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# Training with own-race faces can improve processing of other-race faces: Evidence from developmental prosopagnosia

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#### ABSTRACT

Faces of one's own race are discriminated and recognized more accurately than faces of an other race (other-race effect - ORE). Studies have employed several methods to enhance individuation and recognition of other-race faces and reduce the ORE, including intensive perceptual training with other-race faces and explicitly instructing participants to individuate other-race faces. Unfortunately, intensive perceptual training has shown to be specific to the race trained and the use of explicit individuation strategies, though applicable to all races, can be demanding of attention and difficult to consistently employ. It has not yet been demonstrated that a training procedure can foster the automatic individuation of all otherrace faces, not just faces from the race trained. Anecdotal evidence from a training procedure used with developmental prosopagnosics (DPs) in our lab, individuals with lifelong face recognition impairments, suggests that this may be possible. To further test this idea, we had five Caucasian DPs perform ten days of configural face training (i.e. attending to small spacing differences between facial features) with own-race (Caucasian) faces to see if training would generalize to improvements with other-race (Korean) faces. To assess training effects and localize potential effects to parts-based or holistic processing, we used the part-whole task using Caucasian and Korean faces (Tanaka, J. W., Kiefer, M., & Bukach, C. M. (2004). A holistic account of the own-race effect in face recognition: evidence from a cross-cultural study. Cognition, 93(1), B1–9). Results demonstrated that after training, DPs showed a disproportionate improvement in holistic processing of other-race faces compared to own-race faces, reducing their ORE. This suggests that configural training with own-race faces boosted DPs' general configural/holistic attentional resources, which they were able to apply to other-race faces. This provides a novel method to reduce the ORE and supports more of an attentional/social-cognitive model of the ORE rather than a strictly expertise model.

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# 1. Introduction

A consistent and robust finding in the face recognition literature is that faces of one's own race are recognized more accurately than faces of an other race. This has become known as the otherrace effect (ORE; for review, see Meissner & Brigham, 2001; Sporer, 2001). The ORE begins to develop in infancy (Ferguson, Kulkofsky, Cashon, & Casasola, 2009; Sangrigoli & De Schonen, 2004) and continues to be influenced by ones environment throughout development and into adulthood. For example, greater contact with members of other races has shown to improve recognition of faces

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from that race (Hancock & Rhodes, 2008; Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005). Own-race faces have been consistently shown to be encoded in a more configural and holistic manner than other-race faces, which may account for some of the greater proficiency with own-race face recognition (Michel, Caldara, & Rossion, 2006; Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2004; but see McKone, Brewer, MacPherson, Rhodes, & Hayward, 2007 for an exception).

Two predominant models account for the ORE – perceptual expertise and social-cognitive (for a review, see Sporer, 2001). The perceptual expertise model suggests that repeated discrimination, over a period of weeks to years, engages configural and holistic processing and enhances the ability to categorize stimuli, in an automatic manner, at a more subordinate or individual level of categorization (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Rhodes, Tan, Brake, & Taylor, 1989). With regard to the ORE, this suggests that repeated discrimination of faces of

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one's own race leads to more efficient recruitment of configural and holistic processing to better individuate these faces. One key assumption of expertise theories is that training configural and holistic skills with one race will not generalize to faces of other races, possibly due to featural and structural differences between faces of different races (Zhuang, Landsittel, Benson, Roberge, & Shaffer, 2010). Supporting the expertise account, Kelly et al. (2007) showed that infants at 3 months are able to recognize both ownand other-race faces equally. However, by 9 months they demonstrate a robust advantage for recognizing own-race faces (Kelly et al., 2007), suggesting that the ORE develops with more own-race face experience and, perhaps, perceptual narrowing mechanisms to preferentially process own-race faces. Additionally, Sangrigoli et al. (2005) demonstrated that cross-cultural adoption at a young age abolishes the ORE (for the race of the adopting parents), suggesting that experience individuating other-race faces can overcome children's ORE (Sangrigoli et al., 2005).

In contrast to perceptual expertise theories, social-cognitive theories suggest that the manner in which a face is processed depends on whether the face is perceived as a member of one's in-group or out-group: in-group members are processed more at the individual level and recruit more configural and holistic processes, whereas out-group members are processed less deeply (Hugenberg, Young, Bernstein, & Sacco, 2010) and may even be processed more efficiently at the level of race (Levin, 2000; Ge et al., 2009; though see Rhodes, Locke, Ewing, & Evangelista, 2009). Levin and colleagues (2000) provided initial support for this model, demonstrating that searching for an other-race face among an array of own-race distractors is faster than searching for an own-race face among an array of other-race distractors. This finding suggests that the automatic bias to individuate own-race faces interferes with detecting own-race faces but that other-race faces that are less automatically individuated are easier to detect. Additional evidence from Michel, Corneille, and Rossion (2007) reveals that participants recruit less holistic processing when they perceive the same ambiguous race faces as from an other-race than when they were perceived as from one's own-race (Michel et al., 2007; though see Rhodes, Lie, Ewing, Evangelista, & Tanaka, 2010). Furthermore, in-group/out-group membership has shown to enhance/impair face recognition ability, respectively, in a manner very similar to the ORE: more individuating resources are devoted to in-group members and out-group effects have shown to be reduced with volitional attention (Bernstein, Young, & Hugenberg, 2007). This suggests that the ORE may be a special case of more general ingroup/out-group effects (Sporer, 2001).

Over the last 40 years several methods have been employed to enhance processing of other-race faces and reduce the ORE (Elliott, Wills, & Goldstein, 1973; Hills & Lewis, 2006; Hugenberg, Miller, & Claypool, 2006; Tanaka & Pierce, 2009). Most of these methods have been motivated by expertise models and involve mass discrimination of other-race faces. For example, Eliot and Goldstein (1973) showed that after Caucasian participants performed paired associate learning with Asian faces, they significantly improved their ability to recognize novel Asian faces. More recently, Hills and Lewis (2006) improved other-race recognition by training participants, for several hours, to attend to facial features more diagnostic for recognition of other-race faces (such as wider noses in African American faces). Furthermore, Tanaka and Pierce (2009) demonstrated that individuation training with other-race faces, but not categorization training, can enhance other-race recognition and reduce the ORE. They found improvements in recognition for other-race faces after participants trained for several hours to label individual other-race faces, likely engaging configural/holistic processing. However, there was no improved recognition for otherrace faces when participants trained to categorize these faces at the level of race over the same time period. This underscores the importance of active individuation, rather than passive experience, as a mechanism that can both produce or abolish an own-race advantage. Collectively, the effects of these short-term training procedures have shown to be specific to the race of the training faces rather than producing race-general enhancements and support expertise models of the ORE. These effects may be from enhancing attention to configural/holistic information in the trained faces, from tuning configural and holistic perceptual mechanisms to other-race faces (Tanaka & Pierce, 2009), or from enhancing attention to specific areas of the face more diagnostic for individuation (Hills & Lewis, 2006).

In contrast to these intensive training procedures, recent demonstrations suggest that other-race recognition can be enhanced by simply instructing participants to individuate otherrace faces (Hugenberg et al., 2006; Rhodes et al., 2009). After participants were explicitly informed about the ORE and instructed to try to individuate other-race faces (Hugenberg et al., 2006), they showed significantly improved recognition of other-race faces, suggesting that volitional attention to individuating aspects of faces can provide a race-general strategy to overcome the ORE. It also suggests that individuals have latent skills to successfully encode and recognize other-race faces, but only utilize these skills when there is enough motivation to do so. One negative implication of this finding is that volitional attention may be required to gain access to these race-general individuation skills, which pits other-race individuation against several other ongoing processes for control of volitional attention (for example, see Knudsen, 2007). In the current study, we investigated whether a face training procedure could create a more automatic bias to attend to configural and holistic aspects of other-race faces, and that similar to Hugenberg's demonstration, if this more automatic bias could create a race-general effect.

Evidence from a training procedure developed in our lab based on configural training with computer-generated faces suggests that this is possible. This procedure was used to enhance the general face recognition ability in an individual suffering from developmental prosopagnosia (DP), a lifelong deficit in learning and recognizing faces (DeGutis, Bentin, Robertson, & D'Esposito, 2007; Duchaine & Nakayama, 2006a). Compared to healthy controls, DPs have been shown to be consistently deficient in using configural (Barton, Cherkasova, Press, Intriligator, & O'Connor, 2003; Carbon, Gruter, Weber, & Lueschow, 2007) and holistic information to individuate faces (Yovel & Duchaine, 2006). Since our initial successful demonstration of using this procedure to improve general face recognition in a single DP, a different DP that successfully completed training reported that she became particularly better at being able to discriminate other-race (Asian) faces in her everyday life. This report was remarkable in that the version of her training only used computer-generated faces with own-race (Caucasian) features. This self-report suggested that our procedure may have created a general bias towards attending to configural and holistic aspects of all faces, including faces from other races.

To further test the idea that own-race training can produce race-general processing improvements and shed more light on the nature of the other-race effect, the current study had five new DPs perform ten days (~40 min/day) of configural face training (as described below) using computer-generated faces with Caucasian features and measured how this affected their perceptual discrimination abilities of Caucasian and Korean faces using the part-whole task (Tanaka et al., 2004). Using the part-whole task allowed us to directly measure holistic processing, the mode of processing that has consistently shown to be recruited more for own-race faces (Michel et al., 2006a, 2006b; Tanaka et al., 2004).

Based on the one DP's self-report, we hypothesized that after training DPs would exhibit enhanced attention to configural and holistic aspects of all faces, including Korean faces. This could either equally improve configural/holistic processing of both own- and other-race faces or, since DPs may have more room for improvement with other-race faces (possibly due to allocating the majority of their individuating resources to own-race faces), may produce larger improvements in other-race face perception. An alternative prediction, consistent with expertise accounts and some socialcognitive accounts, is that training to more efficiently attend to configural and holistic aspects of computer-generated faces with Caucasian features would enhance processing of Caucasian faces more than Korean faces and could possibly lead to an increased ORE.

# 1.1. Participants: developmental prosopagnosics

Five Caucasian developmental prosopagnosics (3 females) with an average age of 31.6 (SD=7.4), with normal or corrected-tonormal vision participated in the study. All participants in this study, including DPs and healthy controls (below), gave informed consent in compliance with the institutional review board of the VA Boston Healthcare System and were tested at either the VA Boston Medical Center in Jamaica Plain, MA, or the Vision Science Laboratory at Harvard University in Cambridge, MA.

To be considered a developmental prosopagnosic, each participant had to report a significant lifelong history of facial recognition deficits and answer "yes" to the following questions: (1) Do you find it hard to recognize someone you just met?, (2) Do you have difficulty recognizing casual acquaintances out of context?, (3) When you meet someone, do you pretend to recognize them until their identity is revealed?, (4) Do you have trouble recognizing people when they are in uniform?, (5) Do you find it hard to keep track of characters in TV shows and movies?, (6) Do you have trouble visualizing the faces of family and close friends?, (7) When trying to find an acquaintance, do you have trouble if they are in a room full of people?, and (8) Do you have trouble recognizing a close friend or family member in a photograph? In addition to these questions, participants also had to score 1.5 standard deviations worse than the mean of healthy controls on 2 out of 3 face tests: (1) Famous Faces Test (http://www.faceblind.org/facetests), (2) Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006b), and (3) Cambridge Face Perception Test (CFPT; Duchaine, Germine, & Nakayama, 2007). Lastly, any participant that scored above a clinical cutoff of 32 on the Autism Spectrum Quotient questionnaire (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) was excluded.

#### 1.2. Participants: healthy controls

In addition to DPs, 14 Caucasian participants (7 females) with an average age of 38.9 years old (SD = 12.8) participated in experiments for compensation. All control participants reported having never experienced difficulties with face recognition, had normal or corrected-to-normal vision, have never been diagnosed with neurological or neuropsychiatric disorders, have never lost consciousness for more than 10 min, and did not report having autism or Asperger's syndrome.

#### 1.3. Overall study procedure

DPs performed the pre-training assessments on Day 1 that included blocks of Caucasian male and Korean female faces, training was completed on Days 2–11, and the post-training evaluation was completed on Day 12. During post-training, participants completed the part-whole task for Caucasian male and Korean female faces as well as two additional tasks that included novel sets of Korean male and Caucasian female faces to ensure that training effects were not due to increased stimulus familiarity. Healthy controls performed one session of testing, completing all four part-whole blocks (Caucasian male, Korean female, Caucasian female, Korean male).

## 1.4. Part-whole task

#### 1.4.1. Part-whole stimuli

Face stimuli were identical to those in Tanaka et al. (2004) and used with permission from James Tanaka (University of Victoria). Face templates, which included the outer aspects of the face such as hair and jaw-line, were created for one Caucasian male, one Caucasian female, one Korean male, and one Korean female face. For each template, six target faces were created by inserting a combination of six different pairs of eyes, noses, and mouths of corresponding race and gender into each target face. Thus, each target face was unique; no feature appeared on more than one target face.

#### 1.4.2. Part-whole procedure

In the part-whole task, participants began each trial by fixating on a central cross for 500 ms. Next, a target face appeared in the center of the screen for 1000 ms, followed by a scrambled face mask for 500 ms (see Fig. 1). Next, either the whole target face was presented next to a distractor face, or an isolated feature from the target face was presented next to a distractor feature. For whole trials (50% of trials), participants indicated which whole face in the test phase matched the original target face while for part trials (50% of trials), participants indicated which isolated feature matched that of the original target face. For each trial, trial type (whole or part) was random, whether the distractor would differ in the eyes (1/3 of trials), nose (1/3 of trials), or mouth (1/3 of trials) was random, and the position of the test stimuli (left or right) was random. The test stimuli were presented until participants responded, either by pressing 1 for the left stimulus or 2 for the right stimulus on a standard keyboard. The interval between trials was 1500 ms. Before training, DPs completed two blocks of testing (one block of Caucasian males and one of Korean females) for a total of 144 trials. After training, DPs completed four blocks of testing (Caucasian male, Caucasian female, Korean male, Korean female) for a total of 288 trials. It has been previously demonstrated that gender does not interact with the ORE (Zhao & Bentin, 2008), so the use of different genders during the pre-training testing session is unlikely to bias the ORE results. We confirmed this assumption with additional analyses (see healthy controls and DPs sections in results).

#### 1.5. Training procedure

#### 1.5.1. Rationale

The training procedure is based on the previous observation that a prosopagnosic was able to make accurate spacing judgments between two facial features in close proximity (i.e. distance between the mouth and the nose) but was slow and inaccurate when making judgments requiring attention to multiple feature spacings across a large spatial extent of the face (Bukach, Bub, Gauthier, & Tarr, 2006). This demonstration, along with other recent studies (Caldara et al., 2005), suggests that prosopagnosics can apply some configural processing to faces, but only over a spatially limited area. Considering this, the aim of the current training was to enhance prosopagnosics' ability to integrate feature spacings across the entire spatial extent of the face. We designed a task requiring prosopagnosics to make category judgments based on integrating two vertical feature spacings, the distance between the eye and eyebrows and between the mouth and nose (see Fig. 2). The logic was that prosopagnosics would quickly become faster and more accurate at making serial judgments about each feature spacing and, after thousands of trials, would learn to allocate attention to both



**Fig. 1.** Part-whole task. A target face appeared in the middle of the screen for 1000 ms followed by a scrambled face mask for 500 ms. Next, either the whole target face was presented next to a distractor face, or an isolated feature from the target face was presented next to a distractor feature. For whole trials, participants indicated which whole face in the test phase matched the target face (correct face shown in green), while in part trials, participants indicated which isolated feature matched that of the original target face (correct part shown in green). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

feature spacings simultaneously in a more efficient and possibly holistic manner.

#### 1.5.2. Training protocol

Training took place at DPs' homes using laptop computers. Each DP viewed a series of computer-generated faces with Caucasian features and hairstyles and were asked to categorize each face based on the location of the eyebrows and mouth. Faces that had relatively lower eyebrows and lower mouths belonged to category 1 and faces with relatively higher eyebrows and higher mouths belonged to category 2 (see Fig. 3). After each trial, the participant received feedback indicating their accuracy. For 10 days, participants completed 3 blocks of 250 trials each day, for a total of 7500 trials. After each training block, participants checked their accuracy and response time for each face to try and boost their performance on the next block. Participants were told to focus on both their accuracy and speed, with an accuracy goal of above 90% with under one second reaction time. In order to facilitate learning a general skill rather than particular faces, during the first 5 days of training, 5 different template faces were provided. These template faces were repeated on training days 6 through 10.

#### 1.6. Race contact survey

Following initial testing, DPs were asked to complete a survey regarding their contact with Asian faces. They were asked the following questions: "Since birth, what cities have you lived in, and for how many years?" and "For each city listed above, how often did you interact with an Asian person face to face: (a) every day, (b) every week, (c) every month, (d) not at all". In order to approxi-



Mouth Height (mm from lowest value)

В

Α

**Eyebrow Height** 

Template Faces for Different Training Days



Fig. 2. (A) Examples of faces used in the training procedure based on one template face. Faces varied in their eyebrow height and mouth height to produce a matrix of 10 faces. Faces surrounded by black frames required a left button press (L) and face surrounded by grey frames required a right button press (R). (B) Template faces used for the different training days.

mate the amount of contact, we created a composite contact score by taking the number of years at each residence and multiplying this by the approximated contact with people of Asian descent per residence (i.e. 0: no interactions, 12: every month, 52: every week, 365: every day).

## 1.7. Data filter

To reduce the effect of outlier trials with long reaction times, any trial that exceeded 2 standard deviations above the participant's mean response time for that block was removed. Additionally, any trial with a reaction time below 200 ms was removed from the analysis. Before training, DPs had an average of 4.2 trials removed

in Korean blocks and 2.8 trials removed in Caucasian blocks. After training, DPs had an average of 3.6 trials removed in each Korean block, and an average of 3.8 trials removed in each Caucasian block. Similar to DPs, healthy controls had an average of 3.5 and 3.6 trials removed for Korean and Caucasian blocks, respectively.

#### 2. Results

## 2.1. Part/whole task: healthy controls

Healthy controls did not significantly differ from DPs in terms age (DPs: M = 31.6, stdev = 7.4; Healthy Controls: M = 38.9,



Fig. 3. Pre- vs. post-training accuracy results for Whole (A) and Part (B) Trials for DPs compared to Healthy Controls without training (Caucasian male and Korean female blocks). Error bars indicate the standard error of the mean and the dashed line indicates chance performance.

stdev = 12.8; t(17) = 1.51, p = .15) or proportion of males/females (DPs: 2 males/3 females; Healthy Controls: 7 males/7 females; t(17) = .36, p = .72).

To test whether the current results replicate the partwhole findings of Tanaka et al. (2004), healthy controls' results were analyzed using a 2 × 2 within-subject ANOVA (stimulus race × part/whole) collapsing across stimulus gender. The results revealed a significant main effect of part/whole (F(1,13)=17.98, p < .001) similar to Tanaka, showing that recognition of the face part was better in the context of the whole face than in isolation. The results also showed a significant main effect of race (F(1,13)=5.36, p < .05) with own-race faces more accurate than other-race faces. Also similar to Tanaka's results, we found a significant race × part/whole interaction (F(1,13)=7.17, p < .05), showing a larger holistic advantage for own-race compared to other-race faces.

To test the assumption that stimulus gender does not interact with the other-race effect, we performed a  $2 \times 2 \times 2$  withinsubject ANOVA (stimulus race  $\times$  part/whole  $\times$  gender). We did not find a significant main effect of stimulus gender (F(1,13)=2.16, p=.17), nor a significant interaction between part/whole and gender (F(1,13)=.02, p=.88), race and gender (F(1,13)=2.95, p=.11), nor a significant three-way interaction between part/whole, race, and gender (F(1,13)=.01, p=.91).

#### 2.2. Part/whole task: DPs

To determine whether DPs showed significant performance changes following training, DPs' results were analyzed using a  $2 \times 2 \times 2$  within-subjects ANOVA (pre/post training × stimulus race × part/whole). The main effect of pre/post trended towards significance (F(1,4)=6.11, p=.07; M=.59 before training; M=.70 after training) and there was a trend of a main effect of race (F(1,4)=7.19, p=.06; M=.61 Korean female faces; M=.68 Caucasian male faces), but not a significant main effect of part/whole. The interaction pre/post × race × part/whole was significant (F(1,4)=87.84, p=.001) and was driven by a dramatic improvement in holistic processing of Korean female faces after training: participants improved from a mean of .51 to a mean of .73 (see Fig. 3). In fact, analysis of simple effects of whole trials revealed

that, after training, DPs' accuracy on Korean female whole trials was not significantly different from Caucasian male whole trials.

In order to rule-out whether these holistic improvements in processing Korean faces were due to DPs simply being more familiar with the Korean stimuli post-training, we performed the same analysis as above comparing the pre-training scores with only scores from the post-training tests with novel stimuli (i.e. Korean male and Caucasian female faces). The  $2 \times 2 \times 2$ within-subjects ANOVA (pre/post × stimulus race × part/whole) again showed a trend of a main effect of pre/post (F(1,4) = 6.50, p=.06), a significant main effect of stimulus race (F(1,4)=9.1, p = .039; M = .63 before training; M = .69 after training), and similarly there was no main effect of part/whole. Critically, the interaction  $pre/post \times stimulus race \times part/whole remained significant$ (F(1,4) = 24.24, 4, p = .008), and was, like above, driven by a greater improvement in holistic processing of Korean faces after training. To additionally confirm that during the post-testing session there was no difference between the repeated tests (Caucasian male and Korean female) and novel tests (Caucasian female and Korean male), we performed a  $2 \times 2 \times 2$  within-subjects ANOVA (stimulus race  $\times$  part/whole  $\times$  version (repeated/novel)) and found no significant main effect of version (F(1,4) = 2.67, p = .18), or significant interaction between version and stimulus race (F(1,4) = .64, p = .47), version and part/whole (F(1,4) = .05, p = .84), or version by stimulus race by part/whole interaction (F(1,4) = .15, p = .72).

We also calculated holistic advantage for each DP (whole trial accuracy minus part trial accuracy) and differences from pre- to post-training were analyzed using a 2 × 2 within-subjects ANOVA with pre/post and stimulus race as factors (see Fig. 4). The ANOVA revealed a significant interaction that was driven by DPs processing Korean faces significantly more holistically post-training compared to pre-training (t(4) = 3.778, p < .05). Interestingly, there was no pre/post difference for whole minus part for Caucasian trials (t(4) = .178, p = .867).

#### 2.3. Part/whole task: DPs vs. healthy controls

Comparing DPs before training with healthy controls showed that DPs were significantly less accurate than controls on Korean female whole and part trials (whole: t(17)=2.95, p < .01; part: t(17)=2.43, p < .05) and showed a trend towards DPs being worse

# Whole vs. Part Advantage for CPs and Controls



**Fig. 4.** Whole vs. Part Advantage for DPs and Healthy Controls during Caucasian male and Korean female blocks. Postive values indicate greater accuracy on whole than part trials whereas negative values indicate greater accuracy on part than whole trials. Error bars indicate the standard error of the mean.

than controls on Caucasian male whole trials (t(17)=1.78, p=.09), but not part trials (t(17)=1.48, p=.16); see Fig. 3). Additionally, before training DPs showed a reduced holistic advantage (whole trial accuracy minus part trial accuracy) for Korean female faces compared to controls (t(17)=2.32, p<.05), though DPs' and controls' holistic advantage for Caucasian trials was not significantly different (t(17)=.87, p=.40); see Fig. 4).

Comparing DPs after training with healthy controls showed no significant difference in accuracy on Korean female whole and part trials nor Caucasian male whole and part trials (see Fig. 3). DPs were also not significantly different from controls in accuracy on Korean male whole and part trials nor Caucasian female whole and parts trials. However, after training there was a slight trend for DPs to show a reduced holistic advantage compared to controls for Caucasian male faces (t(17) = 1.68, p = .11; see Fig. 4), but there was no significant difference between DPs' and controls' holistic advantage for Korean females, Korean males, nor Caucasian females.

#### 2.4. Race contact survey

Composite contact scores ranged from 0.00 to 18.25 (M=9.75, SD=7.50). Pearson correlations were performed to determine if DPs' composite contact score was related with own-race and other-race part/whole performance before and after training (correlations were evaluated at the Bonferonni-corrected alpha of .0125), but no correlation reached significance likely due to a lack of statistical power.

#### 3. Discussion

The present study demonstrates that training DPs to improve their configural/holistic processing abilities using training faces with *own-race* features improved holistic processing of *other-race* faces more than *own-race* faces and, correspondingly, substantially reduced DPs' ORE. These results support a model of DPs' ORE that is at least partially driven by a socially motivated attentional bias to holistic/configural information in own-race but not other-race faces, and demonstrates that this bias can be overcome by training a general tendency to attend to configural and holistic aspects of all faces. The generalization from training on computer-generated faces with own-race features to improvements in other-race faces suggests that, consistent with previous studies (Hugenberg et al., 2006; Rhodes et al., 2009), training with *other-race* faces. Furthermore, it suggests that DPs have some latent ability to individuate other-race faces that was uncovered by training. The current findings extend these previous studies in that DPs improved at other-race faces by employing a more automatic strategy rather than a volitional strategy. Together, the current results are more consistent with a social-cognitive account of the ORE and are somewhat counter to expertise theories, which would suggest that training with ownrace face features would produce only own-race improvements.

Comparing results pre- and post-training, DPs showed the most improvement on other-race whole trials and substantially less improvement on own-race whole trials (see Fig. 3A). Interestingly, this other-race whole trial improvement occurred without a decrement in part performance (see Fig. 3B), suggesting that effects were specific to whole trials rather than from a trade-off between whole and part-based processing. DPs' relatively smaller improvement for own-race whole trials compared to other-race whole trials likely reflects the upper limit of DPs' configural/holistic processing capacity as well as the upper limit of their attention allocation to these trials. This is consistent with a social-cognitive account of the ORE in that before training, DPs allocated more attention to holistic and configural aspects of own-race faces compared to other-race faces and that training boosted attention to configural and holistic aspects of other-race faces up to this upper limit of processing capacity.

DPs' overall post-training performance was comparable to healthy controls (see Fig. 3), even when assessed with stimuli that were novel during the post-training session. This shows that training generally improved DPs' part-whole performance closer to the normal range of behavior. One notable difference is that DPs showed a trend towards a smaller holistic advantage for Caucasian male faces compared to controls during both pre- and post-training sessions (see Fig. 4). This smaller holistic advantage for own-race faces in DPs compared to controls may reflect an upper limit of DPs' configural processing capacity. It may be possible that more long-term training with the same procedure (such as has been employed previously in our lab, DeGutis et al., 2007) could improve DPs' configural abilities with own-race faces and produce a holistic advantage more similar to healthy controls.

These findings provide several insights into the ORE in the normal population. First, the current experiment further emphasizes the importance of configural and holistic processing to the ORE (Michel et al., 2006a, 2006b; Tanaka et al., 2004). DPs showed a negligible holistic processing improvement with own-race faces compared to other-race faces after training. This suggests that training, which created a configural and holistic attention bias, did not affect own-race faces because DPs were already biased to maximally allocate their configural and holistic resources to own-race faces. This is consistent with previous studies showing robust OREs for holistic and configural coding (Hayward, Rhodes, & Schwaninger, 2008; Rhodes, Hayward, & Winkler, 2006; Rhodes et al., 1989) and less consistent for feature coding (Hayward et al., 2008; Rhodes et al., 2006). Together, these results underscore the importance of configural and holistic abilities as well as attentional allocation to these aspects of faces as mechanisms of the ORE.

The current results also suggest that *attention* to configural and holistic aspects of faces is an integral part of the ORE. Specifically, the results suggest that some portion of DPs' ORE is due to the fact that configural and holistic processing are attention-demanding operations (Palermo & Rhodes, 2002) and that, to conserve these resources, DPs are biased to only attend to configural and holistic aspects of regularly individuated faces (i.e. own-race faces). This conservation of individuation resources for in-group members is consistent with social-cognitive models (Hugenberg et al., 2010; Sporer, 2001). The results further suggest that training created a bias to allocate attention to configural and holistic aspects of all faces and significantly improved holistic perception of other-

race faces. Because training using faces with own-race features generalized to improvements with other-race faces, this suggests that attention to configural and holistic aspects of faces is a racegeneral rather than a race-specific process. This is consistent with recent evidence suggesting that face processing may rely on its own general pool of attentional resources separate from general object attention (Awh et al., 2004; Landau & Bentin, 2008; Palermo & Rhodes, 2007). For example, using an attentional blink paradigm, Awh et al. (2004) found that discriminating between digits impaired the subsequent discrimination between letters but not faces, possibly because letter and digit discrimination require featural attention whereas face discrimination relies more on configural and holistic attention. The current results further suggest that these face-specific attention resources can be applied to faces of all races. Though the nature of these configural and holistic attentional resources for faces require further characterization (such as their capacity and how they are allocated), the current results suggest that the bias to allocate these face-specific attention resources more to own-race faces than other-race faces is a substantial component of DPs' ORE, consistent with social-cognitive theories.

In addition to these insights into the mechanisms of the ORE, the current results also demonstrate a novel method to reduce the ORE. This training procedure is unique in that it created an automatic bias to attend to configural aspects of faces, produced effects that generalize to another race, and lasted as least 24 h beyond the training session. What are the mechanisms of training and why was it effective? The automaticity and longevity of the training effects are likely because participants performed thousands of trials over a period of 2 weeks, producing a routinized and readily available method of allocating attention to faces. This is in line with previous visual discrimination training experiments of comparable length (Gauthier et al., 1999; Wong, Palmeri, & Gauthier, 2009; for a review, see Bukach, Gauthier, & Tarr, 2006). The generalization of training to other-race faces may be because the procedure focused on spacings of the inner facial components, which may be similar across races (Sporer, 2001), creating a general bias in configural and holistic attention to spacings in all faces. This generalization may also be because training primarly affected visual attention processes in DPs more than perceptual processing mechanisms (due to the relatively short-term nature of training) and training visual attention has shown to generalize more than visuo-perceptual training (Fahle, 2005; Green & Bavelier, 2008). Additionally, the generalization of training to other-race faces could be because the training faces were computer-generated and somewhat generic-looking. Because the faces looked slightly unreal and somewhat ambiguous in their race despite having Caucasian features, the attention skills trained may have more easily transferred to other-race faces.

Taken together, the results fit better with an attentional/socialcognitive account of DPs' ORE and are less consistent with a purely expertise account. However, some levels of face processing expertise are necessary to explain the results. First, DPs must have some skill in efficiently detecting the race of a face in order to know whether to apply configural and holistic attention. It may be that DPs' limited face detection abilities are sufficient for gross race detection (Garrido, Duchaine, & Nakayama, 2008). Also, DPs have to have some ability to perform configural and holistic processing of own and other-race faces. These abilities may be acquired by DPs through limited successful face discriminations (Avidan & Behrmann, 2008) and possibly through more implicit subcortical mechanisms of face recognition (Johnson, 2005).

While some expertise is necessary to explain the current results, the main problem with a purely expertise account is that training uncovered DPs' latent ability to recognize other-race faces. This suggests that DPs can apply configural and holistic processing to other-race faces, but that attentional/social-cognitive biases masked these abilities. These biases could be from: (a) cognitive disregard of out-group members (Rodin, 1987), (b) because attending to aspects of other-race faces that aid in race categorization may interfere with attending to individuating aspects of these faces (Levin, 2000), or (c) that in order to conserve attentional resources, attention to configural and holistic aspects of faces is only devoted to regularly individuated faces. Regardless of the source of these biases, the current results suggest that promoting an attention bias to holistic and configural aspects of all faces can overcome them. This suggests that though subjects' attention biases are strong and automatically elicited they can be readily overcome with several hours of attention training.

Though the current study demonstrates a significant ORE in DPs and a novel way to reduce this effect, it could be that these results are specific to the part-whole task and also specific to DPs. Recent studies of holistic encoding of own- and other-race faces, as measured by the part/whole and composite effects, have shown to not significantly correlate with the size of participants' ORE in recognition memory (Michel et al., 2006a, 2006b). However, the weakness of these correlations may due to methodological factors (ie the duration of presentation of the target face in the part/whole task), as other studies have shown significant correlations between holistic processing differences between own- and other-race faces and the size of the ORE in recognition memory (Hancock & Rhodes, 2008; Rhodes et al., 1989). Also, a recent study suggests that otherrace memory effects may be even stronger than perceptual effects (Papesh & Goldinger, 2009). Thus, the current results may be even more pronounced when tested using a more long-term recognition memory task that has been traditionally used to measure the ORE. To address the second issue of whether the results are specific to DPs, we ran a preliminary group of healthy controls through the training protocol. Three out of four healthy controls show a similar effect of improving holistic processing of other-race faces after training (see supplementary Figure 1). There may be several reasons why DPs show different results from healthy controls such as healthy controls' greater proficiency with holistic processing and their potentially less reliance, compared to DPs, on attention mechanisms to discriminate faces. Thus, a more thorough investigation with additional participants would be useful to determine if this effect is general to the unimpaired population or more particular to DPs.

In summary, the current study demonstrates that hours of training DPs to improve at attending to configural and holistic aspects of all faces substantially improved DPs' other-race face performance, likely by overcoming their bias not to allocate attentional resources to configural and holistic aspects of other-race faces. Together, these results strongly support the involvement of attentional/social-cognitive factors in the ORE in which DPs allocate attention to configural and holistic aspects of regularly individuated in-group/own-race faces, but not out-group/other-race faces.

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#### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.neuropsychologia.2011.04.031.

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