Holistic face encoding is modulated by perceived face race: evidence from perceptual adaptation

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Abstract

Human expertise at processing faces relies on how facial features are encoded: as a whole template rather than as a sum of independent features. This holistic encoding is less prominent for other-race faces, possibly accounting for the difficulty one encounters in recognizing these faces (the 'other-race effect'). Here, we tested the hypothesis that the magnitude of holistic face encoding can be modulated by racial categorization of the face. Caucasian participants performed a face-composite task with 'racially-ambiguous' face-stimuli (cross-race morphed faces, equally categorized as Asian or Caucasian faces in an independent task). The perceived race of the ambiguous faces was manipulated using adaptation. Experiment 1 showed that identical morphed face-stimuli were processed more holistically when perceived as 'same-race' than as 'other-race', i.e., following adaptation to 'other-race' versus 'same-race', respectively. Experiment 2 ascertained that the determining factor in the observed holistic processing modulation was the race of the racially-ambiguous face as perceived, rather than expected, by the participants, which supports the idea that the holistic processing of the face-stimuli was modulated by their race-categorization at the perceptual level.

Introduction

Human adults are experts at processing faces: they can identify and discriminate hundreds of faces, despite their extremely high similarity as visual patterns. It is widely acknowledged that this expert skill relies at least partly on holistic processing of the facial structure (e.g., Sergent, 1984; Tanaka & Farah, 1993; Maurer, Le Grand, & Mondloch, 2002; Peterson & Rhodes, 2003; Rossion, 2008). 'Holistic face processing' refers to the processing of a face as a template or a gestalt, without a representation of the facial features as separate entities (e.g., Farah, Wilson, Drain, & Tanaka, 1998; Galton, 1883; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987; Rossion, 2008). This mode of encoding has been supported by studies providing evidence for a 'whole/part' effect (i.e., the fact that recognizing a facial feature is influenced by the identity and position of the other features in the whole face; Tanaka & Farah, 1993; see also Leder & Carbon, 2005) and for a composite-face effect (i.e., the fact that it is more difficult to recognize the top (or the bottom) part of a face when it is aligned with the bottom (or the top) part from another identity than when these two parts are presented in a misaligned format; Young et al., 1987).

In Asian and Caucasian people these two effects are stronger for same-race than other-race faces (Michel, Caldara, & Rossion, 2006; Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2004), indicating that holistic processing is stronger for faces of the observer's own race than for other-race faces. Given the critical role of holistic processing for face expertise, this differential holistic encoding may account for one's relative difficulty at recognizing individual other-race faces (Michel et al., 2006a, 2006b; Tanaka et al., 2004), the so-called 'other-race effect' (ORE; for a meta-analysis on the ORE, see Meissner & Brigham, 2001). Yet, the reason why other-race (OR) faces are not processed as holistically as same-race (SR) faces remains unclear. The present study aims at providing evidence for the role of race categorization (i.e., "Asian" or "Caucasian") in modulating the differential holistic processing for OR and SR faces.

Several studies have provided evidence that the racial categorization of a face can affect the perception of its features. For instance, racially-ambiguous faces appear darker when labeled 'Black' than when labeled 'White' (Levin & Banaji, 2006), and are judged as being broader with a broader mouth and more protruding eyes when African rather than Hispanic hair are added to the face (MacLin & Malpass, 2001). Converging evidence was also reported in studies that examined the role of racial categorization in moderating cross-race deficit effects, this time using memory measures (e.g., Hugenberg, Miller, & Claypool, 2006).

We recently hypothesized that the racial categorization of a face may also affect the mode of processing that is applied to it, with a more holistic face processing applied to faces categorized as a ‘SR’ rather than as ‘OR’. The latter hypothesis received support in a study where we found that racially-ambiguous face-stimuli elicit a weaker face-composite effect in Caucasian participants when they are presented among a majority of unambiguous Asian faces than among a majority of unambiguous Caucasian faces (Michel, Corneille, & Rossion, 2007). Presumably, the inclusion of racially-ambiguous faces in a SR (OR) block of trials induces the perceptual categorization of these faces as being SR (OR), which in turn reduces holistic processing of these faces. However, as we will explain in greater details in the general discussion, one cannot exclude that the latter findings may have been driven by a carry-over effect (with the holistic processing of the many Caucasian faces spilling over the processing of the fewer racially-ambiguous faces).

In the current study, we aimed at strengthening our demonstration by relying on another paradigm that has been widely used in the face processing literature over the last few years: a face perceptual adaptation paradigm (e.g., Jiang, Blanz & O’Toole, 2006; Leopold, O’Toole, Vetter & Blanz, 2001; Rhodes & Jeffery, 2006). This paradigm allowed us to bias the categorization of racially-ambiguous face-stimuli *away from* a contextual face category, thereby decreasing the likelihood of a carry-over effect that may have been involved in our previous findings. The adaptation technique consists in exposing the observer for a prolonged observation to an ‘adapting stimulus’. As initially theorized by Köhler and Wallach (1944) this prolonged observation leads to a prolonged firing, followed by a loss of responsivity – also called ‘satiation’ (Köhler & Wallach, 1944) or ‘fatigue’ (e.g., Webster, Kaping, Mizokami, & Duhamel, 2004) – of the neural coding underlying the processing of the adapting stimulus in the visual cortex (e.g., Bednar & Mukkulainen, 2000; Tolhurst & Thompson, 1975). As a result, the observer’s perception of particular stimulus attributes is biased towards the opposite of the adapting stimulus, which is called a ‘visual aftereffect’ (e.g., Leopold, Rhodes, Müller, & Jeffery, 2005).

Historically, perceptual distortions induced by adaptation, or ‘visual aftereffects’, were examined with very simple stimuli as a particular orientation (e.g., Gibson, 1937), luminance (e.g., Craik, 1940) or motion direction (e.g., Barlow & Hill, 1963). Recently, the study of visual aftereffects has been extended to higher-level processes such as face perception. For example, numerous studies demonstrated ‘Face distortion aftereffects’, consisting in misperceiving a normal-looking face as being distorted (e.g., expanded) after a prolonged exposure to a face distorted in the opposite manner (e.g., contracted; Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003; Rhodes, Jeffery, Watson, Jaquet, Winkler, & Clifford, 2004; Webster & MacLin, 1999; Zhao & Chubb, 2001). A similar effect was also observed with famous faces, with people misidentifying a configuraly alterated picture of a famous face as being the veridical picture after being exposed to the famous face altered in the opposite way (Carbon & Leder, 2005, 2006; Carbon, Strobach, Langton, Harsanyi, Leder, & Kovacs, 2007). The perceived identity of faces can also be biased, following adaptation to an ordinary-looking face (e.g., Leopold et al., 2001; Rhodes & Jeffery, 2006).

More relevant for the purpose of the present study, adaptation aftereffects have been demonstrated for natural categories such as facial expression (Fox & Barton, 2007; Hsu & Young, 2004; Webster et al., 2004), gender and race (Webster et al., 2004), consisting in a shift of the facial category boundaries following adaptation. For example, following adaptation to a fearful face, a morphed face between 'fearful' and 'neutral' is less easily perceived as a fearful face (Hsu & Young, 2004). In the same vein, and most central to the present research endeavor, an Asian-Caucasian morphed face is perceived as 'Caucasian' (or as 'Asian') after prolonged exposure to the original Asian (or Caucasian) face (i.e., the face that has been used to create the morphed face; Webster et al., 2004). This latter result reveals that an adaptation paradigm can be a useful tool to probe the mechanisms involved in perceiving the race of a face-stimulus.

Building upon this recent literature, we reasoned that 'racially-ambiguous' face-stimuli obtained by morphing Asian and Caucasian faces (see Stimuli section) should be perceived as Asian versus Caucasian when presented following a long exposure to the original Caucasian or Asian face, respectively. The magnitude of holistic encoding for these 'racially-ambiguous' face-stimuli was measured using the face-composite effect, generally considered as the most compelling evidence that faces are represented holistically (e.g., Maurer et al., 2002; Rossion, 2008), in a same/different matching task. In such a task, participants tend to perceive identical top halves of two face-stimuli as being different when they are aligned with different bottom halves ('the composite illusion'; see Fig. 1A). This visual illusion disappears when the two face halves are laterally offset or 'misaligned' (e.g., Goffaux & Rossion, 2006; Le Grand, Mondloch, Maurer, & Brent, 2004; Michel et al., 2006b; Michel et al., 2007; Fig. 1B), or when faces are presented upside-down (e.g., Hole, George, & Dunsmore, 1999; Fig. 1C).

According to our race-categorization hypothesis, the exact same stimuli (here racially-ambiguous faces) should be processed more holistically (i.e., should give rise to a larger face-composite effect) by Caucasian participants when perceived to be Caucasian than when perceived to be Asian, following adaptation to the relevant (i.e., respectively Asian versus Caucasian) face-stimuli.

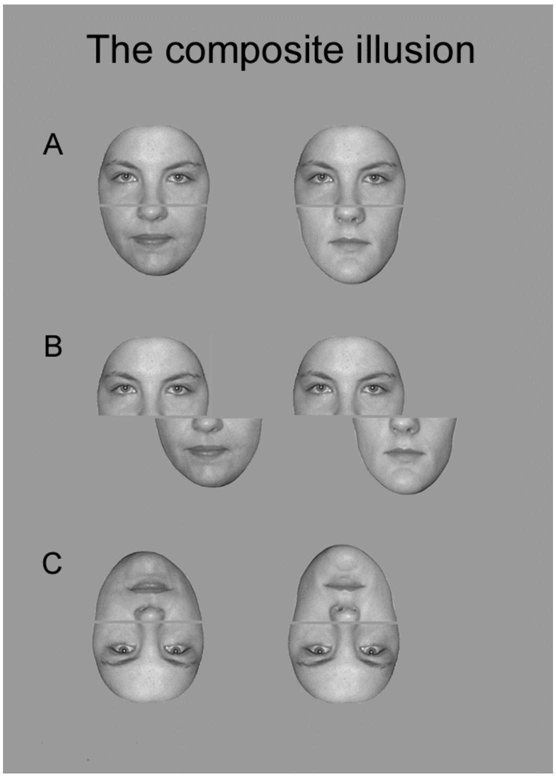

Figure 1. *Illustration of the 'face-composite illusion'. Identical top halves of two face-stimuli tend to be perceived as being different when they are aligned with different bottom halves (A). This visual illusion disappears when the two face halves are laterally offset (B), or when the faces are presented upside-down (C).*

Experiment 1

Method

Participants

Twenty-three Caucasian students from the University of Louvain, Belgium, took part in the experiment for course credit (21 females, mean age = 20 years, range: 19-23 years). None of them had any significant experience with OR faces (as assessed by a questionnaire) and all had normal or corrected-to-normal vision. As in our recent study (Michel et al., 2007), there was no need to test Asian participants here: the critical comparison concerned identical morphed face-stimuli, perceived as SR (Caucasian) versus as OR (Asian), depending on the race (Asian vs. Caucasian, respectively) of the adapting face-stimulus. Therefore, should a difference be observed, it could not be attributed to a stimulus-effect.

Stimuli

A set of 20 greyscale racially-ambiguous face-stimuli were used as base stimuli in our face-composite experiments (Fig. 2, bottom panel). Each of them represented the blending of an Asian and a Caucasian original faces (Fig. 2, top panel), created with a morphing software (Morph^{TM}), in such a proportion (variable, see Fig. 2, bottom panel) that the face-stimulus was equally often categorized as 'Asian' and as 'Caucasian' by Caucasian participants (N=34) in a preliminary race-categorization experiment (see Fig. 2 middle panel for details).

Each racially-ambiguous face-stimulus was divided into a top and a bottom segments by slicing it off in the middle of the nose (see Fig. 3, left panel). These 'original racially-ambiguous composite faces' were then paired with several 'new racially-ambiguous composite faces', created by recombining the top and bottom halves of different original racially-ambiguous composite faces. Four kinds of pairs were created: (a) 'same-aligned' pairs, (b) 'same-misaligned' pairs, (c) 'different-aligned' pairs, and (d) 'different-misaligned' pairs. In the 'same' pairs, an original racially-ambiguous composite face was paired with a new racially-ambiguous composite face having the same top part but a different bottom part (same gender). In the 'different' pairs, an original racially-ambiguous composite face was paired with a new racially-ambiguous composite face having *both* the top and the bottom parts different (see Fig.3, left panel), with the bottom part being identical to the one used to create the new racially-ambiguous face in the 'same' pair, and the top being extracted from another original racially-ambiguous composite face. The top and the bottom segments of the new racially-ambiguous composite face in a pair were either 'aligned' ('same-aligned' and 'different-aligned' pairs) or 'misaligned' (i.e., offset laterally: 'same-misaligned' and 'different-misaligned' pairs; see Fig.3, left panel). Even for aligned trials, a small gap of 3 pixels in height (<0.1°) between top and bottom parts was used so that participants could identify the top parts to match/discriminate equally easily in the aligned than in the misaligned condition (where top and bottom parts were segmented by the spatial misalignment).

A color version of the 20 original Asian (Chinese faces, from Bejing) and the 20 original Caucasian faces (from Belgium, half males) that were used to create the above mentioned original racially-ambiguous face-stimuli were used as 'adapting face-stimuli' in our experiments. These faces depicted students (between 18 and 25 years old) unfamiliar to the participants, posing full-front with a neutral expression and external features removed (visual angle ~ 2.85° by 3.7°; Fig. 3, left panel).

Stimuli were displayed using E-Prime 1.1, against a neutral grey background.

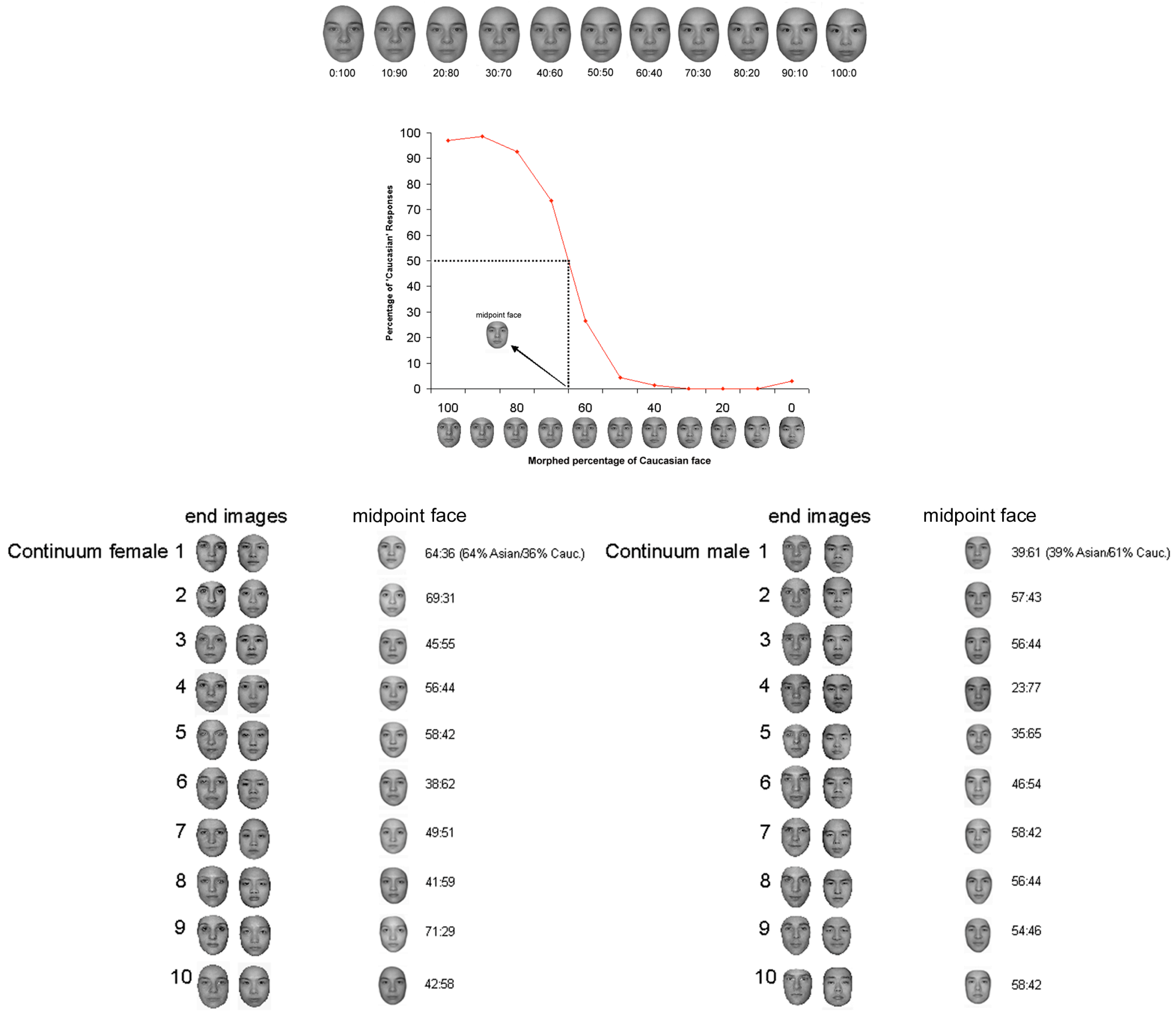

Figure 2. Top: *One of the 20 continua of face-stimuli used in the preliminary race-categorization experiment. Each face-stimulus represents the blending of an original Caucasian face and an original Asian face in a given proportion, from 0:100 (i.e., 0% Asian and 100% Caucasian) to 100:0 (100% Asian and 0% Caucasian). Twenty Asian-Caucasian continua were created, for a total of 220 blended face-stimuli, that were presented two times each in a random order (presentation time: 200 ms) to 34 Caucasian participants, for a race-categorization task ('Asian' or 'Caucasian'?).* ***Middle:*** *For a given Asian-Caucasian continuum, the 'midpoint face', which was equally often (50%) categorized as an Asian and as a Caucasian face in the race-categorization experiment, was used as a racially-ambiguous face-stimulus in the main experiments. Here, the midpoint face is the 35:65, that is the morphed face including 35% of the original Asian face and 65% of the original Caucasian face.* ***Bottom:*** *The twenty midpoint faces (one for each continuum, half females) that have been brought out of the preliminary race-categorization experiment to be used as base racially-ambiguous face-stimuli in the main experiments. Each racially-ambiguous face is*

defined by a specific proportion of the Asian (first number) and of the Caucasian (second number) original faces (end images) that have been used to generate the linear continuum of blended images.

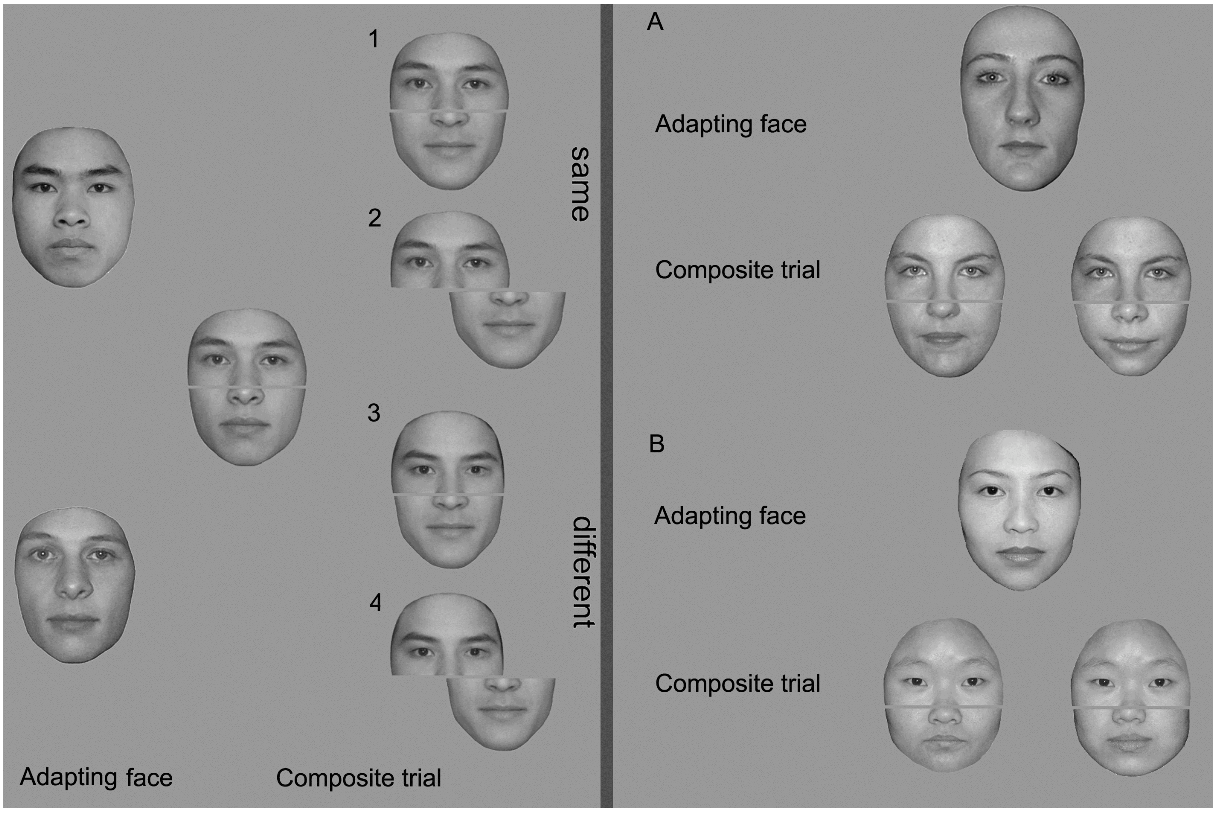

Figure 3. *Figure 3.* ***Left:*** *Examples of Asian (top) and Caucasian (bottom) adaptation trials used in Experiments 1 and 2. After a long exposure (16 seconds) to an Asian (top) or a Caucasian (bottom) adapting face, a composite trial was presented, in which an original racially-ambiguous composite face was followed by one of the four new racially-ambiguous composite faces it was paired with, having either the same top part and a different bottom part (same-aligned and same-misaligned pairs) or both different top and bottom parts (different-aligned and different-misaligned pairs). The (racially-ambiguous) target face of the composite trial was always the face that had been created by morphing the (Asian or Caucasian) adapting face presented previously with another (Caucasian or Asian, respectively) face, with the latter being used as the adapting face for the same pair of composite faces in another trial (different block). The bottom part of the four new racially-ambiguous composite faces associated with a base racially-ambiguous composite face was identical.* ***Right:*** *Examples of Caucasian (top) and Asian (bottom) 'catch trials' used in Experiment 2, taken from the 'same-aligned' condition. The adapting face was of the same race (Caucasian or Asian) but of a different identity than the following composite trial. The composite trial was created in the same way than a racially-ambiguous composite trial in the 'same-aligned' condition, with the two composite faces having the same top part aligned on a different bottom part.*

Procedure

Participants were tested individually, at a distance of 100 cm from the computer screen. Each trial started with a fixation cross (200 ms) appearing at the center of the computer screen, followed by a Caucasian or an Asian adapting face-stimulus appearing for 16 seconds. This exposure time was selected[1] because it has been shown that visual aftereffects are obtained after an adaptation period of 5 seconds (e.g., Anderson & Wilson, 2005; Fox & Barton, 2007; Hsu & Young, 2004; Jiang et al., 2006; Leopold et al., 2001; Rhodes & Jeffery, 2006) at least (Leopold et al., 2005), with the effect of the adapting stimulus growing stronger as adaptation duration increases and weaker as test durations increases (Leopold et al., 2005; Troje, Sadr, Geyer, & Nakayama, 2006), and being relatively strong with 16000 and 600 milliseconds as a combination of adaptation and test duration (see Fig. 5 in Leopold et al., 2005). The participants were informed that the adapting face did not have to be considered in the task, but were instructed to 'inspect' it carefully and continuously during the 16 seconds, without tilting their head sideways[2]. After a 100 ms blank screen, the 'target face' of the 'composite trial' appeared for 600 ms (as in previous experiments with this paradigm; e.g., de Heering, Rossion, Turati, & Simion, 2008; Goffaux & Rossion, 2006; Michel et al., 2006b; Michel et al., 2007) at the center of the computer screen. The target face was the original racially-ambiguous composite face that had been created by morphing the original (Asian or Caucasian) adapting face presented previously with another original (Caucasian or Asian, respectively) face (see Fig. 3, left panel).

After a 300 ms blank screen, the target face was followed by a 'test face', being one of the new racially-ambiguous composite face it has been paired with. This second composite face had either the same top part ('same pairs') or a different top part ('different pairs') and was presented either in an aligned ('same aligned' or 'different aligned' pairs) or in a misaligned ('same misaligned' or 'different misaligned' pairs) format for a maximum of 1 second. The bottom part of the test face was always different from the bottom part of the target face (see Fig. 3, left panel). Participants were required to decide as accurately and as fast as possible (max. 1 sec., after which the next trial started automatically) whether the top part of the test face was the same than the top part of the target face or if it was different, ignoring the bottom parts (left or right key, with mapping of key to response counterbalanced across participants).

The location of the test face was slightly jittered horizontally and vertically – about 40 pixels – to avoid participants resorting to image-based strategies. Participants performed two experimental blocks of 56 trials presented randomly (intertrial interval: 1 sec). In 28 trials, the pair of ambiguous composite faces (i.e., target and test faces) was preceded by the corresponding Caucasian adapting face (‘Caucasian adaptation trials’). In the remaining 28 trials, the ambiguous composite faces were preceded by the corresponding Asian adapting face (‘Asian adaptation trials’). The exact same composite trials that were presented after the corresponding Asian adapting face in the first block (18 ‘same’ and 10 ‘different’ trials) were presented after the corresponding Caucasian adapting face in the second block, and vice versa, with the order of the blocks counterbalanced across participants. Seventy-six out of the 112 composite trials required a ‘same’ decision (half aligned; 18 ‘Asian adaptation’ and 20 ‘Caucasian adaptation’ trials in the first block and vice versa in the second block) and the remaining 36 trials required a ‘different’ decision (half aligned). The disproportion between ‘same’ and ‘different’ trials was introduced because ‘same’ trials only were of interest to measure the face-composite effect (e.g., Le Grand et al., 2004; Michel et al., 2006b; Rossion & Boremanse, 2008): the face-composite effect was reflected by the decline of performance in the ‘same aligned’ condition, relative to the ‘same misaligned’ condition (see for example Goffaux & Rossion, 2006; Le Grand et al., 2004; Michel et al., 2006b; Michel et al., 2007).

According to our hypothesis, the face-composite effect should be larger, either in terms of accuracy or in terms of response times (as previous research provided evidence for a face-composite effect on both measures), when the exact same composite faces followed an Asian than when they followed a Caucasian adapting face. Before the experiment started, a fixed set of 8 trials (half ‘Asian adaptation’ trials; half aligned) drawn from the experimental blocks were presented in a random order as practice trials. At the end of the experiment, participants filled out a questionnaire about their experience with OR faces.

Results

Accuracy

Accuracy rates on the ‘same’ trials were submitted to a 2 x 2 analysis of variance (ANOVA) with *race of adapting face* (Asian vs. Caucasian) and *alignment* (aligned vs. misaligned) as within-subjects factors. We found a significant main effect of *race of adapting face* ($F(1,22) = 5.14$, $p< .05$, $\eta^2 = .19$), participants being overall more accurate on Caucasian (M = 81.58 %) than on Asian adaptation trials (M = 76.2 %; see Fig. 4A). We also found a significant main effect of *alignment* ($F(1,22) = 18.2$, $p< .001$, $\eta^2 = .45$), with more accurate responses on misaligned (M = 85.58%) than on aligned (M = 72.2 %) trials (the face-composite effect). More important for the purpose of the present research, there was a significant interaction between *race of adapting face* and *alignment* ($F(1,22) = 4.84$, $p < .05$, $\eta^2 = .18$): although the face-composite effect was significant on both Asian adaptation trials (Fig. 4A; M = 67.28 % and 85.13 % for aligned and misaligned conditions, respectively; post-hoc $t(22) = 3.99$, $p < .005$) and Caucasian adaptation trials (M = 77.12 % and 86.04 %; post-hoc $t(22) = 3.17$, $p < .005$), the effect was about twice larger on the exact same ambiguous faces preceded by an Asian adapting face: 17.85 % *vs.* 8.92 %).

Response Times (RTs)

A 2 x 2 ANOVA was conducted on correct response times with *race of adapting face* (Asian vs. Caucasian) and *alignment* (aligned *vs.* misaligned) as within-subjects factors. We found a significant main effect of *race of adapting face* ($F(1,22) = 12.6$, $p < .005$, $\eta^2 = .36$), with faster responses on Caucasian adaptation trials (M = 611 ms) than on Asian adaptation trials (M = 627 ms). We also found a significant main effect of *alignment* ($F(1,22) = 9.8$, $p < .01$, $\eta^2 = .31$), participants being faster at performing misaligned (M = 605 ms) than aligned (M = 634 ms) trials (the face-composite effect). The interaction between the two factors was not significant ($F(1,22) < 1$). Results are depicted in Figure 4B.

Discussion

In agreement with our hypothesis, the exact same ambiguous face-stimuli gave rise to a larger composite effect when adaptation led to the perceptual categorization of this face as being SR rather than OR. This finding suggests that the holistic processing of a face-stimulus depends on its racial membership, as *perceived* by the observer. Accordingly, for an incoming racially-ambiguous face-stimulus, its facial features are integrated more or less into a holistic representation, depending on the perceived race identity of this face (SR or OR).

There is however one limitation to the interpretation of this experiment: since an adapting face-stimulus was never followed by a composite trial perceived as being of the same race, it could be that after a while, participants *expected* the composite trial to be Asian when presented with a Caucasian adapting face, and vice versa. Hence, the degree of holistic processing could have been affected by the observer's *expectation* regarding the race of the forthcoming face-stimulus. Such a modulation of the holistic processing by the observer's expectation about the face race could actually happen in two different ways. First, the observer may have focused on the cues that fit with his/her racial expectation to disambiguate the ambiguous race face-stimulus (what could be called an ‘assimilation’ effect; see for example Niedenthal & Halberstadt, 2003, for similar top-down influence on the perception of ‘emotionally-ambiguous’ face-stimuli). Second, although quite unlikely (see Michel et al., 2007, Experiment 2), the observer may have tuned the degree of holistic processing depending on his/her expectations about the race of the next face to appear.

If holistic processing modulation of racially-ambiguous faces in Experiment 1 was due to an ‘expectation effect’, then it should not be observed anymore when the race of the adapting face no longer predicts the race of the forthcoming composite face. This possibility was examined in Experiment 2.

Experiment 2

Method

Participants

Seventeen Caucasian students from the University of Louvain, Belgium, participated in the experiment for course credit (15 females, mean age = 20.76 years, range: 19-23 years). None of them had any significant experience with OR faces (as assessed by a questionnaire, as in Experiment 1) and all had normal or corrected-to-normal vision.

Stimuli

Among the 56 pairs of racially-ambiguous composite faces used in Experiment 1, 40 were used in Experiment 2, keeping the disproportion introduced in Experiment 1 between the number of pairs requiring a ‘same’ (28 pairs; half aligned) versus a ‘different’ decision (12 pairs; half aligned) in the composite task.

Forty additional pairs of composite faces (20 Asian; 20 Caucasian) used in a previous study (Michel et al., 2006b) were also used as ‘catch trials’ (see Procedure) in the present Experiment. These Asian and Caucasian pairs of composite faces were created from a set of 9 Asian and 9 Caucasian original composite faces in the very same way as the pairs of racially-ambiguous composite faces. They included an original Asian or Caucasian composite face and another composite face of the same race differing by the bottom part only or by both the top and the bottom parts (see Fig. 3, right panel).

Finally, a further set of ten Caucasian and ten Asian original faces (half males) were used as ‘adapting face-stimuli’ preceding the composite ‘catch trials’ (see Procedure). As ‘adapting face-stimuli’ used in the trials of interest (i.e., racially-ambiguous composite trials), these adapting faces depicted students (between 18 and 25 years old) unfamiliar to the participants, either from Belgium or from China (Beijing), posing full-front with a neutral expression and external features removed (visual angle ~ 2,85° by 3,7°; see Fig. 3, right panel).

Procedure

The procedure was identical to the procedure used in Experiment 1, except for the following changes: participants performed two experimental blocks of 80 trials. Among the 80 trials, 40 included a pair of racially-ambiguous composite faces preceded by the corresponding Asian adapting face (‘Asian adaptation trials’: N = 20) or by the corresponding Caucasian adapting face (‘Caucasian adaptation trials’: N = 20). The 40 remaining trials were ‘catch trials’ inserted in the experiment in order to avoid any expectation regarding the race of the composite trial following a given (Asian or Caucasian) adapting face. In 20 ‘catch trials’, an Asian adapting face was followed by an Asian composite trial (‘Asian catch trials’) and in the remaining 20 trials, a Caucasian adapting face was followed by a Caucasian composite trial (‘Caucasian catch trials’).

In each block, a ‘same’ decision was required in 14 ‘Asian adaptation trials’, 14 ‘Caucasian adaptation trials’, 14 ‘Asian catch trials’ and 14 ‘Caucasian catch trials’ (half aligned). A ‘different’ decision was required in the remaining 6 ‘Asian adaptation trials’, 6 ‘Caucasian adaptation trials’, 6 ‘Asian catch trials’ and 6 ‘Caucasian catch trials’ (half aligned). As in Experiment 1, the racially-ambiguous composite trials that were presented after the corresponding Asian adapting face in the first block (14 ‘same’ and 6 ‘different’ trials) were presented after the corresponding Caucasian adapting face in the second block, and vice versa, with the order of the blocks counterbalanced across participants. However, the same 20 Asian and 20 Caucasian ‘catch trials’ were presented in the two blocks, with the identity of the (Asian or Caucasian) adapting face (identical in the ‘aligned’ and the ‘misaligned’ versions of the composite trial) being different (but same gender) from the identities depicted in the composite faces (target and test faces) that followed (see Fig. 3, right panel).

Results

Accuracy

The comparison of interest concerned the racially-ambiguous composite trials following the Asian versus the Caucasian adapting face. Accuracy rates on these 'same' trials were submitted to a 2 x 2 ANOVA with *race of adapting face* (Asian *vs.* Caucasian) and *alignment* (aligned vs. misaligned) as within-subjects factors. There was a significant main effect of *race of adapting face* ($F(1,16) = 5.33$, $p< .05$, $\eta^2 = .25$), with a better performance on Caucasian adaptation trials (M = 81.72 %) than on Asian adaptation trials (M = 77.1 %). We also found a significant main effect of *alignment* ($F(1,16) = 19.08$, $p< .001$, $\eta^2 = .54$), with a better performance on misaligned (M = 87.6 %) than on aligned trials (M = 71.22 %; the face-composite effect). However, even though there appears to be a larger face-composite effect when the adapting face was Asian than when it was Caucasian (19 % *vs.* 14 %; see Fig. 4C), the interaction between the two factors did not reach significance ($F(1,16)< 1$, *ns*).

Response Times (RTs).

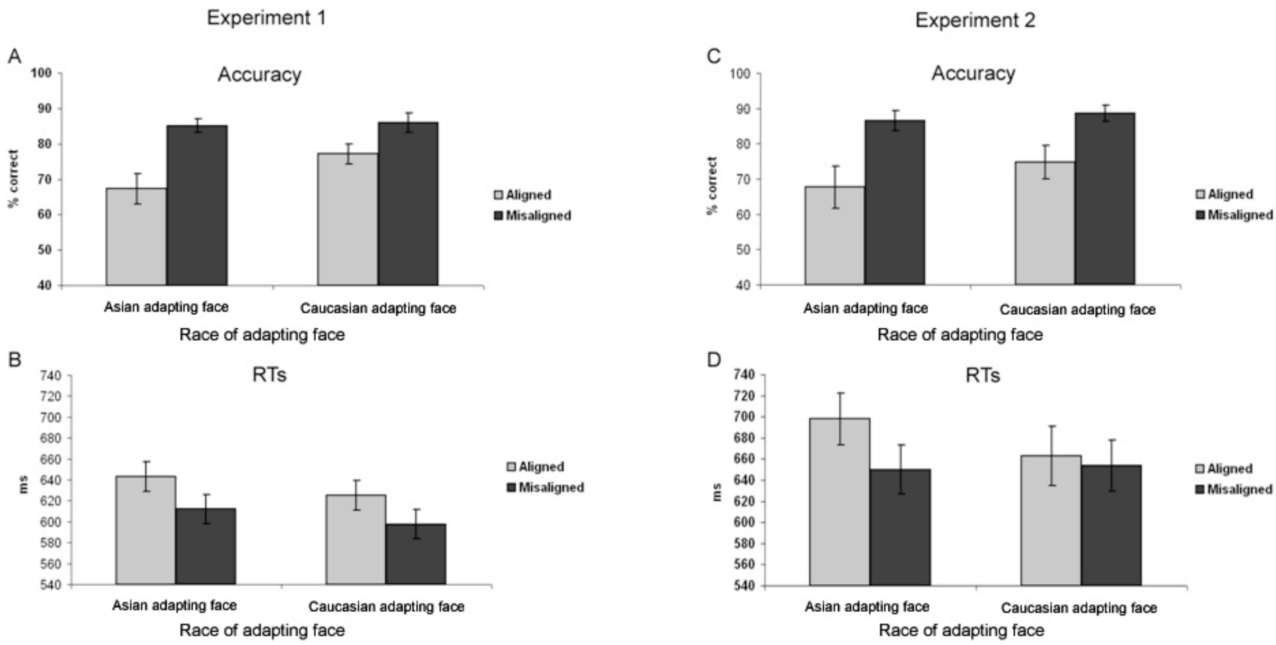

Figure 4. *Figure 4. Performance on the 'same' racially-ambiguous composite trials in Experiment 1 (A: Accuracy; B: Correct response times) and Experiment 2 (C: Accuracy; D: Correct response times), presented after an Asian or a Caucasian adapting face (Asian and Caucasian adaptation conditions, respectively). The composite effect is assessed by the difference between the misaligned and the aligned condition. Errors bars represent standard errors of the mean. The effect is larger after an Asian adapting face in terms of accuracy in Experiment 1 and in terms of response times in Experiment 2.*

Again, the comparison of interest concerned the racially-ambiguous composite trials following the Asian versus the Caucasian adapting face. Correct response times on these (same) trials were submitted to a 2 x 2 ANOVA with *race of adapting face* (Asian vs. Caucasian) and *alignment* (aligned vs. misaligned) as within-subjects factors. The effect of *race of adapting face* was marginally significant ($F(1,16) = 4.26$, $p = .056$, $\eta^2 = .21$), with faster responses on Caucasian adaptation trials than on Asian adaptation trials. Results also showed faster responses on misaligned than aligned trials ($F(1,16) = 5.27$, $p < .05$, $\eta^2 = .25$), revealing the face-composite effect (see Fig. 4D). Most interestingly, there was a significant interaction between *race of adapting face* and *alignment* ($F(1,16) = 5.2$, $p < .05$, $\eta^2 = .24$). The composite-face effect was larger on the exact same ambiguous faces when they were preceded by an Asian adapting face (M = 698 ms and 650 ms for aligned and misaligned conditions, respectively; post-hoc $t(16) = 3.47$, $p < .01$) than when they were preceded by a Caucasian adapting face (M = 663 ms and 654 ms; post-hoc $t(16) < 1$, *ns,* see Fig. 4D)[3].

Discussion

As in Experiment 1, the exact same racially-ambiguous faces were processed more holistically when they were preceded by an Asian than by a Caucasian adapting face. Thus, holistic encoding of racially-ambiguous faces appears to depend on race-categorization of the face. Here, the effect cannot be explained by an expectation account. The effect of interest was observed on accuracy rates in Experiment 1 whereas it was significant on correct RTs only in experiment 2. We can only speculate on the reasons for this difference, which might be related to the paradigmatic modifications introduced for this second experiment. We do not deem it problematic, though, as previous research indexed face-composite effects on both types of dependent variables (e.g., de Heering et al., 2008; Goffaux & Rossion, 2006; Hole, 1994; Le Grand et al., 2004; Michel et al., 2006b; Michel et al., 2007; Rossion & Boremanse, 2008; Young et al., 1987).

General discussion

Our observations provide evidence that holistic face encoding can be modulated by the race-categorization of the face. In two experiments, identical 'racially-ambiguous' face-stimuli were processed more holistically (as revealed by a larger composite-face effect) by Caucasian participants when they were perceived as 'Caucasian' than when they were perceived as 'Asian'. Experiment 2 further ascertained that the race-categorization of the face was determined by the contextual face-stimuli, without observer's expectation about the race of the face being necessary to induce their holistic processing modulation. It is worth discussing the present findings in relation to the previously shown modulation of holistic encoding of racially-ambiguous faces (Michel et al., 2007).

In our previous study (Michel et al., 2007), the categorization of racially-ambiguous face-stimuli was biased *towards* the contextual face category, in a paradigm that could be assimilated with a 'multiple-prime categorical priming paradigm'[4]. More precisely, racially-ambiguous face-stimuli were inserted (without participants' knowledge) within a majority of either SR or OR faces, in order to bias their classification towards the same- or the other-race, respectively. The very same ambiguous faces were processed more holistically when assumed to be categorized as 'SR' (i.e., presented in SR blocks) than when assumed to be categorized as 'OR' faces (i.e., in OR blocks).

However, due to the blocked presentation of Asian versus Caucasian face-stimuli in this previous study, a 'carry over effect' may have underlied the reported results. That is, when embedded in blocks of Caucasian faces, racially-ambiguous faces could have benefited from holistic processes carried over all along the block. Moreover, if holistic processing of racially-ambiguous faces was modulated by their race-categorization, such a race-categorization process could have depended on the observer's expectation about the race of the forthcoming face in that study.

These two shortcomings were overcome in the present study. An adaptation paradigm was used to bias the categorization of racially-ambiguous face-stimuli *away from* the contextual face category. More precisely, racially-ambiguous faces were presented here after a prolonged exposure to a SR or an OR adapting face, in order to 'fatigue' the neural coding of SR or OR cues (see Webster et al., 2004) such that the morphed faces would be perceived as OR or SR, respectively. First, this allowed us to manipulate the race-categorization process in a non-blocked design, decreasing the likelihood of a carry over effect. Second, whereas in our previous study, a composite face task was performed for each and every trial, probing such carry over effects of processes, there was no specific process instructed to be applied to the adaptor here: it was presented passively, without instructions. Finally, a carry-over effect would cause a larger holistic processing for the racially-ambiguous faces presented after Caucasian than Asian faces. Showing the opposite profile of results, our findings definitely exclude this alternative hypothesis.

The second shortcoming of our previous research (i.e., the uncertainty regarding the role of the observer's expectation on the race-categorization process) was addressed here in the second experiment, in which the race of the forthcoming face was unpredictable. Thus, the results ascertained that holistic processing of racially-ambiguous faces was modulated by the *perceived* (rather than *expected*) race of these faces, which as depends here solely on the facial context these faces appeared in. Whether or not the observer's expectation about the race of racially-ambiguous faces could also modulate their degree of holistic processing would be worth investigating in further studies.

By showing that simply categorizing a face as belonging to another race leads the observer to process it less holistically, the present findings suggest that race-categorization may also play a role in the differential holistic processing observed for *veridical* SR and OR faces (Michel et al., 2006a, 2006b; Tanaka et al., 2004). This is in line with a 'socio-cognitive' account of the ORE, according to which OR faces would not be accorded the specialized processing mechanisms applied by default on SR faces, because of their membership to another racial group (e.g., Hugenberg et al., 2006; Johnson & Fredrickson, 2005; Levin, 1996, 2000; MacLin & Malpass, 2001). What remains to be clarified is whether the weaker holistic processing observed for *veridical* OR faces is exclusively imputable to a race-categorization process or if it also partly results from an inability of our perceptual system to generalize holistic processing to faces whose morphology largely differs from the morphology of faces one has a lot of visual experience with (i.e., SR faces; see Farkas, 1994). The strong version of the socio-cognitive account would be supported only in the former case. In the latter case, foiling the race-categorization process or its consequences would *not* be sufficient to process *veridical* OR faces as holistically (or as efficiently) as SR faces. Note that, in practical terms, the present findings are particularly relevant for naturally 'ambiguous' faces with mixed racial heritage, which do not fit neatly into one race-category or another. The perceived race of the face is likely to be less flexible for veridical SR and OR faces with clear-cut morphological properties (i.e., it is unlikely that a 100% OR face could be perceived as 'SR').

Although widely considered an invaluable tool to shed light on the neural coding mechanisms underlying face perception, an adaptation aftereffect remains an artificial phenomenon induced in laboratory. Thus, we deem it important to briefly discuss the potential implications of the present set of findings for the processing of mixed-race faces in a more natural context. There is evidence suggesting that racially-ambiguous faces tend to be categorized as OR faces (see Webster et al., 2004). Consequently, according to the present results, such a mixed-race face may be processed less holistically when it is encountered out of context. If an adaptation phenomenon similar to the one induced experimentally in the present study can occur in natural circumstances, one would expect the holistic processing of this mixed-race face to be larger in an OR than in a SR context. However, the faces we encounter in our environment (mostly SR) may rather induce a natural priming phenomenon, such that a mixed-race face would benefit from a larger holistic encoding when encountered among SR faces than OR faces (see Michel et al., 2007). Webster et al.'s results (2004) suggest that natural adaptation can occur, modulating the appearance of the faces we encounter in natural circumstances. Indeed, besides revealing the natural propensity people have to categorized a mixed-race face as 'OR' (revealed by a shift of the race-boundary towards the race of the faces we mostly encounter in our everyday life), Webster et al.'s results (2004) revealed that the race-boundary in Asian participants who had been resident in US for one year shifted towards the boundary observed in Caucasian participants. Moreover, the amplitude of this shift was positively correlated with the amount of contact these participants had with Caucasian individuals. However, Webster et al. (2004) also observed a similar shift for the gender-boundary (i.e., mixed-gender face-stimuli tended to be categorized as 'female' by male participants and vice versa). Therefore, that the shift observed for the race-boundary is due to a natural adaptation phenomenon remains uncertain. An alternative possibility, supported by the gender results, is that people tend to categorize a mixed-face as belonging to the other category (i.e., other-race or other-gender category), rather than as belonging to the category they are not used to see in their everyday life. Note that such a natural shift of the race-boundary has not been replicated in our preliminary race-categorization results. The categorical boundary observed in our Asian-Caucasian continua was situated at 53:47 on average for female continua (i.e., a morphed face-stimulus including 53% of the original Asian face and 47% of the original Caucasian face), and at 49.7: 50.3 on average for male continua, with the expected shift to the Caucasian endface observed for only 4 continua out of 10 in both female and male continua (see Fig. 2, bottom panel). Whether or not the present findings can be extended to the perception of racially-ambiguous faces in natural circumstances thus remains to be investigated.

In summary, the present study provides original evidence that holistic encoding depends on the perceptual race-categorization of the face, as a function of contextual face-stimuli. This modulation of holistic processing by race-categorization is of most critical relevance for naturally 'ambiguous' faces, whose race-categorization can be modulated by the context in which they appear.

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Endnotes

1. Note that our adaptation period was longer than the five seconds adaptation period used in several previous studies (e.g., Anderson & Wilson, 2005; Fox & Barton, 2007; Hsu & Young, 2004; Jiang et al., 2006; Leopold et al., 2001; Rhodes & Jeffery, 2005) but can be considered as a short one when compared to the 3 minutes adaptation period used by Webster et al. (2004). A several minutes adaptation period was not selected in the present study because such a long adaptation period at the beginning of the experiment would have implied to use a 'blocked-design' (with a block of racially-ambiguous faces being perceived as 'Caucasian' after adaptation to the set of Asian faces and vice versa) that might have induced a 'carry-over' effect (i.e., participants maintaining across a whole block a general holistic processing tendency initiated by the first trials of the block perceived as 'SR') or an 'expectation effect' (i.e., participants modulating the amount of holistic processing applied on a series of composite trials expected to be 'SR' or 'OR').
2. It has been shown that a strict fixation of the adapting stimulus does not alter adaptation effects (Leopold et al., 2001). Moreover, there is some evidence suggesting that intermittent repeated exposure to adapting stimuli is at least as effective as continuous prolonged adaptation over the same period of time (see Morikawa, 2005, p. 3187). Thus, as in previous studies (e.g., Leopold et al., 2001), participants were merely instructed to 'inspect' the adapting stimulus continuously but were allowed to move their eyes freely. That participants did look at the adapting stimulus during the 16 seconds without tilting their head sideways was ascertained by the constant experimenter's observation during the whole experiment.
3. Note that a face-composite effect in terms of RTs has been reported in previous studies, (e.g., Hole, 1994; Le Grand et al., 2004; Michel et al., 2006b; Rossion & Boremanse, 2008; Young et al., 1987).
4. For another example of priming on race-categorization of pure or racially-ambiguous faces, see Zarate & Sanders, 1999, and Eberhardt, Dasgupta, & Banaszynski, 2003, respectively. For an example of 'multiple-prime paradigm', see Carson & Burton, 2001. For an example of how being sensitised with one kind of information leads to the selective perception of this information in following 'ambiguous' stimuli, see Oliva & Schyns, 1997.