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The Influence of Flankers on Race Categorization of Faces

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Abstract

Context affects multiple cognitive and perceptual processes. In the present study, we asked how the context of a set of faces affected the perception of a target face's race in two distinct tasks. In Experiments 1 and 2, participants categorized target faces according to perceived racial category (Black or White). In Experiment 1, the target face was presented alone, or with Black or White flanker faces. The orientation of flanker faces was also manipulated to investigate how face inversion effect interacts with the influences of flanker faces on the target face. The results showed that participants were more likely to categorize the target face as White when it was surrounded by inverted White faces (an assimilation effect). Experiment 2 further examined how different aspects of the visual context affect the perception of the target face by manipulating flanker faces' shape and pigmentation as well as their orientation. The results showed that flanker faces' shape and pigmentation affected the perception of the target face differently. While shape elicited a contrast effect, pigmentation appeared to be assimilative. These novel findings suggest that the perceived race of a face is modulated by the appearance of other faces and their distinct shape and pigmentation properties. However, the contrast and assimilation effects elicited by flanker faces' shape and pigmentation may be specific to race categorization, since the same stimuli used in a delayed matching task (Experiment 3) revealed that flanker pigmentation induced a contrast effect on the perception of target pigmentation.

Introduction

Contextual information plays an important role in a variety of cognitive and perceptual processes. For example, in the classic Reicher-Wheeler paradigm, participants can identify a letter better when it appears in a word (e.g., DARK) than when it appears in either a pseudoword (e.g., DARL) or a nonword (e.g., DRKL), demonstrating that word context disambiguates and facilitates the recognition of embedded letters (the word superiority effect, Reicher, 1969; Wheeler, 1970). Additionally, scene context can affect object recognition. When participants are presented with a scene, objects that are consistent with that context are recognized more easily than objects that are not (e.g., Bar, 2004; Biederman, Mezzanotte, & Rabinowitz, 1982; Davenport & Potter, 2004; Sun, Simon-Dack, Gordon, & Teder, 2011). For example, the context of a kitchen facilitates recognition of a loaf of bread relative to objects one would not expect to find in a kitchen, like a drum (Palmer, 1975). Context cues also affect face processing. Verbal contexts such as "She just found/lost \$500" can bias the valence ratings of surprised faces in positive or negative directions (Kim et al., 2004). In terms of visual contextual cues, a face appearing with different external features (e.g., hairstyle, speaking position) can be perceived as two distinct individuals even when the internal features of the face are identical (Sinha & Poggio, 1996).

In the current study, we examined a particular kind of contextual influence on face recognition: How does the presence of surrounding faces affect the perception of a single

target? In real-world situations, we frequently encounter faces in the presence of other faces and these surrounding faces may also provide a context that biases the perception of an individual target. Recent studies using faces as stimuli in the Eriksen flanker paradigm (Eriksen & Eriksen, 1974) have shown effects of neighboring faces on the perception of a target face. For example, Fenske and Eastwood (2003) had participants view a centrally presented target face which could express either positive or negative emotion. This target face might be presented alone or with flanking faces expressing positive, negative, or neutral affect presented on either side of the target face. Participants were instructed to ignore the flanking faces and report the affect of the target. The results showed that participants' RTs were faster for targets that appeared with flankers showing the same emotional expression, and participants' RTs were slower for targets that appeared with flankers showing the opposite emotional expression, demonstrating that the centrally presented face is susceptible to the emotional expressions of flanker faces (see also Horstmann, Borgstedt, & Heumann, 2006). The context provided by a set of nearby faces is thus sufficient to modulate perceptual judgments of a target.

Specifically, we aimed to examine how the racial category of surrounding faces affects the perceived race of a target face. Studies have demonstrated that a range of contextual cues (primarily verbal labels) can affect subsequent perceptual and cognitive processing of a face's race. For example, research examining the processing of racially-ambiguous faces has focused on explicit racial categorization decisions (e.g., Halberstadt, Sherman, & Sherman, 2011; Peery & Bodenhausen, 2008) or the effects of applying specific racial labels to ambiguous-race faces (e.g., Eberhardt, Dasgupta, & Banaszynski, 2003; Michel, Corneille, & Rossion, 2007; Pauker & Ambady, 2009; Pauker et al., 2009). Peery and Bodenhausen (2008) showed that when a racially ambiguous face was described as having both Black and White ancestry, participants were more likely to categorize it as Black when they had to make rapid judgments regarding the race of the ambiguous face (i.e., the principle of hypodescent). This finding suggests that minority identities are more accessible for racially-ambiguous faces under conditions of speeded categorization. Additionally, Michel et al. (2007) showed that racially-ambiguous faces are processed more holistically when paired with in-group labels (e.g., Caucasian) than when paired with out-group labels (e.g., Asian). Similarly, Pauker et al. (2009) showed that memory for racially ambiguous faces was improved when they were labeled with the same race as the perceiver. In sum, these studies demonstrate that social category information can easily influence face processing.

To date, however, it is still unclear how strictly visual context, such as the presence of other faces, affects the perceived race of a face. Basic visual properties of White and Black faces, such as luminance and color differences in skin tone, could potentially be the simple mechanisms by which flanking faces could use to modulate the perception of a face's race. For example, studies have shown that pigmentation plays an important role in face recognition. Faces are difficult to recognize from line-drawings (Leder, 1999), which contain minimal pigmentation information. It is also difficult to recognize faces with negated contrast because the perception of pigmentation is disrupted by negation (Russell, Sinha, Biederman, & Nederhouser, 2006). Additionally, skin tone has played an influential role in determining racial category membership. Brown, Dane, and Durham (1998) have shown that skin color is rated as the primary facial cue when making decisions about the race of a face (see also Maddox, 2004; Maddox & Gray, 2002). Moreover, a racially ambiguous face is perceived to be darker when it is labeled as Black, whereas the same face is perceived to be lighter when it is labeled as White (Levin & Banaji, 2006; MacLin & Malpass, 2001, 2003). Therefore, it is reasonable to assume that the perceived skin tone could affect the perceived race of a face. However, a recent study conducted by Brooks and Gwinn (2010) has suggested that this may not be the case. In Brooks and Gwinn (2010), participants were asked to view a target face surrounded by other faces for 3 s and then rate

it either on the perceived skin tone or perceived racial typicality. The results showed that the race of the surrounding faces affected perceived skin lightness but not the perceived race of the target face. That is, a Black, White, or 'mixed race' target face appeared lighter/darker when it was surrounded by Black/White faces (i.e., the lightness contrast illusion), yet perceived race of the target face was not affected by the surrounding faces. The results imply that simple modulation of the perceived luminance signal is not sufficient to affect racial typicality ratings.

In the current study, we used two different recognition tasks to examine how visual context affects the perceived race of a face when it is presented briefly (500 ms). We chose to use a much shorter presentation time than Brooks and Gwinn (2010) since research showing contextual influences on object recognition often uses shorter stimulus presentation times (e.g., Biederman et al., 1982; Davenport & Potter, 2004; Sun et al., 2011). In Experiments 1 and 2, participants performed a race categorization task in which they had to categorize a briefly presented target face as Black or White. In Experiment 1, context was manipulated by presenting the target face alone, or with Black or White flanker faces. We were interested in how flanker faces' race would bias participants' race categorization performance on the target face. Specifically, we hypothesized that flanker faces' race was likely to exert a strong influence on the perceived race of the target faces based on prior studies indicating how contextual cues affect racial categorization. Notably, this prediction differs from the results reported by Brooks and Gwinn (2010), whose work was motivated by an explicit comparison to classic simultaneous brightness contrast, in which a light surround makes a gray square look darker and a dark surround makes it look lighter. The analogous effect with faces of different lightness is contextual, but is contrastive, as opposed to the assimilative effects of other exogenous cues (e.g., race-diagnostic hairstyle). We also chose to manipulate flanker faces' orientation, since inverted faces are known to be more poorly recognized than upright faces even though they are well-matched for many basic visual properties (i.e., the face inversion effect, Yin, 1969). However, studies have also shown that the perceptions of large changes to feature information in faces (e.g., color) are not affected by inversion (McKone & Yovel, 2009). This manipulation therefore allows us to determine the extent to which any influence of flanker faces on target face categorization is a function of face-specific information, or more directly related to the low-level perceptual content of the flankers.

In Experiment 2, we manipulated race-specific shape and pigmentation information (e.g., Black, White) of flanker faces to examine how distinct aspects of the surrounding context would affect the perceived race of a target face. We chose to examine face shape and pigmentation separately in this experiment since recent research has suggested that these cues make independent contributions to face recognition (e.g., Balas & Nelson, 2010; Balas, Westerlund, Hung, & Nelson, 2011; O'Toole, Vetter, & Blanz, 1999; Russell, Biederman, Nederhouser, & Sinha, 2007). For example, studies have shown that independent changes in face shape and pigmentation affect distinct neural responses (e.g., the N170 and N250 ERP components) to own- and other-race faces (Balas & Nelson, 2010; Balas et al., 2011). Dissociating race-specific shape and pigmentation cues allowed us to examine how each aspect of appearance provided a context that affected target face categorization. We hypothesized that both shape and pigmentation of flanker faces were likely to exert a strong influence on the perceived race of a target face based on prior results indicating their import as cues for racial categorization (Bar-Haim, Saidel, & Yovel, 2009; Willenbockel, Fiset, & Tanaka, 2011). Similar to Experiment 1, flanker faces' orientation was also manipulated to examine how upright and inverted flankers would interact with flanker faces' shape and pigmentation on the perception of the target face's race.

Finally, in Experiment 3, we used a match-to-sample paradigm to examine how race-specific shape and color of flanker faces affected the perception of target appearance. Participants in this task were required to report which specific face they believed they had been presented with on each trial, selecting the target from a set of distractors that could vary either in shape alone or pigmentation alone. Compared to Experiments 1 and 2, which only asked participants to assign a category label to each target, Experiment 3 allows us to examine the influence of flankers on the appearance of the target rather than the category label assigned to it.

Overall, the current study builds on prior results concerning how context (e.g., flanker faces' race) affects race perception. We also examine how distinct aspects of appearance (e.g., race-specific shape and pigmentation) function as a context that modulates the categorization and perception of a target face. We thus extend the prior results of Brooks and Gwinn (2010) by incorporating an explicit category judgment, flanker faces that are easily segmentable (rather than overlapping and mutually excluded in their study), and dissociating separate qualities of racial appearance via manipulations of flanker faces' shape, pigmentation, and orientation. We find, in contrast to their results, that flankers do affect race categorization in a manner that is consistent with flankers providing a context that modulates target face categorization. In accord with their work, however, we also find in Experiment 3 that flanker pigmentation exerts a contrastive effect on target appearance in a match-to-sample task, consistent with the idea that there are low-level simultaneous contrast effects for pigmentation.

Experiment 1

The main purpose of Experiment 1 was to examine how briefly presented contextual information affects the perceived race of a target face. To answer this question, we used a race categorization task and focused on whether the perceived race of a target face would be affected by the presence of other faces in the surrounding area. If so, do flankers provide a category label that is then applied to the target (e.g. a face appearing with Black faces is more likely to be Black) or does simultaneous contrast bias categorization in the opposite direction (e.g. a face appearing with Black faces shows lighter skin tone and thus is more likely to be categorized as White)? Additionally, to assess the influence of low-level visual information compared to face-specific appearance, we manipulated the orientation of flanker faces. A subset of low-level features, such as mean luminance and color, and some local shape cues, are not disrupted by inversion, while it is well-known that holistic face processing and other configural processes are significantly impaired in inverted faces. Thus, if context effects are lessened by flanker inversion, we may conclude that they are subserved by higher-level face processing.

Method

Participants—Twenty-one Caucasian undergraduates (7 females) from North Dakota State University performed a race categorization task for course credit. All participants were between 18 and 32 years of age ($M = 20$, $SD = 3$) and self-reported normal or correct-to-normal vision. Furthermore, all of the participants reported little or no contact with Black individuals (e.g., no extensive exposure to a Black family member or friend over a long period of time). Informed consent was obtained from the participants. The experimental protocol was approved by the North Dakota State University Institutional Review Board for the protection of human participants in research.

Apparatus—Participants were tested individually in a room with normal interior lighting. The stimuli were presented on an 18-inch CRT monitor with a 75-Hz refresh rate. A chin rest was used to maintain a constant viewing distance of 80 cm. Responses for the

experimental trials were collected through the computer keyboard. The experiment was programmed with the psychophysics toolbox (Brainard, 1997; Pelli, 1997) implemented in MATLAB (www.mathworks.com).

Stimuli—Fifty faces were created using 3D graphics software (FaceGen, Singular Inversions Inc.) and served as the non-target stimuli; half of the faces were White and the other half were Black. These images were inverted to make another set of upside-down flankers. Additionally, the ‘average’ White face and the ‘average’ Black face were morphed together to produce 5 target face stimuli that spanned a continuum from White to Black in 25% increments (see Figure 1). This means that the 0% stimulus is a Black face, while the 50% stimulus is an equal blend of White and Black. During the experiment, we presented the target face alone in the center of the computer screen or surrounded by four flanker faces. The flanker faces were always presented in the same orientation (i.e., upright or inverted) and they were always from the same racial category within a trial; two of them centered 2.5° of visual angle above and below the target face, and the remaining two centered 2.5° to the right and left of the target face. All the faces were standardized to a height of 130 pixels (2.5 deg at 80cm viewing distance). During the experiment, all faces were presented on a gray background. Figure 2 shows sample stimuli and manipulations for different conditions.

Procedure and design—Each trial began with a stimulus array consisting of a central target face which was presented either in isolation or with four flanker faces for 500 ms, followed by a cross that appeared in the center of the computer screen until the participant responded. Participants were asked to categorize the target faces as Black or White by pressing the “A” or “L” key on the computer keyboard. Participants had unlimited time to respond. No feedback was provided after each response.

The experiment used a 5 (the morph level of target faces: 0%, 25%, 50%, 75%, 100%) $\times$ 2 (the type of flanker faces: Black, White) $\times$ 2 (the orientation of flanker faces: upright, inverted) factorial design. There were 24 trials in each of the 20 conditions. Additionally, a no-flanker control condition was added to each morphed target face as the baseline. There were 48 trials for the no-flanker condition for each morphed target face. Participants first completed a practice session of 30 trials. Following the 30 practice trials, participants completed 720 experimental trials. The 720 experimental trials were presented randomly for each participant, in six blocks of 120 trials each.

Results

We computed the percentage of responses where participants reported the target face as being White for each morph level. We then fit the resulting data points to a logistic function, to determine the PSE (point of subjective equality) for each participant in each flanker condition. In our case, the PSE corresponds to the morph level that is most ambiguous. Curve fits were carried out using the Palamedes toolbox for Matlab (Prins and Kingdom, 2009). The mean estimated PSE values across participants in different experimental conditions are shown in Figure 3. The results of a 2 (the race of flanker faces) $\times$ 2 (the orientation of flanker faces) ANOVA performed on the PSE values showed no main effects of either the race of flanker faces, $F(1, 20) = .256$, $MSE = 14.556$, $p = .618$, or the orientation of flanker faces, $F(1, 20) = .511$, $MSE = 7.595$, $p = .483$. However, the interaction between the race and orientation of flanker faces was significant, $F(1, 20) = 7.430$, $MSE = 6.123$, $p = .013$. Planned comparisons showed that the morphed face to which participants responded equally often with “Black” and “White” needed to contain more information from the ‘average’ Black face when it was surrounded by inverted White faces than it was surrounded by either upright White faces, $F(1, 20) = 6.203$, $MSE = 6.123$, $p = .$

022, or inverted Black faces, $F(1, 20) = 6.147$, $MSE = 6.123$, $p = .022$. However, there was no significant difference between the PSE values when the target face was surrounded by inverted White faces or upright Black faces, $F(1, 20) = 1.243$, $MSE = 6.123$, $p = .278$.

Discussion

Experiment 1 demonstrated that neither the race nor the orientation of flanker faces alone had a significant impact on participants' categorization of a target face. Our analysis of PSE indicated that the most ambiguous target face was more Black when the target was surrounded by inverted White faces. That is, more "White" responses were made overall when inverted White flankers were presented. The results thus suggest that the context of a group of faces can modulate the perceived race of a target, but that this effect is larger when flanking faces are inverted. This further suggests that the low-level properties of the flanking faces, such as skin tone, are capable of driving this effect, since research has shown that the perceptions of significant changes to facial feature information (e.g., color) are not affected by inversion (McKone & Yovel, 2009). However, the results of Experiment 1 also suggest that their contribution may be suppressed in the upright face image, given that no contextual modulations were observed from upright flanker faces. In Experiment 2, we examine these results in more depth by dissociating race-specific shape and color and implementing the same testing paradigm with a larger set of flanking stimuli.

Experiment 2

The results of Experiment 1 showed that the perceived race of a target face is affected by the interaction between flanker faces' race and orientation. Since race-specific shape and pigmentation are usually confounded in natural faces, we continued by asking how the shape and pigmentation cues of the flanking faces may independently contribute to the perception of a face's race. In Experiment 2, we sought to answer this question by separately manipulating flanker faces' shape and pigmentation to examine how shape and pigmentation cues obtained from distinct racial categories (e.g., White, Black) independently affect the perceived race of a target face. Flanker faces' orientation was also manipulated to examine how upright and inverted flankers would interact with flanker faces' shape and pigmentation on the perception of the target face's race.

Method

Participants—Twenty Caucasian students (10 females) at North Dakota State University participated in the race categorization task for course credit or monetary compensation. All of the participants were between 19 and 26 years of age ($M = 21$, $SD = 2$), self-reported normal or correct-to-normal vision, and self-reported greater exposure to White individuals than Black individuals. Additionally, they had not participated in the previous experiment, and were naïve to the purpose of the study. Informed consent was obtained from the participants; the experimental protocol was approved by the North Dakota State University Institutional Review Board for the protection of human participants in research.

Apparatus and stimuli—Experiment 2 was identical to Experiment 1 except that fifty additional faces were created so that half the faces were individuals with White face shape and Black pigmentation, whereas the other half of the faces were individuals with Black face shape and White pigmentation. Note that the individuals with White face shape and White pigmentation used in Experiment 2 were the same as the White flanker faces used in Experiment 1; the individuals with the Black face shape and Black pigmentation used in experiment 2 were the Black flanker faces used in Experiment 1. Figure 4 shows sample stimuli for different combinations of Black/White face shape and Black/White pigmentation.

Procedure and design—The procedure for Experiment 2 was essentially the same as in Experiment 1. However, Experiment 2 used a 5 (the morph level of target faces: 0%, 25%, 50%, 75%, 100%) $\times$ 2 (the shape of flanker faces: Black, White) $\times$ 2 (the pigmentation of flanker faces: Black, White) $\times$ 2 (the orientation of flanker faces: upright, inverted) factorial design; for each combination, there were 24 trials. Furthermore, a no-flanker control condition was added to each morphed target face as the baseline. There were 48 trials for the no-flanker condition for each morphed target face. Participants first completed a practice session of 30 trials. Following the 30 practice trials, participants completed 1200 experimental trials. The 1200 experimental trials were presented randomly for each participant, in six blocks of 200 trials each.

Results

As in Experiment 1, we estimated the PSE by fitting a logistic function to the proportions of trials where the participants reported the target faces as being White for each experimental condition. The mean estimated PSE values across participants in different experimental conditions are shown in Figure 5. The PSE values were submitted to a 2 (the shape of flanker faces) $\times$ 2 (the pigmentation of flanker faces) $\times$ 2 (the orientation of flanker faces) ANOVA. The results of the three-way ANOVA revealed a main effect of the shape of flanker faces, $F(1, 19) = 4.523$, $MSE = 8.100$, $p = .047$, indicating that flanker shape biased categorization in the opposite direction. There was also a significant main effect of the pigmentation of flanker faces, $F(1, 19) = 4.819$, $MSE = 41.640$, $p = .041$, showing that the flanker pigmentation biased categorization in a direction consistent with the flankers. There were no other significant main effects or interactions.

Discussion

The results of Experiment 2 showed that both shape and pigmentation cues of the flanker faces affect participants' race categorization performance on the target face. In particular, shape and pigmentation information of the flanker faces had different influences on the racial category assigned to the target face. Flanker shape exerted a contrast effect on target categorization, but flanker pigmentation was assimilative. Unlike Experiment 1, these effects were not modulated by the orientation of the flankers.

It is also important to note that our data from Experiment 2 differ from that obtained in Experiment 1 in other ways. The conditions that comprised Experiment 1 are a subset of Experiment 2, yet that subset of data from Experiment 2 does not replicate the pattern observed in our first task. We do not see an obvious way to explain this (the same display parameters and the same stimuli should, in general, lead to the same behavior), but it is possible that the expanded design of Experiment 2 relative to Experiment 1 led to changes in response criterion across tasks that are responsible for these differences. Balas and Nelson (2010) observed that the inversion effect only obtained for faces with White shape and pigmentation, suggesting that these faces were perceived as "White" and all other combinations of shape and pigmentation may have been relegated to an other-race category. This may mean that in Experiment 2, observers were presented with a proportionally larger set of faces that appeared "Black," which may have led to the differences between Experiments 1 and 2.

Despite these inconsistencies, Experiment 2 reveals interesting features of how a racial context imposed by discrete flanking faces can affect target categorization. Face shape appears to modulate target categorization via a contrastive influence, while pigmentation appears to function more like a category label that biases the target category towards the category the flankers belong to. The fact that neither of these is affected by flankers' orientation in Experiment 2 suggests that whatever information in the flankers contributes to

these effects is not specific to holistic processing of the upright face, but is available in the inverted stimulus just as well.

We continued in Experiment 3 by using a different testing paradigm (a match-to-sample task) to examine how flanker shape and pigmentation affected the perception of target appearance along these dimensions. Our goal in this final experiment was to determine whether the categorization effects observed in Experiment 2 are supported by actual perceptual differences induced by the flankers. Moreover, we wished to determine if the shape or pigmentation of the flankers was able to influence both aspects of target appearance.

Experiment 3

Experiment 2 showed that flanker faces' shape and pigmentation influence the perceived race of a target face differently. Flanker faces' shape elicited a contrast effect – participants were more likely to categorize target faces as White/Black when presented with Black/White shape flanker faces. By comparison, flanker faces' pigmentation elicited an assimilative effect – participants were more likely to categorize target faces as White/Black when surrounded by faces with White/Black pigmentation. To further examine whether the different flanker contextual effect is grounded in the perceived appearance of the target, we used a four-alternative-forced-choice (4AFC) match-to-sample task to test whether flanker faces' shape and pigmentation would cause similar contrast and assimilation effects on later identification of a target face.

Method

Participants—Twenty Caucasian undergraduates (10 females) from North Dakota State University performed a 4AFC match-to-sample task for course credit. All participants were between 18 and 27 years of age ($M = 20$, $SD = 2$) and self-reported normal or correct-to-normal vision. All of the participants were naïve to the purpose of the present study, had not participated in the previous experiments, and reported little or no contact with Black individuals. Informed consent was obtained from the participants. The experimental protocol was approved by the North Dakota State University Institutional Review Board for the protection of human participants in research.

Apparatus and stimuli—The apparatus in Experiment 3 was identical to that used in previous experiments. The same flanker faces from Experiment 2 were used; additionally, we created 13 faces that varied either in the shape or pigmentation dimension alone. Using the 3D graphics software, FaceGen, an 'average' White face and an 'average' Black face were morphed together to generate a 50% morph which is an equal blend of White and Black. Based on this 50% morph, we generated 12 face stimuli that varied in either the shape or pigmentation dimension. That is, along the pigmentation dimension, six faces were created by keeping their shape the same as the 50% morph, but their pigmentation was morphed in 10% increments toward the Black or White face. Similarly, along the shape dimension, another six faces were created by keeping their pigmentation constant at the 50% morph level, but their shape was morphed in 10% increments toward the Black or White face. Figure 6 shows the face stimuli with different manipulations along the shape and pigmentation dimensions.

In the 4AFC match-to-sample task, the 50% morph face and its four adjacent morph faces were the target faces in the study image. In the subsequent test image, four different test faces were shown to evaluate participants' recognition performance. Note that in the test image, the test faces would be the target face and the morph faces to its immediate left/top and right/bottom in the shape/pigmentation dimension. In addition, the fourth test face

would be the face that was 50% of the time the morph face to the left of the left-flanking test face (relative to the target face) or 50% of the time to the right of the right-flanking test face (relative to the target face). The locations of the test faces varied randomly across trials.

Procedure and design—Each trial started with a fixation cross for 500 ms. Then a study image consisting of a central target face with or without flanking faces was presented for 500 ms, followed by a 500 ms blank interval. After the interval, a test image consisting of four individual faces appeared until the participant responded. Participants were instructed to select the exact face that had been shown in the study image by pressing the key on the computer keyboard (V, B, N, and M, which were labeled as 1, 2, 3, and 4) that corresponded to the location of the face they chose. Participants were given an unlimited amount of time to respond. No feedback was provided after each response. The sequence of events in each trial was shown in Figure 7.

The experiment used a 2 (the shape of flanker faces: Black, White) $\times$ 2 (the pigmentation of flanker faces: Black, White) $\times$ 5 (the morph level of target faces: 40% White shape and 50% White pigmentation, 50% White shape and 50% White pigmentation, 60% White shape and 50% pigmentation, 50% White shape and 40% White pigmentation, 50% White shape and 60% White pigmentation) factorial design. There were 24 trials in each of the 20 conditions. Additionally, a no-flanker condition was added to each morphed target face as the baseline. There were 24 trials for the no-flanker condition for each morphed target face. Participants first completed a practice session of 25 trials. Following the 25 practice trials, participants completed 600 experimental trials. The 600 experimental trials were presented randomly for each participant, in six blocks of 100 trials each.

Results

We analyzed how the flanker faces modulated the distribution of two possible error types in the recognition of target faces (i.e., participants misidentified the morphs either to the left/top or to the right/bottom of the target face in the color/shape dimension as the studied target face). The percentage of responses where participants reported a test face as the studied target face was computed. Participants' responses to the two morphed faces on the left/top and on the right/bottom of the target face in the shape/pigmentation dimension were then collapsed into the Black and White response conditions. The mean responses in different experimental conditions are shown in Figure 8. The mean responses to the test faces varying in shape or pigmentation were submitted to separate 3 (response corresponding to the chosen test face: Black, target, White) $\times$ 2 (shape of flanker faces: Black, White) $\times$ 2 (pigmentation of flanker faces: Black, White) repeated-measures ANOVAs.

The ANOVA for responses to test faces varying in the pigmentation dimension revealed a significant main effect of participants' responses to the test faces, $F(2, 38) = 59.149$, $MSE = .056$, $p < .001$. A paired-samples t-test showed a significant difference in the responses to target faces and to the morphs located on the left side of the target face, $t(19) = 41.994$, $p < .001$. The paired-samples t-test also showed a significant difference in the responses to target faces and to the morphs located on the right side of the target face, $t(19) = 37.176$, $p < .001$. That is, participants chose the actual target face in the test image more often than other test faces, indicating fair memory for the target face.

We also observed a significant interaction between participants' responses to the test faces and the pigmentation of flanker faces, $F(2, 38) = 29.788$, $MSE = .010$, $p < .001$. A paired-samples t-test showed that when the target face was surrounded by flanker faces with Black pigmentation in the study image, participants were more likely to choose a test face containing more White pigmentation as the target face, $t(19) = -4.250$, $p < .001$. Additionally, when the target face was surrounded by flanker faces with White pigmentation

in the study image, participants were more likely to choose a test face containing more Black pigmentation as the target face, $t(19) = 5.447$, $p < .001$. No other significant main effects or interactions were found.

The ANOVA for responses to test faces varying in the shape dimension revealed a significant main effect of participants' responses to the test faces, $F(2, 38) = 10.547$, $MSE = .012$, $p = .000$. A paired-samples t-test showed a significant difference in the responses to target faces and to the morphs located on the left side of the target face, $t(19) = -4.318$, $p < .001$. The paired-samples t-test also showed a significant difference in the responses to target faces and to the morphs located on the right side of the target face, $t(19) = -4.485$, $p < .001$. That is, participants were more likely to misidentify the test faces containing more Black or White shape information as the target face. There were no other significant main effects or interactions.

Discussion

The results of Experiment 3 showed that the two possible error types in the recognition of target faces were affected by the flanker faces' facial features (e.g., shape and pigmentation) that appeared in the study image. However, the effects of flanker faces' facial features on the recognition of target faces were restricted to faces that varied along the color dimension. That is, when the target face appeared with flanker faces with White/Black pigmentation, participants were more likely to choose a test face containing more Black/White pigmentation as the target face. This finding suggests that flanker faces' pigmentation elicited a contrast effect so that the target face was judged as lighter/darker when surrounded by Black/White faces (i.e., the lightness contrast illusion). However, no similar pattern was found for faces that varied along the shape dimension. There were no significant interactions between flanker faces' facial features and the recognition of target faces that varied in shape. Note that participants had worse memory for target faces that varied in shape than that varied in color, which may explain the failure to find effects of flanker faces' facial features on the recognition of target faces (e.g., floor effects).

Synthesizing the data from Experiment 3 with Experiment 2, we see that pigmentation exerts a strong contextual influence in both tasks, but in markedly different ways. The perceived pigmentation of the target face is biased contrastively by the pigmentation of the flankers in a match-to-sample task (Experiment 3), but the category label provided by the pigmentation of the flankers ultimately biases the participant to assign a racial category consistent with that of the flankers in a race categorization task (Experiment 2). There are thus both perceptual and category influences of flankers on the perceptions of target faces, but these influences are opposed to one another and category labels as exogenous cues appear to override induced effects on perception when a race categorization task is implemented.

General Discussion

The three experiments reported in the present study aimed to examine how visual context affects the perceived race of a target face. Results of the three experiments were consistent with previous research showing that contextual information plays an influential role in face recognition. For example, Sinha and Poggio (1996) have demonstrated that recognition of faces that share the same internal features (e.g., eyebrows, eyes, nose) can be affected by various contextual cues, such as hairstyle and speaking position on the stage. MacLin and Malpass (2001, 2003) also showed that the race-diagnostic hairstyle (e.g., Black, Hispanic) affected participants' race categorization performance when they were asked to categorize a series of faces that had identical racially ambiguous features except for their hairstyle. That is, participants rated ambiguous-race faces with the Black hairstyle as Black and ambiguous-

race faces with the Hispanic hairstyle as Hispanic. It is also worth noting that Freeman, Penner, Saperstein, Scheutz, and Ambady (2011) showed that a racially ambiguous face with low-status attire is more likely to be categorized as Black, whereas a racially ambiguous face with high-status attire is more likely to be categorized as White. This study demonstrates how social status cues that often surround a face in the real world (e.g., attire) may change the perceived race of a face. Clearly, face recognition can be affected by surrounding context (see also de Gelder et al., 2006).

Our results further showed that the perceived race of a face is also affected by the appearance of other faces near the target face. For example, the results of Experiment 1 showed that the perceived race of a target face was assimilated by the race of inverted flanker faces so that participants were more likely to categorize the target face as White when it was surrounded by inverted White faces. However, the results were contrary to a previous study showing no effect of flanker faces' race on the perceived racial typicality of a target face (Brooks & Gwinn, 2010). In contrast to the short stimulus presentation time (500 ms) used in our current study, each stimulus array was presented for 3 s in Brooks and Gwinn (2010) so that the influences of the flanker faces might be eliminated by the relatively long viewing time. Research has shown that contextual information plays a prominent role in object recognition, especially when visual information is limited due to certain circumstances, such as short stimulus presentation times and blurred object images (Bar, 2004). Studies have also shown that even when contextual cues are not used to affect participants' final race categorization performance, contextual influences on the perception of a face's racial category could still be observed in the early stage of the decision-making process. For example, Freeman et al. (2011, Experiment 2) had participants categorize the race of morphed faces that varied from White to Black and contextualized by either business or janitor attire. Additionally, participants' hand trajectories were recorded when they move the computer mouse toward the corresponding response regarding the race of the face. The results showed that before participants clicked the final response, their hand movements were attracted toward the race category stereotypically associated with the social status cue. That is, before settling on the White response for a White face with janitor attire, participants' hand movements were attracted toward the Black response; and before settling on the Black response for a Black face with business attire, participants' hand movements were attracted toward the White response. Moreover, this attraction effect grew stronger as racial ambiguity of the morphed face increased. The results showed that before reaching an ultimate categorization response, different information sources (e.g., bottom-up facial cues, top-down stereotypes) could influence the dynamic decision-making process of deciding a face's race. Therefore, when an ambiguous race face is presented for a long period of time (e.g., 3 s), participants may be able to discard the activated contextual information and decide the racial category of the ambiguous face on the basis of its intrinsic features (e.g., color, shape) only. Our current results thus show that under certain conditions, such as short stimulus presentation times, contextual faces' racial categories are able to affect participants' race categorization decision on a target face.

The current study further demonstrates that the visual system is able to extract face shape and pigmentation information separately and use them to modulate the perceptions of a face's race. This finding is consistent with recent research showing that both shape and pigmentation are important cues for face recognition (e.g., Balas & Nelson, 2010; Balas et al., 2011; Brebner, Krigolson, Handy, Quadflieg, & Turk, 2011; Freeman & Ambady, 2011; Russell et al., 2007; Russell & Sinha, 2007). For example, Russell and Sinha (2007) examined the roles of face shape and pigmentation in face processing with a face-recognition task. They made two sets of faces where the individual faces differed only in shape in one set and only in pigmentation in the other; then participants had to recognize these faces. The results showed that participants' performance when they used pigmentation

cue alone was as good as or better than performance with shape cue alone, indicating that shape and pigmentation cues contribute to face recognition independently. Also, face shape and pigmentation are important information for processing own- and other-race faces. For example, Balas and Nelson (2010) examined how distinct neural responses to own- and other-race faces would be affected by independent changes in face shape and pigmentation. They used synthetic 3D models of White and Black faces so that the 3D shape of White and Black model faces could be combined with White and Black skin color. This method created four possible combinations of face shape and pigmentation cues (i.e., White/White, White/Black, Black/White, Black/Black). Then they recorded participants' brain activities while they viewed these faces and found independent effects of face shape and pigmentation on the N170 and N250 ERP components. In a recent study, Balas et al. (2011) have further shown that race-specific shape and pigmentation information have independent contributions to own- and other-race face processing in 9-month-old Caucasian infants as well.

Importantly, the current results also demonstrate that flanker faces' shape and pigmentation have different influences on the perception of a face's race. When flanker faces' shape and pigmentation were manipulated independently in Experiment 2, the results showed that shape elicited a contrast effect because participants were more likely to categorize the target face as White/Black when it was surrounded by Black/White shape faces. However, pigmentation information elicited an assimilation effect because participants were more likely to categorize the target face as White/Black when it was presented with flanker faces with White/Black pigmentation. To our knowledge, no research has examined how flanker faces' shape and pigmentation independently affect the perceived race of a target face. Our current results thus provide novel evidence that face shape and pigmentation both are potent contextual cues modulating the perception of a face's race.

However, it should be noted that flanker faces' shape and pigmentation affect participants' responses to a target face's race differently in categorization and delayed matching tasks. While flanker faces' shape and pigmentation lead to either a contrast or an assimilation effect on the categorization of a target face (Experiment 2), their contextual influences are either absent or reversed in later identification of a target face (Experiment 3). Although no effects of flanker faces' shape were found, the results of Experiment 3 showed that when a target face was surrounded by faces with White/Black pigmentation, participants were more likely to choose a test face containing more Black/White pigmentation as the target face. The results suggest that flanker faces' pigmentation have a contrastive influence on the later identification of a target face. The results are similar to the lightness contrast illusion in which a gray stimuli appears lighter/darker with dark/light surrounds (Agostini & Galmonte, 2002). Therefore, flanker faces' facial features, such as shape and pigmentation, may not exert the same effects on the recognition of faces with different racial appearance under different task demands.

It is also interesting to note that the influence of flanker faces' shape and pigmentation on the perception of a face's race is independent of their orientation. It has been shown that inversion qualitatively changes face perception by impairing some specific mechanisms that are typically involved in the processing of upright faces. For example, upright faces are processed in a more holistic or configural fashion, whereas inverted faces involve mostly feature-based processing. Therefore, changes in the space between facial features are easily detectable when faces are presented upright but not when faces are presented upside down (e.g., Kemp, McManus, & Pigott, 1990; Leder, Candrian, Huber, & Bruce, 2001; Rhodes, Brake, & Atkinson, 1993). However, our results showed that the effects of flanker faces' shape and pigmentation on the perception of a face's race could be observed when the flanker faces were presented either upright or upside down, suggesting that the extraction of

face shape and pigmentation cues is not impaired by inversion. However, it should be noted that our results also showed that when flanker faces' shape and pigmentation were not separated in natural Black and White faces, flanker faces' orientation might interact with flanker faces' race and affect the perceived race of the target face (Experiment 1).

Our results also suggest that distinct appearance cues may be perceived as "sets" in markedly different ways. Studies have shown that the visual system can represent multiple objects as an ensemble to cope with the limitations on visual processing and thus enhance visual cognition (for a review, see Alvarez, 2011). It has been shown that the visual system can compute and represent summary statistics (e.g., the mean) of multiple items in various stimulus dimensions, such as orientation (e.g., Dakin & Watt, 1997; Parkes, Lund, Angelucci, Solomon, & Morgan, 2001), size (e.g., Ariely, 2001; Chong & Treisman, 2003), brightness (e.g., Bauer, 2009), speed (e.g., Atchley & Andersen, 1995; Watamaniuk & Duchon, 1992), position (e.g., Alvarez & Oliva, 2008), and even facial expression and identity (e.g., de Fockert & Wolfenstein, 2009; Haberman & Whitney, 2007, 2009). For example, Haberman and Whitney (2009, Experiment 1) had participants view sets of faces varying in emotionality (e.g., happy to sad) and then indicate whether a test face was a member of the preceding set. The results showed that participants were more likely to respond "yes" when the test face approached the mean emotion of the set, suggesting that participants were able to extract and represent the mean facial expression of a set of faces. Though complex qualities of faces set (e.g., facial expression) are summarized in terms of the average stimulus, it is still unknown how distinct appearance properties (e.g., texture, luminance) are combined in the perception of sets of faces. The results of the current study showed that flanker faces affect the perceived race of a target face either in terms of their identity (Experiment 1) or in terms of their distinct shape and pigmentation (Experiment 2). It is very plausible that participants perceived the four flanker faces as a set and extracted the mean information from the set to affect target face processing. For future research, it would be interesting to explore how different facial properties, such as face shape and skin tone, are summarized and represented.

Finally, our results may provide important constraints for computational models of how shape and surface properties are extracted from face images and employed in the service of recognizing faces presented singly, or in the context of other faces. Our data suggest a dissociation between shape and pigmentation, similar to other proposed dichotomies in face recognition (e.g. featural vs. configural processing, Maurer, Le Grand, & Mondloch, 2002). Computational models have made key theoretical contributions to our understanding of how the distinction between featural and configural processing might arise (Zhang & Cottrell, 2004), in large part by demonstrating what computational processes are necessary for the observed experimental effects to emerge (e.g., Zhang & Cottrell, 2006). We propose that our data, as well as other recent results describing how shape and pigmentation contribute to the face processing as a function of race (Anzures, Pascalis, Quinn, Slater, & Lee, 2011; Balas & Nelson, 2010; Brebner et al., 2011), provides important empirical constraints on theoretical models of face processing. The development of such models will be an important step towards understanding the nature of face shape and pigmentation in the human visual system, and establishing how these qualities are encoded and applied to a range of recognition tasks. In particular, an important open question is whether or not shape and pigmentation as operationalized in our study (and others) are processed via computationally independent feature sets, or whether the observed results emerge naturally from a common representational vocabulary.

In conclusion, the current finding demonstrates that the perceived race of a target face is affected by its surrounding context, such as the appearance of other faces. This is consistent with previous research showing that task-irrelevant stimuli can be processed simultaneously

and used to modulate the evaluation of the target face. Most importantly, the current study yields novel evidence that flanker faces' shape and pigmentation affect the perception of a face's race differently. While race-specific shape exerts a contrastive influence on the perceived race of a target face, race-specific pigmentation exerts an assimilative influence. However, the contrast and assimilation effects elicited by flanker faces' shape and pigmentation may be limited to the race categorization task, since similar effects cannot be generalized to the later recognition of a target face in a delayed matching task. Overall, our results indicate a rich set of competing influences that govern how surrounding faces influence the information extracted from a target.

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Figure 1.
Examples of the target face at different morph levels.

Figure 2.

Example stimuli used in Experiment 1. All images depict trials in which the 50% morph level face served as the target face. (A) A sample image used in the upright Black flanker faces condition; (B) a sample image used in the inverted Black flanker faces condition; (C) a sample image used in the upright White flanker faces condition; (D) a sample image used in the inverted White flanker faces condition; (E) a sample image used in the no-flanker condition.

Figure 3.

Estimated PSE for each condition in Experiment 1. Note that the 0% PSE indicates the 50% morph value. Error bars show standard errors of the mean.

Figure 4.

Example stimuli for different combinations of Black/White face shape and Black/White pigmentation. (A) A sample image used in the Black shape/Black pigmentation flanker faces condition; (B) a sample image used in the Black shape/White pigmentation flanker faces condition; (C) a sample image used in the White shape/Black pigmentation flanker faces condition; (D) a sample image used in the White shape/White pigmentation flanker faces condition.

Figure 5.

Estimated PSE for each condition in Experiment 2. Note that the 0% PSE indicates the 50% morph value. Error bars show standard errors of the mean. (Note: sBpB: flanker faces with Black face shape and Black pigmentation; sBpW: flanker faces with Black face shape and White pigmentation; sWpB: flanker faces with White face shape and Black pigmentation; sWpW: flanker faces with White face shape and White pigmentation.)

Figure 6.

Face stimuli used in Experiment 3. The face in the black square is an equal blend of White and Black. Based on this 50% morph, six faces were created by keeping their shape/pigmentation the same as the 50% morph, but their pigmentation/shape was morphed in 10% increments toward the Black or White face. The faces within the yellow square were used as the potential test faces, but only faces within the green square were used as the target faces in the study images.

Figure 7.

The sequence of events in each trial in the 4AFC match-to-sample task in Experiment 3.

(A)

(B)

Figure 8.

(A) The average percentage of responses where participants indicated a test face with the same shape as the 50% morph but varying in pigmentation as the studied target face in Experiment 3. (B) The average percentage of responses where participants indicated a test face with the same pigmentation as the 50% morph but varying in shape as the studied target face. Error bars show standard errors of the mean. (Note: sBpB: flanker faces with Black face shape and Black pigmentation; sBpW: flanker faces with Black face shape and White pigmentation; sWpB: flanker faces with White face shape and Black pigmentation; sWpW: flanker faces with White face shape and White pigmentation.)