A number of recent behavioral studies have shown that emotional expressions are differently perceived depending on the race of a face, and that perception of race cues is influenced by emotional expressions. However, neural processes related to the perception of invariant cues that indicate the identity of a face (such as race) are often described to proceed independently of processes related to the perception of cues that can vary over time (such as emotion). Using a visual face adaptation paradigm, we tested whether these behavioral interactions between emotion and race also reflect interdependent neural representation of emotion and race. We compared visual emotion aftereffects when the adapting face and ambiguous test face differed in race or not. Emotion aftereffects were much smaller in different race (DR) trials than same race (SR) trials, indicating that the neural representation of a facial expression is significantly different depending on whether the emotional face is black or white. It thus seems that invariant cues such as race interact with variable face cues such as emotion not just at a response level, but also at the level of perception and neural representation.

Keywords: emotion, face perception, racial prejudice, visual adaptation
interlinked. On the other hand, studies directly measuring brain processes that underlie emotion and race perception suggest independent processing of these two types of information.

There are several ways to explain such an inconsistency. One possibility is that the brain represents variable cues like emotion and invariant cues like race independently, as reflected by the imaging and ERP findings, and that subsequent behavioral interactions purely take place at the stage of response preparation, or execution. However, it is also possible that, while the initial processing of emotion- and race-related facial cues is truly independent, as is shown by the multitude of imaging studies, these processing streams interact at some point (possibly at the amygdala, see also Haxby et al., 2002) leading to final interdependent neural representations of emotion and social category as observed in behavioral studies. The key difference between these explanations is thus whether or not the neural representation of emotional expressions changes with the race of the face (and vice versa).

In two experiments, we tested whether identical emotional expressions, expressed by faces with different races (DRs) rely on the same, or on different perceptual representations in the brain. This was tested using a visual adaptation paradigm. Visual adaptation to a face with specific characteristics influences subsequent perception of faces with similar characteristics, notably by diminishing perception of the characteristics of the test face that match the adapting face. For example, after viewing an explicitly angry face, subsequent ambiguous “angry-frightened” faces appear relatively less angry and more frightened (Webster et al., 2004). These face adaptation effects seem to rely on adjustments of relatively high-level representations of different facial features and cues, since the aftereffects are not sensitive to changes in size, orientation, or position (Watson and Clifford, 2003).

Adaptation tasks such as these are specifically suitable to test whether information about social categories and emotional expressions are neurally independent or not. If emotion is represented independently of social categories such as race, then black and white faces expressing the same emotion should engage identical neural substrates, resulting in similar aftereffects for emotional expressions independent of whether the first “adapting” face and the second “test” face are from the same or different racial categories. On the other hand, if the underlying mental representations of emotional expressions differ to some extent as a function of race, then the emotion aftereffect should be diminished or absent when the adapting and test faces differ in race.

Although visual aftereffects such as the emotion aftereffect are behavioral measures, their occurrence provide direct information about the neural representations that underlie our perception. The psychophysical aspects of the aftereffect thus allows us to test whether emotional expressions are represented independently of invariant facial cues, or whether the neural representations of emotions are influenced by perceived social categories such as race.

**EXPERIMENT 1**

In experiment 1 we used visual aftereffects to measure the level of overlap in the neural representation of emotions expressed by black and white faces. In different blocks, the relationship between the adapting face and the test faces was varied. In the Same Race/Same Identity (SR/SI) condition, the test face and the adapting face had the same identity and thus the same race (SR) as well. In the Different Race/Different Identity (DR/NI) condition, adapting faces had a DR, and thus a different identity than the test faces. DR/DI and SR/SI trials do not only differ in the racial (dis)similarity between the adapting and test faces, but also in the absence or presence of identity differences between the adapting and test face. This introduces additional differences between the adapting and test face than just racial features, which could account for any decrease or even absence of emotion adaptation (Wu et al., 2009). To test how much of the difference in emotion aftereffects between DR/DI and SR/SI trials can be attributed to these differences in identity and background facial features (and thus not to differences in race) we added a Same Race/Different Identity (SR/NI) condition. In the SR/DI trials, the adapting and test faces were of the SR, but had different identities. Therefore, if any differential effects observed in the DR/DI condition are due to differences in identity and/or background features, these same differential effects should also be present in the SR/DI condition. If the decrease or absence of adaptation in the DR/DI condition is due to differences in race, these effects should not be present in the SR/DI condition. **Figure 1** shows example trials for each of the three conditions.

**METHODS**

**Participants**

Twenty-two participants participated in Experiment 1. The average age was 20 years, and 16 of them were women. Of the 22 participants, two were African-American, nine were European-American, one was Hispanic, one was Middle Eastern, and nine were Asian.

**Stimuli**

The faces that functioned as adapting and test stimuli were created using Facegen Software. All stimuli were based on four different identities, two white males and two black males. For each identity a 100% angry and a 100% frightened face was generated to function as the adapting stimulus. In addition 13 test faces were generated. These test faces had an ambiguous expression, ranging from 20% angry/80% afraid to 80% angry/20% afraid in 5% increments. When presented on the screen, the faces had a height of approximately 10 cm, and a width of about 5.5 cm.

**Procedure**

At the start of the experiment, each participant was randomly assigned one black and one white identity which would function as the identity of the test faces throughout the experiment. After subjects had read and signed the informed consent, the experiment started with a practice block, in which subjects viewed and categorized just the ambiguous test faces. The practice block consisted of 104 trials, with four repeats for each of the 26 different test faces that were used for that participant. Each face was centrally presented for 300 ms, and was followed by a response screen that consisted of a centrally presented question mark, and the words AFRAID and ANGRY at the bottom of the screen, at the right and left hand corner. Subjects responded using the “a” key (left hand button press for a frightened face) or the “l” key (right hand button press for an angry face).
Adaptation trials consisted of a 5 s adaptation period in which subjects viewed an angry or a frightened face. The adapting face was followed by a 50 ms pattern mask, after which an ambiguous test face was presented for 300 ms. Participants were then asked to indicate whether this ambiguous test face had an angry or a frightened expression with a left or right-hand button press using the same response screen as in the practice trials.

The relationship between the adapting and test faces differed over blocks. In the SR/SI block, the adapting face had the same identity as the test face. In the SR/DI block the adapting and test face were always different people, but with the SR. Therefore, in both the SR/SI and the SR/DI block, a black adapting face was always followed by a black test face, and a white adapting face was always followed by a white test face. In the DR/DI block the adapting and test face were always a DR, and, therefore, also of a different identity, such that a black adapting face was always followed by a white test face and a white adapting face was always followed by a black test face.

Subjects completed three blocks, each consisting of 52 trials [13 ambiguous faces, two identities (1 black and 1 white test identity) and two emotions (angry and afraid adapting face)]. The order in which the three experimental blocks were presented was randomized over subjects.

**Analysis**

For each of the three conditions, SI/SR, DI/SR, and DI/DR, the percentage of “frightened” responses was calculated for the two adapting emotions. The difference between the proportion of “frightened” responses following angry vs. frightened adapting faces was taken to indicate the magnitude of the emotion aftereffect. An ANOVA with the factors Adapting Emotion (angry vs. frightened) and Adaptation Condition (SI/SR, DI/SR, and DI/DR) tested for differences in the magnitude of the emotion aftereffect between the three adaptation conditions. In case of a significant interaction between Adapting Emotion and Adaptation Condition, post-hoc t-tests were performed to test the nature of this interaction. F-tests with more than one degree of freedom in the numerator were adjusted by means of the Greenhouse–Geisser or Huynh–Feldt correction where appropriate. Uncorrected degrees of freedom and corrected p-values are reported.
RESULTS
After seeing an angry adapting face, subjects judged subsequent ambiguous test faces to be more afraid, whereas adaptation to a frightened face made subsequent ambiguous faces seem more angry [F(1,21) = 260.7, p < 0.001, partial η² = 0.93]. Crucially, as Figure 2 shows, this emotion aftereffect was moderated by the relationship between the adapting and ambiguous test face [F(2,42) = 4.4, p = 0.02, partial η² = 0.18]. Post-hoc t-tests showed that the emotion aftereffect was smaller in DI/DR trials compared to both the SI/SR [t(21) = 3.1, p = 0.005, Cohen’s d = 0.96] and DI/SR trials [t(21) = 2.2, p = 0.04, Cohen’s d = 0.67]. The emotion aftereffect was comparable in size for SI/SR and DI/SR trials [t(21) = 0.6, p = 0.58, Cohen’s d = 0.17]. Thus, a switch in race between the adapting and test face significantly reduces the emotion aftereffect. In addition, this reduction in the size of the aftereffect cannot be attributed to the simple difference in identity (which accompanies the difference in race) between the adapting and test face, since a difference in identity alone does not lead to a similar decrease of the aftereffect.

EXPERIMENT 2
The faces in Experiment 1 were presented in color, and the color transition within DR trials (white adapting to black test face, or black adapting to white test face) was obviously larger than within SR trials. It could thus be that the reduction of the aftereffect is simply due to the difference in color of the faces, and not due to the difference in race in itself. In addition, the relationship between the adapting and test face was held constant within each block. This blocked presentation could have allowed participants to adopt different response strategies for the different types of trials. Experiment 2 was conducted to replicate the results of Experiment 1 while removing these two possible confounds. In Experiment 2 subjects viewed the same stimuli as in Experiment 1. However, the stimuli were presented in gray scale, so that a race-switch between the adapting and test face within a trial did not provoke a difference in coloring between the two faces. In addition, the different conditions (SI/SR, DI/SR, DI/DR) were mixed within blocks, so that participants could not build an expectation about the type of test face that would encounter.

METHODS
Participants
Twenty-four participants (average age of 21.8 years, 15 women) participated in Experiment 2. Of these 24 participants one was African-American, 17 were European-American, three were Hispanic, one was Middle Eastern, and two were Asian.

Stimuli
The faces used in Experiment 1 were altered to gray scale images using Adobe Photoshop. In all other regards, the stimuli in Experiment 1 and 2 were identical.

Procedure
The set-up was similar to Experiment 1, except that the three different adaptation conditions (SI/SR, DI/SR, and DI/DR) were presented randomly intermixed, divided in three blocks of 52 trials.

Analysis
The data were analyzed in the same way as in Experiment 1.

RESULTS
As before, subjects showed a strong emotion aftereffect [F(1,23) = 193.1, p < 0.001, partial η² = 0.89], which was again moderated by the relationship between the adapting and test face [F(2,40) = 3.9, p = 0.04, partial η² = 0.14]. The aftereffect was smaller in DI/DR trials compared to both the SI/SR [t(23) = 2.1, p = 0.05, Cohen’s d = 0.65] and DI/SR trials [t(23) = 2.2, p = 0.04, Cohen’s d = 0.60], whereas the aftereffect for SI/SR and DI/DR trials was comparable [t(23) = 0.5, p = 0.60, Cohen’s d = 0.15], see Figure 3. Once more, these results show that a switch in race between the adapting and test face reduces the magnitude of the aftereffect, and this effect cannot be explained by a difference in face identity.
DISCUSSION

These results provide an important indication that variable facial features such as emotional expression and invariant facial features such as social category are jointly processed. After adapting to a white face, subjects showed a smaller emotion aftereffect if the ambiguous test face was black (DR) than when the test face was white (SR). When the adapting and test face only differed in identity and not in race, aftereffects were comparable to trials in which the adapting face and the test faces had the same identity. This indicates that the neural representations of emotions expressed by white faces differ from the neural representations for the same emotions expressed by black faces. In addition, this difference in representation is not a consequence of differences in identity.

It thus seems that there is indeed a neural basis for the behavioral research showing that perception of variable cues like race is influenced by emotional expression and vice versa (Elfenbein and Ambady, 2003; Hugenberg and Bodenhausen, 2003, 2004; Ackerman et al., 2006; Richeson and Trawalter, 2008). Kubota and Ito (2007) have argued that the interdependence of race and emotion in these behavioral tasks only occurred because the stimuli were ambiguous in nature. In the current experiments, the test faces were indeed ambiguous in nature. However, it seems highly unlikely that the observed differences between the adaptation conditions are due to the ambiguity in the test faces. The observed effects hinge on the processing and adaptation of the adapting faces, and those faces were not ambiguous in race cues or emotion cues. In addition, participants were not required to respond to, or engage with the adapting faces in any way other than to just watch them for 5 s. It thus seems unlikely that participants employed specific strategies to deal with ambiguous faces when they processed the adaptive faces. In addition, many of the tasks that show behavioral interactions with ambiguous faces when they processed the adaptive faces.

In the current study, it seems highly unlikely that participants employed specific strategies to deal with ambiguous faces when they processed the adaptive faces. However, currently there are no studies (as far as we are aware) that provide evidence where in the brain the processing of emotion and race comes together. Previous research indicates that the neural mechanism that supports the integration of information about race and emotion does not appear to be cortical (Kubota and Ito, 2007). This suggests that subcortical structures, such as the amygdala, are a more likely site for the neural integration of race and emotion. It is well documented that the amygdala plays an important role in the processing of emotions, especially fear (Morris et al., 1996, 1998; Phelps, 2006). In addition, the amygdala is also implied in the processing of race cues in faces (Golby et al., 2001; Phelps et al., 2000). The fact that the pathways that underlie emotion and race processing cross at the amygdala provide suggestive evidence that the interaction between race and emotion-related perceptual processes could take place here.

Future brain-imaging studies will hopefully shed more light on the actual brain-structures that underlie the interaction between variable and invariant cues in face processing.

CONCLUSION

The race of the people around us has been previously shown to influence many socially relevant processes. The current findings indicate that race is indeed such a fundamental perceptual cue that it changes the basic perception of emotional facial expressions, which is in itself a highly relevant social cue. These results specifically show that racial cues exert their influence at a neural level, shaping the actual representation and perception of emotion, and not just the subsequent interpretation of that emotion.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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