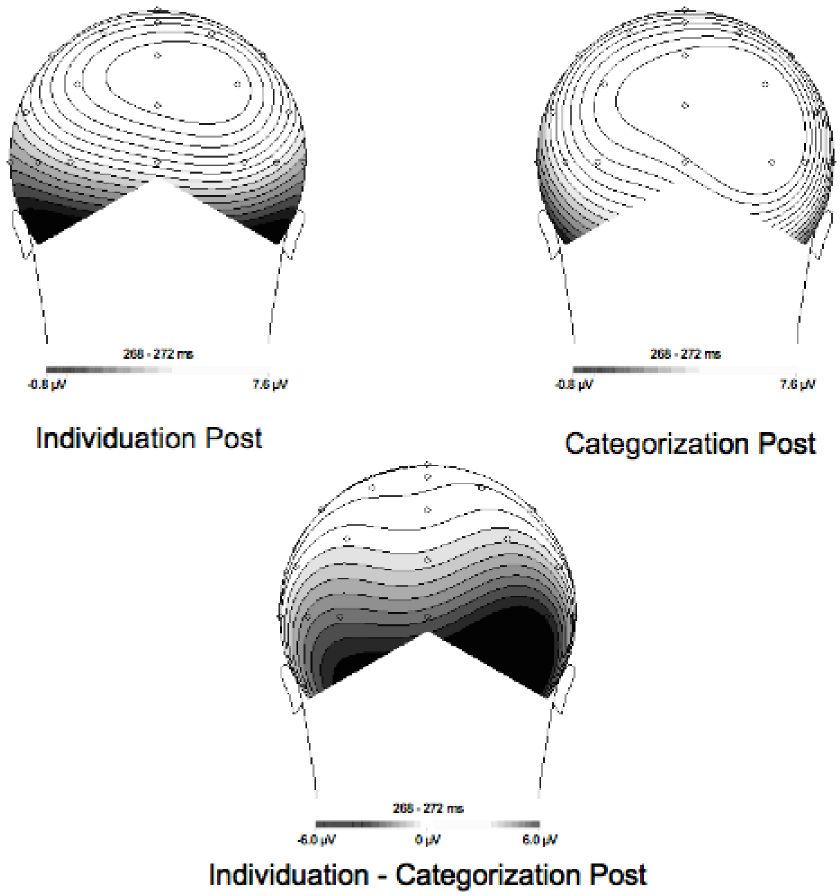
268 - 272 ms
-0.8 µV
7.6 µV
Individuation Post
268 - 272 ms
-0.8 µV
7.6 µV
Categorization Post
268 - 272 ms
-6.0 µV
0 µV
6.0 µV
Individuation - Categorization Post

Figure 5

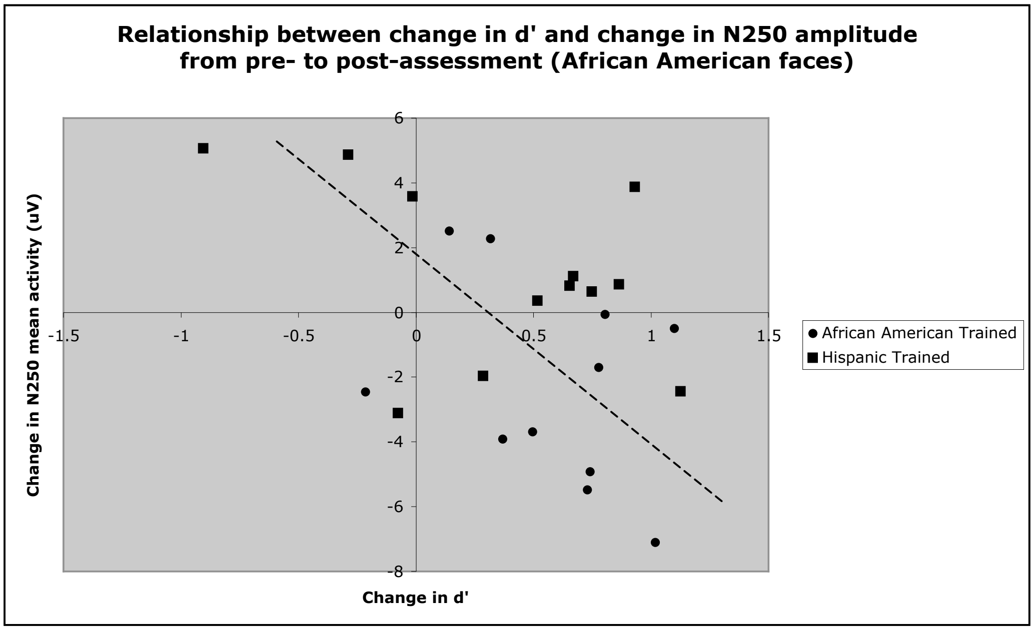
Relationship between change in d' and change in N250 amplitude from pre- to post-assessment (African American faces)
Change in N250 mean activity (uV)
Change in d'
6
4
2
0
-2
-4
-6
-8
-1.5
-1
-0.5
0
0.5
1
1.5
African American Trained
Hispanic Trained

Figure 6